Process Manager Control Functions and Algorithms

PM09-500
Process Manager
Control Functions
and Algorithms

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About This Publication

This publication defines the control functions and I/O functions that are available through software Releases 500 - 520 of the Process Manager.

This is a reference manual for process engineers, control-system engineers, and application engineers who design and implement data-acquisition and control strategies for TotalPlant® Solution (TPS) Systems with Local Control Networks and Universal Control Networks. TPS is the evolution of TDC 3000.

The user should be familiar with the system control functions described in System Control Functions, SW09-501 in the Implementation/Startup & Reconfiguration - 2 binder before using this publication.

Detailed descriptions of the parameters mentioned in this publication can be found in the Process Manager Parameter Reference Dictionary, PM09-540, in the Implementation/Process Manager - 2 binder.

Change bars are used to indicate paragraphs, tables, or illustrations containing changes that have been made by Document Change Notices or an update. Pages revised only to correct minor typographical errors contain no change bars. All changes made by previous Document Change Notices have been incorporated in this update.
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This section contains an introduction to the Process Manager Control functions, and also provides references to other publications that are useful or necessary in implementing control system functions.

1.1 INTRODUCTION

The Process Manager (PM) is designed to provide flexible and powerful process scanning and control capabilities. To do this, it uses a powerful multiprocessor architecture with separate microprocessors dedicated to perform specific tasks. As depicted in Figure 1-1, the PM consists of the Process Manager Module (PMM) and the I/O Subsystem.

![PM Architecture Diagram](image-url)
The PMM consists of a Communication Processor and Modem, I/O Link Interface Processor, and Control Processor. PMM redundancy can be optionally provided. The Communication Processor is optimized to provide high performance network communications, handling such functions as network data access and peer-to-peer communications. The Control Processor is the PM resource dedicated to executing regulatory, logic, and sequence functions, including a powerful user programming facility. Because communication and I/O processing are performed by separate dedicated hardware, the full power of the control processor can be applied to control strategy implementation. The I/O Link Interface Processor is the interface to the I/O Subsystem.

The I/O Subsystem consists of a redundant I/O Link and the I/O Processors. These I/O Processors handle all field I/O for both data acquisition and control functions. The I/O Processors, for example, provide such functions as engineering unit conversion and alarm limit checking independent of the PMM. All control operations are performed within the PMM, with all data acquisition being performed in I/O Processors. The process engineer has complete flexibility of choice, within the maximum PM design limits, in the assignment of point types and control strategies. The interactive tools provided by both the

TotalPlant® Solution (TPS) System Universal Station and Universal Work Station are used to implement these selections. Refer to Section 31 in the Engineer’s Reference Manual for more information.
1.1.1 I/O Functions

The I/O Processors, in conjunction with Field Termination Assemblies (FTAs), perform input and output scanning, and processing on all field I/O. A redundant I/O Link is standard for added security. I/O processing is performed separately from control processing functions so that I/O scan rates are completely independent of I/O quantity, controller loading, processing, and alarming. This partitioning of processing requirements allows more efficient use of control processor capability and future integration of additional I/O Processor types.

The following I/O Processors (IOPs) are available for the PM:

- Analog Input—High Level (16 points)
- Analog Input—Low Level (8 points)
- Analog Output (8 points)
- Analog Output (16 points)
- Digital Input (32 points)
- Digital Input Sequence Of Events (32 points)
- Digital Output (16 points)
- Digital Output (32 points)
- Low Level Multiplexer (32 points)
- Pulse Input (8 points)
- Smart Transmitter Interface (16 points)
- Serial Device Interface (16 points), (not shown in Figure 1-1)

Up to 40 of the above I/O processors can be selected in any mix. An option allows redundant Analog Output and High Level Analog Input processors (up to 40 primary and 40 redundant IOPs). Each of the I/O processor functions is described in Section 2.
1.1.2 Control Functions

The PM provides a variety of control tools that can be customized to address a wide range of process automation needs. Functions from I/O scanning, through regulatory and logic control to more advanced control can be easily implemented through the PM. The PM toolbox includes a sophisticated regulatory control package, fully integrated interlock logic functions, and an advanced process engineer-oriented Control Language (CL/PM). CL/PM is an enhanced version of the Control Language implemented by Honeywell in the Multifunction Controller and Application Module. This language facility includes the sequence structures needed to handle batch or hybrid applications as well as the computational capability needed for some continuous control tasks. Key to the power of this control capability is that each of the functions shares data freely within the PM and can share data from other devices on the Universal Control Network.

The following point types reside in the PMM:

- Regulatory PV
- Regulatory Control
- Digital Composite
- Logic
- Process Module
- Box Flag, Numeric, and Timer

Each of these data point types is described beginning with Section 3 of this publication. In addition, the descriptions of the Regulatory PV (RegPV) and Regulatory Control (RegCtl) points also contain detailed descriptions of the algorithms associated with the respective points.

1.2 COMMON FUNCTIONS

1.2.1 Point Form

Separate functional elements of the PM are used to implement various parts of typical control loops and control strategies. Each of these functional elements can be assigned a user-defined tag name to allow for location-independent reference to the data associated with that function. For example, point tags are assigned by the user for analog input and analog output slots. The I/O Processor data (engineering-unit range for inputs, characterization option for outputs, etc.) is configured as part of the point-build process for these points. A separate tag would be configured for each regulatory control (RegCtl) slot that would be linked to the assigned analog I/O tags through input/output connections.

The PM provides a configurable parameter called PNTFORM (Point Form) that allows the user to define which points are to be used as the primary operator interface for point data. The PNTFORM parameter provides the user with two choices for point form: "Full" and "Component." Points that are configured as having "Full" point form include alarm-related and sometimes, some other miscellaneous parameters. This information is needed when the point is to be used as the primary operator interface to the point's data.
Prior to Release 500, points that were configured as having "Component" point form did not require descriptor data parameters (PTDESC, EUDESC, and KEYWORD), because that type of information was suppressed for "Component" points.

Component point form should be used for points that provide inputs to the "Full" point, and for those points that handle the outputs from the "Full" points. "Component" points should be used as part of the "Full" point that has been designated a primary operator interface point.

**NOTE**

The maximum number of points per Network Interface Module (NIM) is 8000. Both full and component points should be counted when checking against this limit. Note that for the DI and DO portions of a digital composite point, the inputs and outputs from/to the digital composite point are not to be counted as part of the point total if they are implemented using the hardware reference source and destination addresses that are entered on the respective configuration form for the digital composite point.

**CAUTION**

Database security is provided to prevent an operator from starting an IOP that has an invalid database. After initial configuration, each IOP must be set valid. Validating the database of an IOP by selecting the VALIDATE IOP DB target on the display with the keylock in the Engineering position causes the IOP database to be accepted as is (that is, default/null configuration or configuration loaded from IDF). When the IOPs are marked valid, select SAVE DATA to checkpoint the configured data. You cannot checkpoint unless the IOP database is marked valid. Restoring the database from a valid checkpoint also sets the IOP database valid. An IOP cannot be switched from Idle to Run unless its database is valid.

The following paragraphs provide examples of the usage of the "Full" and "Component" point forms.
In Figure 1-2, a single-loop PID controller has the PV of a Smart Transmitter Interface point (FT100) connected to the PV of a RegCtl point (FIC100) that has been configured for a PID algorithm. The output (OP) of the RegCtl point is applied to an analog output (AO) point (FY100). In this case, FIC100 is the primary operator interface and is configured as a "Full" point. FT100 and FY100 are parts (components) of FIC100, and could be configured as "Component" points.
Figure 1-3 shows a single-loop PID controller that is controlling mass flow. The mass flow is computed by the flow compensation PV algorithm in regulatory PV (RegPV) point (FX101). FX101 receives three PVs representing the uncompensated flow, absolute pressure, and absolute temperature from AI points FT101, PT101, and TT101. FX101 provides the PV as mass flow to a RegCtl point (FIC101) that has been configured for a PID algorithm. FIC101 provides an output to an AO point (FY101).

In this example, FIC101 is the primary operator interface and would be configured as a "Full" point. FX101 is part of FIC101 and would be configured as a "Component" point. FT101, PT101, and TT101 could be configured as "Full" or "Component" points. "Full" would be selected for any of these points that require separate alarm reporting, such as alarming for uncompensated flow, line pressure, or fluid temperature. FY101 must be configured as a "Component" point.
Figure 1-4 shows a single-output, single-input digital composite point (MTR100) that interfaces a motor control circuit through digital output (DO) point MTR100OP, and digital input (DI) point MTR100FB. In this example, MTR100 is the primary operator interface and would be configured as a "Full" point. MTR100OP and MTR100FB are parts of MTR100 and would be configured as "Component" points.

Note that assigning tag names in this example for the standard digital input point and digital output point is optional. These points can be alternatively referenced, using the hardware reference addresses that would be assigned as the source and destination on the configuration form for the digital composite point.

NOTE: Full-point form cannot be assigned to DO (digital output) points; they are always component points. Stand-alone digital output points require using a digital composite point that has 0 (zero) inputs and 1 output.
Figure 1-5 shows three types of stand-alone points. FT102 and CT105 are points that could be used for data acquisition; in this case these points would be configured as full points. For the stand-alone digital output (DO) point SW103, a digital composite (DigComp) point would be used and would be configured as having 0 (zero) inputs and 1 output.

![Figure 1-5 — Stand-Alone Points](image)

1.2.2 Associated Display

With Release 510 and later software, an Associated Display can be configured for each HPM point at build time by entering the name of a custom built schematic in the ASSOCDSP parameter. At operating time, the operator can call up that associated custom schematic from a point Detail Display or Group Display.

The ASSOCDSP parameter can be changed from the configuration page of the Detail Display (for points that have a configuration page). The keylevel must = Engineer.
1.3 ALARMING

The following paragraphs describe the common alarming functions that can be configured for PM points. The alarm parameters available depend on the point type. Refer to the individual point description for details. Alarm detection and reporting for a point can be configured only if the full point form is specified.

1.3.1 Alarm Priorities

For each point, a separate alarm priority can be specified for each alarm (for example, PV high alarm can be low priority but PV high high alarm can be emergency). The following alarm priorities are supported for PM points:

- Emergency
- High
- Low
- Journal
- JnlPrint
- Printer
- NoAction

The Journal option causes alarms to be journaled only. The JnlPrint selection causes alarms to be journaled in the HM and printed. If the Printer option is selected, alarms are printed but not journaled. Note that if the printer is not working, alarms could be lost.

Alarm priority configuration information is maintained by the NIM.

1.3.2 Alarm Enable Status

Alarm enable status is applicable to full point forms and allows the user to enable, disable, and inhibit alarms. This function is accomplished through the ALENBST parameter. The alarm enable status function is resident in the NIM.

1.3.3 Contact Cutout

The main purpose of the contact cutout function is to prevent a proliferation of alarms from being reported to the operator. This function can be used to cut out alarms on a point when they are generated because of alarm conditions that have been detected at other points. Contact cutout is provided for all the point types in the PM and is implemented through the CONTCUT parameter. Another point or CL program must write to the CONTCUT parameter in order to change the Contact Cutout state.

When the contact cutout state is applied, alarms at the point are cut out. New alarms are not reported on the alarm summary display at the Universal Station, nor are they journaled on the History Module or Real Time Journal. This is the same way inhibited alarms are handled except Cutout alarms continue to be reported to the AM or CM60 for event initiated processing (EIP). A Contact Cutout True message is journaled for points that are in alarm when cutout. For points that are not in alarm when cut out, no message is journaled.
On event recovery (for example, node failover), the system journals a Contact Cutout True message for points that are currently in alarm and cut out.

When Contact Cutout is removed, points that were in alarm are checked and if the alarm condition still exists, the system generates a new alarm with a current timestamp. A Contact Cutout False message is journaled for points that returned to normal while cut out. No message is journaled for points that were not in alarm while cut out.

**NOTE**

When cutout is removed, it is possible to receive a Contact Cutout False message and an alarm for the same point. This would occur if the point had changed from an alarm state to the normal state, and back to alarm, while it was cut out.

A network configuration option provides two choices for handling unacknowledged alarms that exist on the US Alarm Summary display when Contact Cutout is applied:

- CLEAR IMMEDIATELY clears all of the point’s unacknowledged alarms from the display.
- CLEAR WHEN ACKED (also called the Backlight Option) leaves unacknowledged alarms on the display and the time stamp is backlit. The alarms are cleared when they are acknowledged.

If the second option (above) is selected, the complete backlighting action is as follows:

- When Contact Cutout is applied, unacknowledged alarms on the Alarm Summary Display have their timestamp backlit (indicating that the alarm is inhibited).
- If a point’s alarm state returns to normal while the point is cutout, the timestamp remains backlit. When cutout is removed—
  - backlighting is removed from the timestamp
  - the point’s priority indicator is backlit (indicating return to normal)
  - a contact Cutout False message is journaled
- If the NIM fails over while Contact Cutout is applied to any point, the point’s tagname is backlit in addition to it’s timestamp. As soon as communication is restored, backlighting is removed from the tagname.

When Contact Cutout is removed, backlighting is removed from cutout points.

### 1.3.3.1 UCN Contact Cutout Implementation

Contact Cutout is implemented by using a logic point or a CL program to write a Boolean variable from a primary control point into an alarmable UCN secondary point's CONTCUT parameter. A TRUE (ON) in this parameter will cut out alarming by the secondary point. The secondary point will not resume alarming until a logic point or CL program writes a FALSE (OFF) into the secondary's CONTCUT parameter.
Typical implementation of Contact Cutout uses a primary point's PTINAL parameter (point-in-alarm indicator) to control a secondary point's CONTCUT status. This is a convenient method for providing Contact Cutout for all primary alarms, and we recommend it as the safest and most secure implementation. However, any other valid primary point alarm parameter, such as PVHIFL, PVHHFL, PVLOFL, PVROCNFL or any other valid primary point Boolean parameter can be used. When distributing a primary point's alarm status to the CONTCUT parameter of several points, use only one input connection to make the best use of peer-to-peer resources.

When implementing a Contact Cutout connection using a logic point, the Logic Bad Input handling Option parameter, LIBADOPT, must be set to OFF in case the primary point fails or is deleted while in alarm. This implementation ensures that the secondary point's CONTCUT parameter will be set to OFF in the event of a point failure. In addition, if the primary and secondary points are in different UCN nodes, the logic point should be located in the same node as the secondary point in case the node containing the primary point is idled or fails.

For the same reason, we recommend that CL programs be located in the same node as the secondary point. CL programs should include error trapping code to handle the different failure cases previously described.

In general, Contact Cutout should be implemented using primary point alarming flags as previously described, because these alarm parameters automatically clear (to the OFF state) when the primary points are made INACTIVE or the node containing the primary point is idled. Note that when connecting CONTCUT to other parameters, such as box flags or digital composite PV flags, these parameters do not provide similar protection. Because CONTCUT cannot be changed by the operator, it is possible to end up with a secondary point temporarily or permanently disabled from alarming!

### 1.3.4 Primary Module Points

Primary Module (PRIMMOD) Points are used to collect alarms and events from points that are related for some purpose. All UCN points with alarming capability have a PRIMMOD parameter with which to identify a common PRIMMOD point. All points with a matching Primmod point are considered to be in the same alarm group.

The value for the Primmod parameter can be any point in the same NIM. The value is assigned during point build, but can later be stored by a CL program or from schematics. If a Primmod point name is changed when alarms exist, the alarms are reissued for the new Primmod name.

Up to 10 Primmod points can be grouped into one annunciator group in the Area data base and Primmod points can be assigned to turn on the configurable button alarm indicators.
1.3.5 Auxiliary Units

Alarmable NIM points in Release 520 and later software have an Auxiliary Unit ($AUXUNIT) parameter. If this parameter is set to null (---), alarms and messages on that point go to the primary unit. If a valid Unit ID is specified, alarms and messages from that point go to the Auxiliary Unit.

$AUXUNIT can be configured at build time or, with the proper keylevel, it can be initially assigned or changed by schematics, CL programs, the DEB alter parameters function, or from the configuration page of the Point Detail display. The keylevel necessary to change $AUXUNIT is configurable in the System Wide Values section of the Network Configuration File.

Alarms from a point where $AUXUNIT has been configured are accepted only by Universal Stations having an Area Database in which both the Primary Unit and the Auxiliary Unit are configured.

If an $AUXUNIT assignment is changed and there are outstanding alarms on the old unit, alarms are deleted from the old unit and added to the new unit.

1.4 RED TAGGING

A point can be "red tagged" to indicate that it requires maintenance. This is accomplished by setting the REDTAG parameter to On. Typically, the operator sets the output of the point to a desired safe value before putting on the red tag. Once red tagged, the mode, mode attribute, external mode switching state, and output cannot be changed. The point can not be reconfigured or deleted if the red tag is On. Red tagging is supported for only the analog output, RegCtl (only if it is outputting to an AO or a PWM DO Processor), and digital composite point types. A point must be configured for the full point form in order to be red tagged.

The mode and the mode attribute of the point must be changed to Man and Oper, respectively, and the external mode switching state, if configured, must be Disabled before the point can be red tagged. To red tag a digital composite point, the output of the point must not be configured for the momentary state.

The Red Tag function prevents changes to the output on a point that has the REDTAG parameter set to ON, but it may still be possible to change the output connected to the field. For example, even if a Digital Composite point has REDTAG set to ON, a program/Logic Block can still change the state of the Digital Output.
1.5 REFERENCES

The following publications contain information related to the control functions described in this publication:

- **Control Functions in the System**—System Control Functions, SW09-501 in the Implementation/Startup & Reconfiguration binder.

- **Control Functions in the CM50S**—Refer to the publications in the Implementation/CM50S binder.

- **Control Functions in the Application Module**—Application Module Control Functions, AM09-502 in the Implementation/Application Module binder.

- **Definitions of the PM Parameters**—Process Manager Parameter Reference Dictionary, PM09-540 in the Implementation/Process Manager binder.

- **Configuration, Redundancy, Failover information**—Engineer’s Reference Manual SW09-505 in the Implementation/Startup & Reconfiguration binder.

- **Command Processor Utilities**—Command Processor Operation, SW11-507 in the Implementation/Startup & Reconfiguration binder.


This section defines the I/O functions available in the PM analog and digital data points. The PM control functions are described beginning with Section 3. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary, which is in this binder.

2.1 OVERVIEW

The analog and digital data points in the I/O Processors (IOPs) perform input and output processing on all field I/O. These functions are performed independently of the control functions. The partitioning of processing requirements allows more efficient use of control processor capability and future integration of additional IOP types. The following I/O points are available in the PM, and are described in this section:

- Analog Input—High Level
- Analog Input—Low Level
- Smart Transmitter Interface*
- Analog Output
- Digital Input
- Digital Output
- Pulse Input

To support on-line field maintenance activities, Standby Manual units are recommended for the Process Manager AO and DO I/O Processors.

* Note that the Serial Device Interface IOP is configured as a Smart Transmitter Interface (STI) IOP.
2.2 HIGH AND LOW LEVEL ANALOG INPUT POINT

The analog input point converts an analog PV signal received from a field sensor to engineering units for use by other data points in the PM, and by the rest of the TotalPlant® Solution (TPS) System. To accomplish this function, the analog input point (shown in Figure 2-1) performs

- Analog-to digital conversion
- PV characterization
- Range Checking and PV filtering
- PV source selection
- Alarm detection

High level points are located in the High Level Analog Input (HLAI) IOP. One type of low level point is located in the Low Level Analog Input (LLAI) IOP. This type is generally used for control points. The other type is located in the Low Level Multiplexer (LLMUX) IOP. This type is generally used for data acquisition points. The type of analog input point needed is based on the type of field sensor that is providing the input to the point and the characterization options selected by the user as listed in Table 2-1.
Figure 2-1 — Analog Input Point, Functional Diagram
2.2.1 PV Characterization

The PV signal received from the field is characterized based on the entries that the user makes for the SENSRTYP, PVCHAR, PVTEMP, INPTDIR, and TCRNGOPT parameters as shown in Figure 2-1. The input PV signal is first converted to a raw PV signal (PVRAW) whose units can be %, ratio, millivolts, microvolts, or milliohms depending on the entry made for the SENSRTYP parameter.

The PVRAW signal is then converted to the engineering units. The engineering unit conversions that are performed in the HLAI, LLAI and LLMUX points are listed in the following chart, and described in the following paragraphs.

<table>
<thead>
<tr>
<th>HLAI Point</th>
<th>LLAI Point</th>
<th>LLMUX Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Linear</td>
<td>Linear</td>
</tr>
<tr>
<td>Square Root</td>
<td>Square Root</td>
<td>RTD</td>
</tr>
<tr>
<td>Thermal</td>
<td>Thermal (with reference junction compensation)</td>
<td>Thermal (with reference junction compensation)</td>
</tr>
<tr>
<td>Slidewire</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2.1.1 Linear Conversion

The PVRAW value is converted to a floating-point number. The output value of the linear conversion is PVCALC, which is calculated based on the raw input span (for slidewire and 0-100 mV sensor types only), and the engineering unit span. The state of the input direction parameter (INPTDIR) is taken into consideration during the calculation of PVCALC as follows:

For slidewire and 0-100 mV sensor types, when INPTDIR is Direct:

\[
PV_{CALC} = \frac{(PV_{RAW} - PV_{RAWLO})}{(PV_{RAWHI} - PV_{RAWLO})} \times (PVEUHI - PVEULO) + PVEULO
\]

For 0-5V, 0.4-2V, and 1-5V, sensor types, when INPTDIR is Direct:

\[
PV_{CALC} = \frac{PV_{RAW}}{100} \times (PVEUHI - PVEULO) + PVEULO
\]

For slidewire and 0-100 mV sensor types, when INPTDIR is Reverse:

\[
PV_{CALC} = PVEUHI - \frac{(PV_{RAW} - PV_{RAWLO})}{(PV_{RAWHI} - PV_{RAWLO})} \times (PVEUHI - PVEULO)
\]

For 0-5V, 0.4-2V, and 1-5V, sensor types, when INPTDIR is Reverse:

\[
PV_{CALC} = PVEUHI - \frac{PV_{RAW}}{100} \times (PVEUHI - PVEULO)
\]
Table 2-1 — HLAI, LLAI, and LLMUX Sensor Types and PV Characterization Options

<table>
<thead>
<tr>
<th>Sensor Type (SENSRTYP)</th>
<th>AI Processor Type</th>
<th>PVCHAR Options</th>
<th>PV RAW</th>
<th>PV CALC</th>
<th>Bad PV Detection²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5 Volts</td>
<td>HL &amp; LL</td>
<td>Linear</td>
<td>%</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>HL &amp; LL</td>
<td>Square Root</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>Thermocouple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>RTD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4 to 2 Volts</td>
<td>HL</td>
<td>Linear</td>
<td>%</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>Square Root</td>
<td></td>
<td></td>
<td>HLAI checks for open input</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>Thermocouple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>RTD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 5 Volts</td>
<td>HL &amp; LL</td>
<td>Linear</td>
<td>%</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>HL &amp; LL</td>
<td>Square Root</td>
<td></td>
<td></td>
<td>HLAI checks for open input</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>Thermocouple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>RTD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slidewire</td>
<td>HL</td>
<td>Linear</td>
<td>Ratio</td>
<td>EU³</td>
<td>Bad slidewire source, range check on PVCALC</td>
</tr>
<tr>
<td>0 to 100 mV</td>
<td>LL, LLMUX</td>
<td>Linear</td>
<td>millivolts</td>
<td>EU³</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>LL, LLMUX</td>
<td>Thermocouple</td>
<td>µvolts</td>
<td>EU</td>
<td>Open thermocouple, and range check on PVCALC</td>
</tr>
<tr>
<td>RTD</td>
<td>LL, LLMUX</td>
<td>RTD</td>
<td>milliΩ</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
</tbody>
</table>

**LEGEND:** EU = Engineering Units  
HL = High Level Analog Input  
LL = Low Level Analog Input  
LLMUX = Low Level Multiplexer  
PVCALC = Calculated PV  
PVCHAR = PV Characterization  
PVRAW = PV received from field and converted to digital form by the A/D converter

**Notes:**

1. PVRAW is the voltage signal at the PM Field Termination Assembly as a percentage of the voltage range for the sensor type. The exceptions are as follows
   a. For a thermocouple sensor type, PVRAW is in microvolts after reference junction compensation. If an open thermocouple is detected, PVRAW is set to NaN.
   b. For an RTD sensor type, PVRAW is in milliohms after lead-wire compensation. If an open RTD is detected, PVRAW is set to NaN.
   c. An external power source is used to excite the slidewire. The power source and the slidewire are connected to separate analog input points. One power source input can be used with several slidewire inputs.
      For a Slidewire type, PVRAW is the slidewire ratio (Vin/Vsrc)  
      where: Vin is the FTA voltage input for this data point (slot)  
      Vsrc is the FTA voltage source at the slidewire source slot specified by parameter SLWSRCID. If Vsrc is zero (fails the under-range check), PVRAW is set to "NaN."
   d. For a 0-100 millivolt sensor type, PVRAW is the FTA voltage input for the slot.

2. If the diagnostics determine that the A/D converter has failed, PVRAW of the slot is set to NaN.

3. The normal operating range for PVRAW is configured by the user (for a thermocouple 0% = PVRAWLO, 100% = PVRAWHI; for a slidewire, 0 = PVRAWLO, 1 = PVRAWHI).
2.2.1.2 Square-Root Conversion

The square-root calculation is applied to the PVRAW input such that 100% of span = 1.0. The square-rooted value is then converted to engineering units based on the configured PV engineering-unit range values. (For example, square root of 100% = 100%; square root of 50% = 70.71%). The output value of the square-root conversion is PVCALC, which is calculated based on the state of the input direction parameter (INPTDIR) as follows:

If PVRAW ≥ 0.0 and INPTDIR is Direct:

\[
PVCALC = \sqrt[100]{PVRAW} \ast (PVEUHI - PVEULO) + PVEULO
\]

If PVRAW < 0.0 and INPTDIR is Direct:

\[
PVCALC = -\sqrt[100]{PVRAW} \ast (PVEUHI - PVEULO) + PVEULO
\]

If PVRAW ≥ 0.0 and INPTDIR is Reverse:

\[
PVCALC = PVEUHI - \sqrt[100]{-PVRAW} \ast (PVEUHI - PVEULO)
\]

If PVRAW < 0.0 and INPTDIR is Reverse:

\[
PVCALC = PVEUHI - \sqrt[100]{-PVRAW} \ast (PVEUHI - PVEULO)
\]

2.2.1.3 Thermal Conversion

Thermal linearization is performed on thermocouple and RTD input types, and is selectable by parameter PVCHAR. The following thermocouples are supported by the analog input point:

- Btherm
- Etherm
- Jtherm
- Ktherm
- Rtherm
- Rptherm
- Stherm
- Ttherm

The range of the thermocouple type used with the LLAI or LLMUX points can be increased by selecting Extended as the entry for the TCRNGOPT parameter. Refer to the PM PRD for the normal and extended ranges.

The LLAI and LLMUX points calculate the reference junction compensation from the measured reference junction output level. This value is stored and then later converted back to microvolts, with respect to 0 degrees C, for each thermocouple that is to be compensated. The cold-junction reference compensation (PVREFJN) parameter is expressed in microvolts for the specified thermocouple and is added to the microvolt value for PVRAW.
The following 3-wire RTDs are supported by the analog input point:

PtDinRTD
PtJisRTD
NicklRTD
CopprRTD

For an RTD, the LLAI and LLMUX points calculate the lead-wire compensation and then subtract the value from PVRAW.

The maximum allowable lead-wire resistance and intrinsic safety barrier resistance for the RTDs are listed in the following chart.

<table>
<thead>
<tr>
<th>RTD Type</th>
<th>Maximum Allowable Lead Resistance (Note 1)</th>
<th>Maximum Allowable Intrinsic Safety Barrier Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entire Loop</td>
<td>Per Leg</td>
</tr>
<tr>
<td>Pt: 100 Ω DIN Characterization</td>
<td>20 Ω</td>
<td>10 Ω</td>
</tr>
<tr>
<td>Pt: 100 Ω JIS Characterization</td>
<td>20 Ω</td>
<td>10 Ω</td>
</tr>
<tr>
<td>Ni: 120 Ω Edison Type 7 Characterization</td>
<td>20 Ω</td>
<td>10 Ω</td>
</tr>
<tr>
<td>Cu: 10 Ω SEER Standard Characterization</td>
<td>20 Ω</td>
<td>10 Ω</td>
</tr>
</tbody>
</table>

Note: Proper compensation for lead-wire resistance depends on the resistance being equal in each leg of the RTD. This includes resistance due to lead-wire resistance and intrinsic safety barriers. No provision is made to compensate for lead-wire resistance mismatch or intrinsic-safety-barrier resistance mismatch. Both the lead resistance and the intrinsic-safety-barrier resistance are allowed simultaneously when connected to an RTD in a Division 1 area.

2.2.2 PV Range Checking and Filtering

PV range checking ensures that the PVCALC output of PV characterization is within the limits defined by parameters PVEXEULO and PVEXEUHI. If either of the limits is violated, the output of the PVAUTO is set to NaN if clamping has not been specified. If clamping has been specified, the output of the PVAUTO is clamped to PVEXEUHI or PVEXEULO except when PVRAW (and consequently, PVCALC) is NaN in which case PVAUTO will be NaN.

If the range-checked and filtered value is less than the value specified by the user-configured LOCUTOFF parameter, the final output called PVAUTO is forced to PVEULO.

First-order filtering is performed on PVCALC, as specified by the user through parameter TF (filter lag time).
2.2.3 PV Source Selection

The PVSOURCE parameter allows the user to select the source of the PV for this data point. As shown in Figure 2-1, the PV can be provided by the Range Checking and Filtering circuit (when PVSOURCE is Auto), it can be the manually entered PV (when PVSOURCE is Man), or it can come from a sequence program (when PVSOURCE is Sub).

In addition, the PV source option parameter (PVSRCOPT) determines whether it is permissible to change the PV source to a source other than Auto. PVSRCOPT has two states: OnlyAuto and All. The All state allows the PV to be manually entered for this data point.

2.2.4 Alarming

The analog input data point compares the PV to threshold values and records the alarms in the database of the data point. The alarms are then reported by the Process Manager Module (PMM). The parameters that are associated with alarming in the analog input point are as follows:

<table>
<thead>
<tr>
<th>ALENBST</th>
<th>PVALDB</th>
<th>PVHPR</th>
<th>PVLOTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BADPVFL</td>
<td>PVALDBEU</td>
<td>PVHTP</td>
<td>PVROCNFL</td>
</tr>
<tr>
<td>BADPVPR</td>
<td>PVEXHIFL</td>
<td>PVLLFL</td>
<td>PVROCNPR</td>
</tr>
<tr>
<td>CONT CUT</td>
<td>PVEXLOFL</td>
<td>PVLLPR</td>
<td>PVROCNTP</td>
</tr>
<tr>
<td>EIPPCODE</td>
<td>PVHHFL</td>
<td>PVLLTP</td>
<td>PVROCPFL</td>
</tr>
<tr>
<td>HIGHAL</td>
<td>PVHHR</td>
<td>PVLOFL</td>
<td>PVROCPPR</td>
</tr>
<tr>
<td>HIGHALPR</td>
<td>PVHHHTP</td>
<td>PVLOPR</td>
<td>PVROCPTP</td>
</tr>
<tr>
<td>PTINAL</td>
<td>PVHIFL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Refer to the Process Manager Parameter Reference Dictionary for the definitions of these parameters.
2.3 SMART TRANSMITTER INTERFACE POINT

The Smart Transmitter Interface (STI) point provides an interface to Honeywell's advanced series of Smartline 3000 Smart Transmitters. The STI point can support the following Smartline Transmitter types:

- ST3000 Smart Pressure Transmitter for differential, gauge, and absolute pressure measurements
- STT3000 Smart Temperature Transmitter for temperature, millivolts, and ohms measurements, and
- MagneW 3000 Smart Magnetic Flow Transmitter for flow measurements

The STI points are located on the STI IOP. Each STI IOP has a maximum of 16 inputs, and it can communicate bidirectionally with up to 16 Smartline transmitters, regardless of the mix of transmitter types (pressure, temperature, or flow) using Honeywell’s digitally enhanced (D.E.) protocol.

The STIMV IOP supports all of the above and multi-PV Smartline Transmitter types such as the following:

- SCM3000 Smart Flow Transmitter (Coriolis method)
- Drexelbrook SLT Level Transmitter
- SMV 3000 Multivariable Pressure Transmitter
- SGC 3000 Gas Chromatograph

An STIMV IOP allows up to four multi-PV transmitters or a mix of multi-PV and single PV transmitter inputs that total no more than 16. A multi-PV transmitter is configured as if it were in n contiguous slots where n = the number of PVs expected. The STITAG parameter value for each contiguous slot must be identical. Refer to the PM/APM Smartline Transmitter Integration Manual for complete details.

The STI IOP and the Smartline Transmitters use bidirectional digital communication to allow the user to configure, view, and modify the transmitter database from the Universal Station. This digital protocol allows a more precise PV value to be transferred, thereby permitting more accurate control of the process. In addition, the transmitter can also send a secondary variable such as the transmitter temperature, cold junction temperature, or totalized value, depending on the transmitter type.

The transmitter database can be configured at the Universal Station and down-line loaded to the transmitter and the transmitter database can be up-line loaded to the STI IOP as required, when the STI point is in the inactive state. During normal operation (when the STI point is in the active state), each time that the transmitter broadcasts the PV value to the STI IOP, it also sends the one byte of its database (depending on the selected DECONF mode) to the STI IOP. This allows the STI IOP to compare the stored database to the newly received database to check for database mismatches. If a mismatch is detected, the PV is set to NaN and the status is set to DBCHANGE. The user can easily correct the mismatch by down-line loading the database stored in the STI IOP.
All key transmitter parameters can be accessed from the Universal Station including

- Upper and Lower Range Values
- Damping
- PV type
- DE (Digital Enhanced communications) configuration variables
- Status of the Transmitter
- Transmitter's serial number and software revision number
- Transmitter's scratchpad

The user can access these variables through the point's Detail Display or custom-built schematics. In addition to the tag name assigned to the process point associated with the transmitter, the transmitter is also assigned a tag name and the access mechanism follows the TDC3000 parameter access mechanism. This allows all the LCN capabilities applicable to a data point to be also applicable to the Smartline Transmitters.

The STI IOP maintains a copy of the transmitter's database. When a transmitter failure occurs, the database can be down-loaded to the transmitter. This database save/restore feature can significantly reduce the downtime of a control loop by reducing the time in getting a replacement transmitter in operation. The transmitter database can also be saved to a History Module or removable media if a checkpoint request is initiated. This allows for centralized control of the transmitter database, which significantly minimizes the effort required to establish the transmitter database during startup or normal operation.

The STI IOP also allows the user to access the detailed status of a transmitter. The status is displayed at a Universal Station together with the scratchpad information that has been entered, including any maintenance notes.

Calibration of the transmitter can also be accomplished from the Universal Station. This function allows on-line adjustment of the transmitter's working ranges so that the reference points for a measurement are accurate.

In addition a Smart Field Communicator (SFC), which is a hand-held device, can also be physically connected to the appropriate FTA in the PM cabinet to communicate with Smartline Transmitters without disrupting the process, as required (refer to the *Operating Guide for Smart Field Communicators*).
### 2.3.1 Parameter Comparisons

To configure the STI IOP point to operate with the appropriate Smartline Transmitter, it is necessary to know the parameter relationships between the STI IOP and the transmitter database. Table 2-2 lists and describes these relationships.

<table>
<thead>
<tr>
<th>Smart Transmitter Database Parameter</th>
<th>Corresponding STI IOP Parameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Range Value &amp; Lower Range Value</td>
<td>URV LRV</td>
<td>Define the operating range of the transmitter. These values correspond to the values for PVEUHI and PVEULO, respectively.</td>
</tr>
<tr>
<td>Upper Range Limit &amp; Lower Range Limit</td>
<td>URL LRL</td>
<td>These parameters are the respective built-in maximum and minimum limits of the transmitter and they cannot be changed. These parameters are read-only parameters at the Universal Station. URL must be configured to match the URL value of the transmitter.</td>
</tr>
<tr>
<td>PV Damping</td>
<td>DAMPING</td>
<td>PV damping at the transmitter. Refer to paragraph 2.3.2.5.</td>
</tr>
<tr>
<td>Tag Identifier</td>
<td>STITAG</td>
<td>Transmitter identifier. This parameter is a read-only parameter at the Universal Station.</td>
</tr>
<tr>
<td>Software Version</td>
<td>STISWVER</td>
<td>Revision level of the software in the transmitter. This parameter is a read-only parameter at the Universal Station.</td>
</tr>
<tr>
<td>Serial Number</td>
<td>SERIALNO</td>
<td>Serial number (PROM) of the transmitter. This parameter is a read-only parameter at the Universal Station.</td>
</tr>
<tr>
<td>Secondary Variable</td>
<td>SECVAR</td>
<td>For a pressure transmitter, the secondary variable is the meter-body temperature of the transmitter. For a temperature transmitter, the secondary variable is the cold-junction temperature. For a flowmeter, the secondary variable is the totalized value. This parameter is a read-only parameter at the Universal Station.</td>
</tr>
<tr>
<td>Linear / Square Root Characterization</td>
<td>PVCHAR</td>
<td>Refer to Table 2-3.</td>
</tr>
<tr>
<td>Communication Mode</td>
<td>DECONF</td>
<td>Refer to paragraph 2.3.3.</td>
</tr>
<tr>
<td>Cold Junction Compensation Active</td>
<td>CJTACT</td>
<td>Applicable to STT 3000 only.</td>
</tr>
</tbody>
</table>
2.3.1

For more information on the STI IOP, refer to the appropriate Smartline transmitter publication and to the *PM/APM Smartline Transmitter Integration Manual*. For more information on STI IOP parameters, refer to the *Process Manager Parameter Reference Dictionary*.

A detail display of a typical STI point is shown in Figure 2-2. It also shows the location of the transmitter database parameters.

![Figure 2-2 — STI Point Detail Display](image-url)
Figure 2-3 — Smart Transmitter Input Point, Functional Diagram
2.3.2 STI IOP Functions

A functional diagram of the STI IOP point is shown in Figure 2-3. The STI point performs the following functions:

- PV characterization
- Range Checking and PV filtering
- PV source selection
- Alarm detection

2.3.2.1 PV Characterization

The PV signal (PVRAW) received from the transmitter has been characterized by the transmitter in terms of linear or square-root characterization and damping. For the STT 3000, PVRAW is further characterized based on the entries that the user makes for the SENSRTYP, PVCHAR, and INPTDIR parameters as shown in Figure 2-3. Table 2-3 lists the PV characterization options available for the various transmitter (sensor) types.

2.3.2.2 Linear Conversion

If the entry for PVCHAR is Linear, the PVRAW input from the FTA is calculated as a proportion of the input span in percent, as determined from upper and lower range values URV and LRV. This proportion is then used in generating an identical proportion of the output span, as determined from PVEUHI and PVEULO shown in Figure 2-4. The URV and LRV values are the 100% and 0% values that correspond to the PVEUHI and PVEULO values, respectively.

![Figure 2-4 — Linear Conversion, STI IOP](image-url)
Table 2-3 — STI Sensor Types and PV Characterization Options

<table>
<thead>
<tr>
<th>Transmitter (Sensor) Type (SENSRTYP)</th>
<th>PVCHAR Options</th>
<th>PV RAW&lt;sup&gt;1,3&lt;/sup&gt;</th>
<th>PV CALC</th>
<th>PV Detection&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spt_Dp (Differential Pressure)</td>
<td>Linear</td>
<td>% in H&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>Square Root</td>
<td>% in H&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td>Spt_Gp (Gauge Pressure)</td>
<td>Linear</td>
<td>% in H&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td>Spt_Ap (Absolute Pressure)</td>
<td>Linear</td>
<td>% in H&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td>Stt (Temperature)&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Linear</td>
<td>% mV</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>Thermocouple</td>
<td>% °C</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>RTD</td>
<td>% °C</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td></td>
<td>RTD Ohms</td>
<td>% Ohms</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
<tr>
<td>Sfm (Flow)</td>
<td>Linear</td>
<td>% m&lt;sub&gt;3&lt;/sub&gt;/Hr</td>
<td>EU</td>
<td>Range check on PVCALC</td>
</tr>
</tbody>
</table>

LEGEND: EU = Engineering Units
PVCALC = Calculated PV
PVCHAR = PV Characterization
PVRAW = PV received from transmitter and multiplied by 100 by the STI IOP

Notes:
1. PVRAW is a percentage of the configured range for the sensor type. For Multivariable transmitters, PVRAW Engineering Units are different for each PV slot.
2. If the transmitter gross status indicates Output mode or Bad, PVRAW of the STI point is set to NaN, and PVSTS is set to Bad.
3. The normal operating range for PVRAW (0% = PVRAWLO, 100% = PVRAWHI) is configured by the user.
4. For the supported temperature ranges, refer to the definition of the PVCHAR parameter in the Process Manager Parameter Reference Dictionary.

2.3.2.3 Square-Root Conversion

If square root is selected, this function is performed by the smart transmitter in its computation of PVRAW. The value for PVCALC is then determined in the same manner as linear conversion. These conversion equations are provided below.

For INPTDIR = Direct:

\[ \text{PVCALC} = \frac{\text{PVRAW}}{100} \left( \text{PVEUHI} - \text{PVEULO} \right) + \text{PVEULO} \]

If INPTDIR = Reverse:

\[ \text{PVCALC} = \frac{\text{PVRAW}}{100} \left( \text{PVEULO} - \text{PVEUHI} \right) + \text{PVEUHI} \]
2.3.2.4 Thermal Conversion

Thermal linearization is available for the thermocouple and RTD inputs of the Stt (temperature) transmitter. Thermal linearization is selectable by parameter PVCHAR. The following thermocouples are supported for an STI point:

- Btherm
- Etherm
- Jtherm
- Ktherm
- NiNiMoTC
- Ntherm
- RhRad
- Rtherm
- Stherm
- Ttherm
- W5W26TC
- W3W25TC

The STI point calculates the reference junction compensation from the measured reference junction output level. This value is stored and then later converted back to millivolts, with respect to 0 degrees C, for each thermocouple that is to be compensated. The external cold-junction reference compensation (CJTACT) parameter is expressed in millivolts for the specified thermocouple and is added to the millivolt value for PVRAW.

The following 3-wire RTDs are supported by the STI point:

- PtDinRTD (Pt100D)
- PtJisRTD (Pt100J)
- NicklRTD (Ni500)
- Pt200RTD
- Pt500RTD
- Cu10RTD
- Cu25RTD

For an RTD, the STI point calculates the lead-wire compensation and then subtracts the value from PVRAW.
2.3.2.5 PV Range Checking and Filtering

PV range checking ensures that the PVCALC output of PV characterization is within the limits defined by parameters PVEXEULO and PVEXEUHI. If either of the limits is violated, the output of the range check is set to BadPV if clamping has not been specified. If clamping has been specified, the output of the range check is clamped.

If the range-checked and filtered value is less than the value specified by the user-configured LOCUTOFF parameter, the final output called PVAUTO is forced to PVEXEU.

PV filtering can be implemented at the STI IOP, or at the Smartline Transmitter. At the STI IOP, first-order filtering is performed on PVCALC, as specified by the user through parameter TF (filter lag time). At a transmitter, filtering is performed on the PV depending on the value entered for the DAMPING parameter using the SFC. The user should decide the type of filtering required based on the following guidelines:

- The DAMPING parameter allows for better control accuracy because more PV samples are used in calculating the filtered PV value at the transmitter.
- TF can be changed on-process from the Universal Station. To change the DAMPING value requires the point to be made inactive and requires the database to be down-line loaded to the transmitter after the change has been made.

For better control accuracy, the use of the DAMPING value is preferred over the TF value. The transmitter accepts only certain DAMPING values from the STI IOP, and the value received must first be converted to one of the predefined DAMPING values that reside in the transmitter. This conversion is accomplished automatically by the STI IOP by finding the DAMPING value that is nearest to the desired DAMPING value.

DAMPING values differ between the Smartline Transmitters. The valid DAMPING values for each transmitter type are contained in the following listing.

<table>
<thead>
<tr>
<th>Pressure (Spt)</th>
<th>Temperature (Stt)</th>
<th>Flow (Sfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0.16</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>0.32</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>0.48</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>1.00</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>2.0</td>
<td>6.3</td>
<td>4.0</td>
</tr>
<tr>
<td>4.0</td>
<td>12.7</td>
<td>5.0</td>
</tr>
<tr>
<td>8.0</td>
<td>25.5</td>
<td>10.0</td>
</tr>
<tr>
<td>16.0</td>
<td>51.1</td>
<td>50.0</td>
</tr>
<tr>
<td>32.0</td>
<td>102.3</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* The values listed are the first-order filter time constants in seconds.
2.3.2.6 PV Source Selection

The PVSOURCE parameter allows the user to select the source of the PV for this data point. As shown in Figure 2-3, the PV can be provided by the Range Checking and Filtering circuit (when PVSOURCE is Auto), or it can be the manually entered PV (when PVSOURCE is Man or Sub).

In addition, the PV source option parameter (PVSRCOPT) determines whether it is permissible to change the PV source to a source other than Auto. PVSRCOPT has two states: OnlyAuto and All. The All state allows the PV to be manually entered for this data point.

2.3.2.7 Alarming

The STI point compares the PV to threshold values and records the alarms in the database of the data point. The alarms are then reported by the Process Manager Module (PMM). The parameters that are associated with alarming in the STI point are as follows:

<table>
<thead>
<tr>
<th>ALENBST</th>
<th>PVHHPR</th>
<th>PVLOPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BADPVFL</td>
<td>PVHHTP</td>
<td>PVLOTP</td>
</tr>
<tr>
<td>BADPVPR</td>
<td>PVHIFL</td>
<td>PVROCNFL</td>
</tr>
<tr>
<td>PRIMMOD</td>
<td>PVHIPR</td>
<td>PVROCNPR</td>
</tr>
<tr>
<td>PTINAL</td>
<td>PVHITP</td>
<td>PVROCNTP</td>
</tr>
<tr>
<td>PVALDB</td>
<td>PVLLFL</td>
<td>PVROCPFL</td>
</tr>
<tr>
<td>PVALDBEU</td>
<td>PVLLPR</td>
<td>PVROCPPR</td>
</tr>
<tr>
<td>PVEXHIFL</td>
<td>PVLLTP</td>
<td>PVROCPFP</td>
</tr>
<tr>
<td>PVXLOFL</td>
<td>PVLOFL</td>
<td></td>
</tr>
<tr>
<td>PVHHFL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Refer to the Process Manager Parameter Reference Dictionary for the definitions of these parameters.

2.3.3 Smart Transmitter Communication Modes

All communications between the STI IOP and the Smartline transmitters are in bit-serial form using the Honeywell DE (digital enhanced) protocol. The communication mode for the transmitter is selectable through the DECONF (DE configuration mode) parameter, whose possible entries are as follows:

<table>
<thead>
<tr>
<th>DECONF Entry</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog</td>
<td>Not supported</td>
</tr>
<tr>
<td>Pv</td>
<td>Transmitter communicates only the PV (4-byte format)</td>
</tr>
<tr>
<td>Pv_Sv</td>
<td>Transmitter communicates the PV and the Secondary Variable (SV) (4-byte format)</td>
</tr>
<tr>
<td>Pv_Db*</td>
<td>Transmitter communicates the PV and the database (6-byte format)</td>
</tr>
<tr>
<td>Pv_Sv_Db*</td>
<td>Transmitter communicates the PV, SV, and the database (6-byte format)</td>
</tr>
</tbody>
</table>

* The use of these two modes is recommended because they offer database mismatch detection and on-process mismatch recovery.
2.3.4 Database Considerations

During normal operation, the STI point database and the corresponding transmitter database contain the same information. If under special conditions, the databases are not the same, a status message appears on the STI point's Detail Display to indicate a database mismatch. Three possible ways that a database mismatch can occur between the STI IOP database and the transmitter database are as follows:

- Smart Field Communicator (SFC) is used to change PV-related values in the transmitter.
- A write operation from the Universal Station to the STI IOP (during a checkpoint restore or point building).
- The same transmitter has been reinstalled after bench calibration, or after the transmitter electronic module has been replaced and the LRV/URV values have been modified.

The following parameters of the STI IOP database and the transmitter database are compared when the STI IOP checks for database mismatches:

- CJTACT
- DAMPING
- DE_CONF
- FREQ60/50
- PIUOTDEN
- PVCHAR
- SENSRTYP
- STITAG
- URL
- URV, LRV

If a database mismatch is detected, the first four parameter mismatches are displayed in the S1 status field of the STI point's Detail Display at the Universal Station. These mismatched parameters are preceded by the message "DATA BASE DISCREPANCY."
The user can correct the mismatch by one of the following methods:

- Download the STI IOP database to the transmitter by issuing a DnLoadDb command through the COMMAND parameter when the point is in an Inactive state. If the loading is successful, the point STATE changes to OK when the point is made active.
- Upload the transmitter database to the STI IOP by issuing an UpLoadDb command through the COMMAND parameter when the point is in an Inactive state. If the loading is successful, the point STATE changes to OK when the point is made active.
- Correct the mismatched parameter using the SFC. If the parameter or parameters are updated by the SFC to the same value as in the STI IOP database, the state changes from Mismatch to OK when the next database transfer from the transmitter occurs.

If a mismatch occurred because the Smart Field Communicator (SFC) was used to change a parameter in the transmitter database, the data in the transmitter database may be correct. In this case, the STI IOP does not know which value to use and issues an "SFC MODIFIED XMTR DATABASE" message, which appears on the Detail Display. The user should wait until the next database transfer occurs from the transmitter before taking action. At that time, the specific change is displayed.
A database mismatch can also occur because the transmitter was miswired during installation. This can be fixed by correcting the transmitter wiring.

For the MagneW3000, the URL value displayed on the SFC is a factor of 10 higher than the actual value displayed at the Universal Station. The value displayed at the SFC is the scaled limit while the value displayed at the Universal Station represents raw data. Also, the STI IOP does not respond to changes made in the MagneW3000 database parameters for up to 3 minutes when the database changes are made using the Local Setting Card. This card is an option that is available with the MagneW3000.

### 2.3.5 Point States

The STATE parameter indicates the current status of the STI IOP and the transmitter. The various states are listed in Table 2-4.

#### Table 2-4 — STI IOP Point States

<table>
<thead>
<tr>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK</td>
<td>Normal state; indicates that the STI point and the transmitter are OK. Transmitter is updating the PV value at the STI point. STATE remains OK when the point is made inactive.</td>
</tr>
<tr>
<td>DBChange</td>
<td>Indicates that a database mismatch between the STI point and the transmitter has been detected. Transmitter is not updating the PV value at the STI point. STATE remains DBChange when the point is made inactive.</td>
</tr>
<tr>
<td>Loading</td>
<td>Indicates that database loading between the STI point and the transmitter is occurring.</td>
</tr>
<tr>
<td>Loadcomp</td>
<td>Indicates that the database transfer between the STI point and the transmitter has been successfully completed.</td>
</tr>
<tr>
<td>Loadfail</td>
<td>Indicates that the parameter transfer between the STI point and the transmitter has not been successfully completed.</td>
</tr>
<tr>
<td>Calib</td>
<td>Indicates that certain parameters are being calibrated at the transmitter by the STI point.</td>
</tr>
<tr>
<td>Calcomp</td>
<td>Indicates that the calibration has been successfully completed.</td>
</tr>
<tr>
<td>Calfail</td>
<td>Indicates that the calibration has not been successfully completed.</td>
</tr>
</tbody>
</table>

### 2.3.6 STI IOP Commands

The COMMAND parameter allows the engineer to load configuration parameters in the smart transmitter and to calibrate the transmitter. (The point must first be placed in the Inactive state through the PTEXECST parameter.) The enumerations of the COMMAND parameter are as follows:
### COMMAND Selection

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DnLoadDB</td>
<td>Load the STI IOP database into the transmitter (down-line load).</td>
</tr>
<tr>
<td>UpLoadDb</td>
<td>Loads the transmitter database into the STI IOP (up-line load).</td>
</tr>
<tr>
<td>Set_LRV</td>
<td>Set the Lower Range Value</td>
</tr>
<tr>
<td>Set_URV</td>
<td>Set the Upper Range Value</td>
</tr>
<tr>
<td>Cor_LRV</td>
<td>Corrects the Lower Range Value</td>
</tr>
<tr>
<td>Cor_URV</td>
<td>Corrects the Upper Range Value</td>
</tr>
<tr>
<td>Cor_Inpt</td>
<td>Corrects the zero point</td>
</tr>
<tr>
<td>RstCor</td>
<td>Sets all input calibration parameters to their factory default values.</td>
</tr>
<tr>
<td>Null</td>
<td>A command has not been issued by the STI IOP.</td>
</tr>
</tbody>
</table>

The result of issuing a command to an STI IOP point is reflected in the STATE parameter for the point.

### 2.4 ANALOG OUTPUT POINT

The analog output point converts the output value (OP) to a 0-20 mA output signal for operating final control elements such as valves and actuators in the field. The OP parameter value can be controlled from a PM regulatory point, an AM regulatory point, the operator, or a user program, depending on the selected mode and the entries for the RCASOPT and PNTFORM parameters.

To convert the OP value to a 0-20 mA signal, the analog output point performs:

- Direct/reverse Output Function
- Nonlinear Output Characterization

An option allows redundant Analog Output points (see section 3.6). Figure 2-5 is a functional diagram of the analog output point.

#### 2.4.1 Direct/Reverse Output

Parameter OPTDIR allows the user to specify whether the output of the data point is direct acting (where 4 mA = 0%, and 20 mA = 100%) or reverse acting (where 4 mA = 100%, and 20 mA = 0%). The default mode is direct acting. In direct operation, an output request of -6.9% is treated as a request for 0 ma. In reverse operation, an output request for 106.9% causes a physical output of 0 ma.

#### 2.4.2 Output Characterization

Output characterization allows the user to specify an output transfer function, using configurable X-Y coordinates that provide five linear segments as shown in Figure 2-6. The length of each segment is variable according to the coordinates that can be entered as applicable constants for OPOUT1-4 and OPIN1-4 parameters, which are real numbers.
2.4.2

Output Value (from AM Regulatory Point) → RCASOPT
None

Output Value (from Operator) → Oper
MODATTR
None

Output Value (from Program) → Prog
MODE
Man
Full

Output Value (from PM Regulatory Point) → Componnt
PNTFORM

OP

OPCHAR
Off

DIRECT/REVERSE CALCULATION

On

OPIN0 OPIN1 OPIN2 OPIN3 OPIN4 OPIN5

OUTPUT CHARACTERIZATION

OPOUT0 OPOUT1 OPOUT2 OPOUT3 OPOUT4 OPOUT5

CALIBRATION COMPENSATION

OPFINAL
(To FTA)

NOTE: All parameters are shown in the defaulted entry positions.

Figure 2-5 — Analog Output Point, Functional Diagram
As shown in Figure 2-6, the end points of the curve are fixed at coordinates \( OPOUT0, OPIN0 \) (at -6.9%) and \( OPOUT5, OPIN5 \) (at 106.9%). These coordinates are fixed at these values to ensure that neither the characterization function nor its inverse can provide output values which are outside the -6.9% to 106.9% range.

Depending on the output value, the analog output point interpolates linearly between the two nearest values. The interpolated value becomes the output value \( OPFINAL \).

Output characterization is an optional function that can be implemented by setting parameter \( OPCHAR \) to On. Refer to Figure 2-5.

2.4.3 Calibration Compensation

The final stage of output processing in the analog output point is calibration compensation. This is accomplished in the data point using internal offset and scale constants. The output value \( OPFINAL \) is then routed to the field through the appropriate FTA.

NOTE

Slot or module level soft failures can prevent a point (or points) from outputting to the field. The regulatory control point will initiate a “Bad Output” alarm (if configured) when any connection is broken. If all configured point connections to the field are broken, the regulatory control point driving that analog output slot goes into initialization.
2.5 DIGITAL INPUT POINT

A digital input point converts a digital PVRAW signal received from the field to a PV that can be used by other data points in the PM and the system. A functional diagram of the digital input point is shown in Figure 2-7.

Bad PV Flag—Control strategies can test for a bad Digital Input PV. Parameter BADPVFL is set ON when—

- The PV source has been switched to Substituted, and the point is inactive or the module status is Idle.
- The PV source is AUTO and the PV is not being updated, because either the point is inactive, the module is idle, there is a slot soft failure, or the FTA is missing.

The digital input point is a single-input point that can be configured as a status input, a latched input, or for accumulation, as described in the following paragraphs.

2.5.1 Status Digital Input Point

For this digital input type, the PVAUTO value represents the state of the raw input signal after the direct/reverse conversion is performed. The status digital-input point can be configured for PV source selection, detection of off-normal alarms, and for reporting any PV state changes to the system. The status digital input point is selected by entering Status for the DITYPE parameter.

The current state of the PV input is represented on the Universal Station Group and Detail Displays as two boxes, as shown in Figure 2-8. The boxes are lighted or extinguished depending on the current state of PVRAW and the input direction as configured through the INPTDIR parameter, as shown in the chart in Figure 2-8. The current PV state is also available to be used as an input to logic slots, and other PM control functions.

2.5.1.1 PV Source Selection

The PV source parameter (PVSOURCE) option determines the source of the PV for a status input point. The source can be the PV input from the field (PVauto), the PV state entered by the operator (PVman), or it can be supplied by a user program (PVsub). PVSOURCE has no effect on the latched and accumulation options of the digital input point. If PVSOURCE is PVauto, PV tracks PVRAW.
2.5.1.2 Off-Normal Alarming

Enabling, Disabling, and Inhibiting Off-Normal Alarms—The ALENBST parameter allows the operator to enable (permit), disable, or inhibit the off-normal alarm. Disabling the alarm still allows the alarm to be listed on the Group and Detail displays. Inhibiting the alarm prevents the current PV state from being compared to the configured normal state.

Off-Normal Alarming & PV Change Reporting—Off-normal alarming can be selected for the digital input point through the ALMOPT parameter. An off-normal alarm is generated when the input PV state is different than the configured normal (desired) state for the point as specified by the PVNORMAL parameter. The priority of the off-normal alarm is determined through the OFFNRMPR parameter (ALPRIOR may also be used to maintain compatibility with schematics and CL programs designed for pre-R500 software).

Additionally, all PV state changes can be historized as determined by HM volume configuration.

Change Of State Reporting—Digital Input Status points can be configured for Change Of State (COS) alarm reporting through the ALMOPT parameter. The alarm is generated when the input changes state in either direction. Alarm priority is determined through the OFFNRMPR/ALPRIOR parameters as before.

COS alarms are removed from the Alarm Summary display following acknowledgement. The Point does not remain in alarm so there is no Return-to-Normal. Point Detail or Group displays will never show a point in COS alarm.

Older digital input IOPs may need to have a new firmware chip for COS reporting. Check the IOP’s detail display. For COS reporting the Digital Input IOP firmware revision must be 5.0 or later.

Note that when a point with COS reporting is changed from Inactive to Active, a COS alarm is generated if the PV = 1. There is no COS alarm if the PV = 0. The same alarming occurs if the point is active and the IOP is put into Run mode.

Alarm Delay—When off-normal alarming has been configured and an off-normal alarm is detected, the event is reported to the system. Further off-normal alarms for the same data point are not reported until the time delay (0 to 60 seconds) specified by the DLYTIME parameter expires. When the time delay expires, the time-delay function is disabled and the off-normal alarm for the data point can again be reported.

For Change of State alarms, when a PV state change occurs, a COS alarm is produced and the delay timer is started. When DLYTIME expires, two situations are possible—

- the PV is in the same state and future state changes are immediately alarmed.
- the PV is in the opposite state (it may have changed many times during the DLYTIME period) so a second COS alarm is produced and the timer starts again.
2.5.1.3 Event Reporting

The EVTOPT parameter for the status input allows the user to optionally specify the tag name (EIPPCODE) of a data point in the system that is to be notified when the PV changes state, and/or specify that a time stamp be added to the reported PV state change.

For a status input point, EVTOPT has the four possible entries: None, EIP, SOE, and EIPSOE. EIP specifies that the user supply the tag name of the data point in the system that is to receive the PV state change, while SOE specifies that a time stamp is added to the PV state change to establish a sequence of events.

Change of State Reporting can initiate Event Initiated Processing if the point is configured for both COS and EIP. Note that digital input points that have COS (or Off Normal alarming) and EVTOPT EIP configured will have EIP triggered twice. EIP processing associated with COS reporting is not recoverable for NIM/PM failovers.

2.5.2 Latched Digital Input Point

To capture the occurrence of momentary digital inputs, such as from pushbuttons, requires the user to configure the digital input point as a latched digital input point. Configuring the point as a latched point is accomplished by entering Latched for the DITYPE parameter.

When configured as a latched input point, an input pulse that is on for a minimum of 40 milliseconds is latched true for 1.5 seconds. This ensures that any control function that needs to monitor this event will execute at least once during the time that the signal is latched on.

The current state of the latched PV input is represented on the Universal Station Group and Detail displays as two boxes, as shown in Figure 2-8. The boxes are lighted or extinguished depending on the current state of PVRAW and the input direction as configured through the INPTDIR parameter, as shown in the chart in Figure 2-8. The current PV state is also available to be used as an input to logic slots, and other PM control functions.
Figure 2-7 — Digital Input Point, Functional Diagram
### 2.5.2

#### 2.5.2.1 Event Reporting

The EVTOPT parameter for the latched input allows the user to optionally specify the tag name (EIPPCODE) of a data point in the system that is to be notified when the PV changes state. For a latched input point, EVTOPT has two possible entries: None and EIP.

#### 2.5.3 Accumulation Digital Input Point

The accumulation type digital input point counts the transitions of the digital input pulses received from the field. The digital input point is configured for accumulation by entering Accum for the DITYPE parameter.

##### 2.5.3.1 Up/Down Accumulation

The accumulation type digital-input point can be incremented or decremented depending on the entry made for the COUNTDWN parameter. If the entry for this parameter is Off, the point is to be incremented by the field transitions; if the entry is On, the point is decremented. The accumulated or decremented value is the value of parameter AV.
2.5.3 Accumulator Commands

The operator has the capability of issuing start, stop, and reset commands to the accumulator for starting, stopping, and resetting the accumulation. For resetting the accumulator, the operator can specify the value to which the accumulator is reset by using the RESETVAL parameter to enter the value. When the accumulator is reset, the old accumulated value is displayed using the OLDAV parameter.

2.5.3.3 Target Value

The operator can specify the accumulator target value through the AVTV parameter. When the accumulated value (PVAUTO) reaches the target value (PVT), parameter AVTVFL is set to On. AVTVFL is set to Off when the accumulator is reset.

2.5.3.4 Overflow

If the accumulated value AV overflows the accumulator (AV > 999999), the OVERFLOW parameter is set to On. In addition, it is set to 0 when the accumulator is configured for counting up (incrementing); it is set to 32767 if it is configured for counting down (decrementing).

2.6 DIGITAL OUTPUT POINT

The digital output point provides a digital output to the field based on the origin of the input and the configured parameters. A functional diagram of the digital output point is shown in Figure 2-9. The digital output point does not have any modes.

There are two types of digital output points: pulse-width modulated (PWM) output and status output. Selection of the output type is accomplished through the DOTYPE parameter shown in Figure 2-9. The PWM type is used in combination with RegCtl algorithms to provide true proportional control. The status type output is the normal configuration for digital outputs that are linked to digital composite points. Actual output action can be status, latched or momentary, depending on the configuration of the digital composite point. The default for untagged component DO points is Status.

2.6.1 Pulse Width Modulated (PWM) Output Type

The pulse width modulated output type can receive its input from a PM regulatory point (that has been configured for a PID type algorithm) through a user-specified output connection. The length of the pulse is derived from the OP parameter provided by the regulatory point. Because OP is in percent, the percent value becomes the percent on-time for the pulse whose period (1 to 120 seconds) is specified by the PERIOD parameter, as shown in the timing diagram in Figure 2-9.

The output direction of the output signal can be configured to be direct or reverse acting by using the OPTDIR parameter, as shown in the timing diagram in Figure 2-9.
The pulse on-time for direct and reverse acting outputs is calculated as follows:

For direct action:

\[
\text{Pulse On-Time} = \frac{\text{OP} \times \text{PERIOD}}{100}
\]

For reverse action:

\[
\text{Pulse On-Time} = \frac{100 - \text{OP} \times \text{PERIOD}}{100}
\]

If the value of OP is less than 0%, it is clamped to 0%; an OP with a value greater than 100% is clamped to 100%.

2.6.2 Status Output Type

The status output type can be controlled from a digital composite-point output, a logic slot output, or a RegCtl point (that has been configured for the PosProp algorithm) as determined by the output connection. The output latch function is obtained by linking digital composite-point output connections to the SO parameter. Pulsed operation (pulse-on or pulse-off) can be obtained by linking the output connections to the ONPULSE and OFFPULSE parameters, respectively.

The ONPULSE parameter sets SO to On for the specified duration, as shown in Figure 2-9. At the end of the pulse time, SO is set to Off. If ONPULSE is specified as 0.0, SO is immediately set to Off. This also applies to the OFFPULSE, except that the OFFPULSE sets SO to Off.

If SO is received from a logic slot, the SO output of the digital output point tracks the SO output provided by the logic slot.

2.6.3 Initialization Request Flag

When ON, this parameter indicates (for Status Output type points) that control strategies in the PM cannot manipulate the output. Parameter INITREQ is set ON when—

- a PWM type output is configured
- a Status Output type is configured and—
  - the point is inactive
  - the module is idle
  - there is a soft failure such that the point is not working.

**Digital Composite Points and Position Proportional Points**—Note that Digital Composite points or Position Proportional control algorithms are automatically forced to initialize when outputting to a Digital Output point whose INITREQ is ON.
2.6.3

OP (from PID Algorithm)

PWM

DOTYPE Status

On-Pulse Generator

Off-Pulse Generator

SO

Direct

OPTDIR Reverse

PERIOD

From Digital Composite Point or Logic Block

Figure 2-9 — Digital Output Point, Functional Diagram and Waveforms
2.7 PULSE INPUT POINT

The Pulse Input IOP accepts variable frequencies from a variety of devices such as turbine meters, vortex type flow meters and positive displacement meters and converts input pulses to flow rate in engineering units. Each Pulse IOP module contains eight input points. The input frequency supported is up to 20 KHz per channel. Alarming and filtering are provided by the IOP. Pulse Input points are configured under the Analog Input point selection on the NIM Process Point Building Menu. Figure 2-10 is a functional drawing of the Pulse IOP.

2.7.1 Operation

For each point, the IOP is able to calculate flow rate in engineering units based on user selected scaling factors. The Pulse IOP module always provides two related functions simultaneously: totalizing and frequency counting.

2.7.1.1 Totalizing

Totalizing means the IOP maintains a 32-bit accumulation (AV) for each channel (updated every 20 ms). The least significant bits are provided by the hardware accumulator. The 32-bit entity continually rolls (that is, there is no start, stop, or reset). The Pulse IOP only sets the parameter AV to zero when the point is inactive, the IOP is in Idle, or an error is detected. In the case of an error, status parameter AVSTS is set to BAD. Refer also to the Regulatory PV Totalizer algorithm description in subsection 7.7.7.

2.7.1.2 Frequency Counting

Frequency counting is expressed by parameter PVRAW.

\[
PVRAW = \frac{\text{Delta AV}}{\text{Elapsed Time in Seconds}} = \text{Pulses Per Second}
\]

2.7.1.3 PVCALC

PVCALC is PVRAW after scaling (for example, barrels per minute)—

\[
PVCALC = \frac{C_1}{C_2} \times \text{TIMEBASE} \times PVRAW
\]

C1 is an engineering units scale factor and is dimensionless, for example, barrels per gallon.

C2 is a meter factor in pulses per engineering unit (for example, pulses per gallon). If the instrument vendor instead supplies the factor K in engineering units per pulse (for example, gallons per pulse), then C2 must represent the reciprocal of the factor K, that is, C2 = 1/K.

TIMEBASE is a time scale factor. The choices are seconds, minutes, or hours.
2.7.1.4 Rate Value

The rate value is treated similar to an analog input PV and is supported by high/low alarms, Rate of Change (ROC) alarming, filtering, etc., on a half second processing interval (every four seconds for ROC only).

The Pulse IOP calculates the signed integer AVDELTHS every half second. AVDELTHS is the change in AV from the last half second and is intended for display purposes. The parameter’s value is normally constant, but the operator will observe a change if the pulse input rate varies.

2.7.1.5 Pulse Period

The pulse period (1/PV) can be determined with CL.

2.8 SERIAL DEVICE INTERFACE

The Serial Device Interface (SDI) uses an SDI IOP module and special Field Termination Assemblies (FTA) to transfer serial data from and to specific external devices.

The special FTAs contain firmware that is programmed by Honeywell to communicate with each specific type of external device. Communications with the device mimics a Smart Transmitter analog input point. The SDI IOP module is configured as if it is a Smart Transmitter Interface Module (STIM).

Currently interfaces for the following device have been developed:

- Manual/Auto Station
- Toledo Weigh Scale, Model 8142-2089
- Toledo Weigh Scale, Model 8142-2189
- UDC 6000 Process Controllers

2.8.1 Serial Device Interface Description

Each SDI board can support two serial channels and each FTA can communicate in ANSI/EIA-232 (RS-232) or EIA 422/485. The EIA232 interface connects to one serial device and the EIA-485 interface can connect to a multidrop network of up to eight devices.

Figure 2-11 illustrates the Serial Device Interface.
2.8.1 Implementation and Control

**Implementation**—You can communicate directly with the SDI using CL or control algorithms. Other implementation methods are described in the *Process Manager Implementation Guidelines* or the *PM/UDC 6000 Integration Manual* (see References).

**Control**—Operators typically control and SDI device from a custom schematic. You can build your own schematic or contract with Honeywell Engineering Services to build it.

2.8.2 Manual/Auto Station Interface

The Manual/Auto Station interfaces with the Process Manager through the Serial Device Interface FTA using EIA-485 protocol at 19.2 k baud. Up to four M/A stations can be connected in multi-drop to each of the two SDI FTAs. Each of eight slots in the SDI IOP can be configured for use with one Manual/Auto station. Slots 1–4 correspond to logical address for FTA one and slots 9–12 correspond to logical address 1–4 on FTA two (slot one = M/A Station 1 on FTA1, etc., and slot 9 = M/A Station 1 on FTA2 etc.).

Refer to the *Process Manager Implementation Guidelines* manual for additional information.

2.8.2.1 Communications

**Invalid data**—Both data received from the SDI IOP and data received from the M/A station are checked for reasonableness. Very small values may be rounded to .001. Very large (absolute) values are either rejected or stored as NaN.

**Time out**—A time out signal is sent from the SDI IOP to the FTAs every half second. Loss of this signal for 10 seconds or more halts all communications with the Manual/Auto stations connected to that FTA.

**Communications failure**—When communications between the FTA and an M/A Stations fails, the FTA makes two attempts to send the last message after the time out, then the point is put in bad input soft failure. As long as the slot remains active, there is an attempt to restore communications, but the M/A station is marked as not communicating.

Refer to the *Manual/Auto Station* manual for additional information on the Manual/Auto Station itself.
2.8.2.2 Implementation

The PV and OP process signals are directly connected to appropriate modules in the PM. Process and status signals are sent from the PM to the M/A station and operator changes to the Set Point, at the M/A station, are read into the PM as if those changes were at a Universal Station. Figure 2-12 illustrates a typical Manual Auto Station implementation.

Unless the PM Override flag is set, the PM responds to SP, OP, or mode change operations from the M/A Station's front panel. The PM Override function can inhibit operator functions attempted from the M/A station front panel that would affect SP, OP, or Mode.
Tables 2-5 through 2-7 show how to relate parameters seen at the Universal Station through the STI point and their meaning as Manual/Auto station parameters.

**Table 2-5 — PV Related Parameters Sent to the Manual Auto Station**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning as an STI Point Parameter</th>
<th>As an M/A Station Parameter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRV</td>
<td>Low end of operating range for PVRAW</td>
<td>Low end of operating range for PVRAW</td>
<td>PV (in engineering units)</td>
</tr>
<tr>
<td>PVEUHI</td>
<td>PV high range in eng. units</td>
<td>PV high range in engineering units</td>
<td>Must be set to 100.0</td>
</tr>
<tr>
<td>PVEULO</td>
<td>PV low range in eng. units</td>
<td>PV low range in engineering unit</td>
<td>Must be set to 0.0</td>
</tr>
<tr>
<td>PVEXEUHI</td>
<td>PV extended range high limit in engineering units</td>
<td>PV extended range high limit in eng. units</td>
<td>Must be set to 100.0</td>
</tr>
<tr>
<td>PVEXEULO</td>
<td>PV extended range low limit in engineering units</td>
<td>PV extended range low limit in engineering units</td>
<td>Must be set to 0.0</td>
</tr>
</tbody>
</table>

**Table 2-6 — Control, Status, and Other Parameters Sent to the Manual Auto Station**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning as an STI Point Parameter</th>
<th>As an M/A Station Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>CJTACT</td>
<td>Internal cold junction reference active</td>
<td>OFF = Manual Mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ON = Auto Mode</td>
</tr>
<tr>
<td>DAMPING</td>
<td>Damping</td>
<td>M/A Station Alarms:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Alarm 1 true</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = Alarm 2 true</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 = Both Alarms true</td>
</tr>
<tr>
<td>PIUOTDCF</td>
<td>Open thermocouple detect enable</td>
<td>ON = In Override</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OFF = Not in Override</td>
</tr>
<tr>
<td>PTEEXECST</td>
<td>Point execution state</td>
<td>Active = Point is active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inactive = Point is inactive</td>
</tr>
<tr>
<td>PVTV</td>
<td>PV target value</td>
<td>Setpoint in eng. units</td>
</tr>
<tr>
<td>STITAG</td>
<td>Transmitter tag name</td>
<td>M/A Station Tag Name</td>
</tr>
<tr>
<td>URL</td>
<td>Upper range limit of PV</td>
<td>OP in percent</td>
</tr>
<tr>
<td>URV</td>
<td>Upper range value of PVRAW</td>
<td>Valve position in percent</td>
</tr>
</tbody>
</table>
Table 2-7 — Parameters Sent from the Auto Manual Station

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning as an STI Point Parameter</th>
<th>As an M/A Station Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVRAW</td>
<td>Raw PV input value</td>
<td>Setpoint (in eng. units) from M/A Station</td>
</tr>
<tr>
<td>SECVAR</td>
<td>Value of Secondary Variable</td>
<td>OP (in per cent) from the M/Auto Station</td>
</tr>
<tr>
<td>SLOTSF</td>
<td>Slot soft failures</td>
<td>Soft failure due to bad input</td>
</tr>
<tr>
<td>STATE</td>
<td>Current point state</td>
<td>FTA Information</td>
</tr>
<tr>
<td>STI_EU</td>
<td>Smart Transmitter, engineering units</td>
<td>Change Requests:</td>
</tr>
<tr>
<td></td>
<td>INH20</td>
<td>0 = No change request</td>
</tr>
<tr>
<td></td>
<td>MM_HG</td>
<td>1 = SP change request</td>
</tr>
<tr>
<td></td>
<td>PSI</td>
<td>2 = OP change request</td>
</tr>
<tr>
<td></td>
<td>KPA</td>
<td>3 = Manual Mode request</td>
</tr>
<tr>
<td></td>
<td>MPA</td>
<td>4 = Auto Mode request</td>
</tr>
<tr>
<td>STISWVER</td>
<td>Smart Transmitter software revision level</td>
<td>FTA information:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(sent from FTA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 1 = M/A application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 2 = Software gen date.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 3 = Software rev date.</td>
</tr>
</tbody>
</table>

In addition to configuring the SDI IOP as an STI point, at least one, and preferably two logic points must be built to read data from each M/A station, perform necessary processing and then write the processed data, control, and status signals back to the M/A station.

The primary logic point handles the control functions and the following rules apply:

**Parameter Change Requests (STI_EU)**—an SP or OP change request takes on the enumeration value shown for approximately five seconds, after which it is reset to H2O (indicating no change request). The Manual Mode change request and Auto Mode change requests are similar except their enumeration value is reset to H2O as soon as the new mode is written to the M/A station (by means of CJTACT).

**OP (SECVAR)**—An OP request is read from the Manual/Auto Station, processed and written back to the M/Auto Station through the URL parameter.
2.8.2

SP (PVRAW)—An SP request from the Manual/Auto Station is processed and written back to the Manual/Auto Station using the PVTV parameter.

The second logic point is optional and is used to write back information such as Valve Position, Alarm state, and the Override flag using the parameters shown in the tables.

Refer to the *Process Manager Implementations Guidelines* (see References) for detailed information about implementing the above rules.

### 2.8.2.3 Operating Considerations

To modify any Regulatory Control Point parameter from the M/A station, the external Mode Switching Enable parameter ESWENBST must be set to ENABLE.

The Regulatory Control Point’s Mode attribute parameter (MODATTR) must be set to PROG so that OP can be modified by a Logic point.

Only a one second scan period is supported for the M/Auto Station Logic points.

The PV High, PV Low, and PV Extended Range parameters must be configured with the values shown in Table 2-5 in order to transfer an SP change request to the Regulatory Control point’s set point parameter SPP.
2.8.3 Toledo Weigh Scale Interface

The Toledo Weigh Station model T8142 interfaces with the Process Manager through the Serial Device Interface IOP using RS232-D protocol at 9600 Baud. One Toledo Weigh Station can be connected to each of the two SDI FTAs. Slots one and nine in the SDI IOP can be configured as to communicate with the Toledo Weigh Station. The SDI IOP is implemented as a Smart Transmitter Interface Module (STIM).

2.8.3.1 Communications

Invalid data—The following parameters are checked for reasonableness: DAMPING, PVTV, URL, LRV, and DECONF.

Communication failure—When communications between an FTA and a Toledo Weigh Station fails, the FTA makes two additional attempts to send the last message, then the Toledo Weigh Station is marked as not communicating and PVRAW (the weight) is set to NaN.

To recover from most communication failures, switch the point execution status PTEXECST to inactive and back to active.

Scan Rate—Weight (PVRAW) and Flow Rate (SECVAR) are updated every 250 ms or faster.

Refer to the Toledo Weigh Scale manual for more information.

The following tables explain the parameters used to communicate with the Toledo Weigh Scale using an SDI interface configured as an STI module.

**Table 2-8 — Parameters Sent from the Toledo Weigh Station**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning as an STI Point Parameter</th>
<th>Meaning as a Weigh Scale Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVRAW</td>
<td>Raw PV input value</td>
<td>Weight (W)</td>
</tr>
<tr>
<td>SECVAR</td>
<td>Value of Secondary Variable</td>
<td>Flow Rate (R)</td>
</tr>
<tr>
<td>STI_EU</td>
<td>Smart Transmitter, type of eng. units used</td>
<td>Feed Status:</td>
</tr>
<tr>
<td></td>
<td>0 = In_H2O</td>
<td>Feed is Off (x)</td>
</tr>
<tr>
<td></td>
<td>1 = MMHg</td>
<td>Feed is On (F)</td>
</tr>
<tr>
<td></td>
<td>2 = PSI</td>
<td>Feed is in alarm (A)</td>
</tr>
<tr>
<td>STISWVER</td>
<td>Smart Transmitter software revision level</td>
<td>FTA information:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(sent from FTA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 1 = Application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 2 = Software gen. date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slot 3 = Software rev. date</td>
</tr>
<tr>
<td>Parameter</td>
<td>Meaning as an STI Point Parameter</td>
<td>Meaning as a Weigh Scale Parameter</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------</td>
</tr>
</tbody>
</table>
| CJTACT     | Internal cold junction reference active | Feed Control:  
On = Start Feeding/Feeding  
Off = Not Feeding |
| DAMPING    | Damping                           | Weight Filter (F)*               |
| PIUOTDCF   | Open thermocouple detect enable   | Mode:  
On = Ascending Mode (A)  
Off = Descending Mode (D) |
| PVTV       | PV target value                   | Weight Setpoint* (S)             |
| URL        | Upper range limit of PV           | Alarm Setpoint* (A)              |
| LRV        | Low end of operating range for PVRAW | Decimal Point Position (D)  
1 = 1.0  
2 = 0.1  
3 = .01  
4 = 0.001  
5 = 0.0001 |
| DECONF     | Digitally Enhanced Configuration Mode | Parity Selection:**  
0 = No Parity  
1 = Odd Parity  
2 = Even Parity  
3 = No Parity  
4 = No change |
| LRL        | Lower Range Limit                 | Weight recorded when feed status switched from On to Off. |

* Values are modified to 6 digits or less by moving the decimal point per LRV.  
** Odd parity should not be used. Even parity is preferred.
CONTROL FUNCTIONS OVERVIEW
Section 3

This section provides an overview of the control functions available in the PM. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

3.1 CONTROL PERFORMANCE

The Process Manager is a high-performance device capable of an assured rate of 160 regulatory control loops per second. Users can customize their control configuration to meet the application requirements.

The parallel processing architecture of the Process Manager allows the control processing capability of the PM to be totally independent of other PM functions such as the number of I/O points built, data requests for PM data from the Network Interface Module and other UCN devices, and alarming functions; therefore, only two factors must be considered when configuring the control processing: control slot type, and the scheduled frequency of execution otherwise referred to as scan rate. These factors are described in the following paragraphs.

3.1.1 Control Slot Types

The following control slot types are resident in the Process Manager Module:

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>Max No. of Points(Slots)*</th>
<th>Applicable Parameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Composite</td>
<td>255</td>
<td>NDCSLOT</td>
<td>Refer to Section 4</td>
</tr>
<tr>
<td>Logic Slot</td>
<td>80</td>
<td>NLOGSLOT</td>
<td>Refer to Section 5</td>
</tr>
<tr>
<td>Process Module</td>
<td>160</td>
<td>NPMSLOT</td>
<td>Refer to Section 6</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>80</td>
<td>NPVSLOT</td>
<td>Refer to Section 7</td>
</tr>
<tr>
<td>Regulatory Control</td>
<td>160</td>
<td>NCTLSLOT</td>
<td>Refer to Section 8</td>
</tr>
</tbody>
</table>

*Subject to limitation of execution time.

The point mix is defined by specifying the number of slots of each type using the NDCSLOT, NLOGSLOT, NPMSLOT, NPVSLOT, NCTLSLOT parameters that are found on the UCN/PM Configuration Form. This configuration form allows the user to specify the particulars of the PM Box Data Point.
The slot numbers for each point type range from 1 to the user-specified maximum number listed in the above chart. For example, if NPVSLOT is set to 35, the RegPV points can be configured in any RegPV slot from slot 1 to slot 35. Similarly, if NLOGSLOT is set to 40, the logic points can be configured to run in any logic slot from slot 1 to slot 40. The point types and slot numbers are used for the initial configuration of a data point and for specifying the processing order.

3.1.2 Scan Frequency

Regulatory type (RegPV, RegCt1) and digital type (DigComp, Logic) slots can be configured for scanning at different rates as specified by the SCANRATE parameter and by the Fast Slots parameters. SCANRATE deals with the base scan rate for all points of a certain type. The Fast Slots parameters allow a specified number of regulatory or digital type slots to be processed at a quarter second rate without regard to the base scan rate for the rest of the group. These are PM Box Data Point parameters.

3.1.2.1 Scan Rate

The scan rates indicate the number of times that all slots of that particular type (except Fast Slots) are scanned and processed each second. For example, a scheduled frequency of 1/4 sec for the regulatory slots indicates that all the regulatory slots in this PM will be scanned and processed four times each second. The scan rate has an impact on the number of slots that can be processed as described in paragraph 3.1.3.

The following chart contains the scheduled frequency of the respective entries for the SCANRATE parameter:

<table>
<thead>
<tr>
<th>Entry for SCANRATE Parameter</th>
<th>RegCtl &amp; RegPV Slots</th>
<th>Logic &amp; DigComp Slots</th>
<th>ProcMod Slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reg1Log1</td>
<td>1 sec</td>
<td>1 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Reg1Log2</td>
<td>1 sec</td>
<td>1/2 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Reg1Log4</td>
<td>1 sec</td>
<td>1/4 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Reg2Log2</td>
<td>1/2 sec</td>
<td>1/2 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Reg2Log4</td>
<td>1/2 sec</td>
<td>1/4 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Reg4Log4</td>
<td>1/4 sec</td>
<td>1/4 sec</td>
<td>1 sec</td>
</tr>
</tbody>
</table>
3.1.2 Fast Slots Parameters

Fast Slots parameters allow a specified number of the regulatory control, regulatory PV, digital composite, or logic slots to be processed at a quarter second rate without regard to the scan rate for the rest of the group. When fast slots are specified, they are the lower numbered slots for that type. For example, if there are 50 regulatory control slots and 15 are specified as Fast (NFASTCTL = 15), then slots 1-15 are scanned every quarter second, and slots 16-50 are scanned at the rate specified by the parameter SCANRATE. The Fast Slots parameters are—

- NFASTCTL Number of Fast Regulatory Control slots
- NFASTDC Number of Fast Digital Composite slots
- NFASTPV Number of Fast Regulatory PV slots
- NFASTLOG Number of Fast Logic slots

If the SCANRATE parameter is configured for four times per second, then all of the points for those types are scanned at the quarter second rate and the number of fast slots is forced to the same as the total number of slots for that type. For example, if SCANRATE = REG1LOG4, then the number of Fast Logic slots parameter (NFASTLOG) are set equal to the number of Logic slots (NLGSLOT).

PERIOD—this parameter shows the processing period in seconds. Refer to the Process Manager Parameter Reference Dictionary for additional information.

3.1.2.3 Point Processing Executive

The point processing executive in the PMM runs at quarter-second (or 250 milliseconds) intervals or "cycles." (Each quarter second cycle is further divided into two subcycles to provide a breakpoint for database synchronization.) Slot scheduling determines the assignment of slots to cycles and the ordering within a cycle. This operation is automatically performed at the time of transition from IDLE to RUN state, based on the following rules:

- There are four cycles per second. The slots executing at four times per second are processed on every cycle. The slots executing at two times per second are processed on every other cycle, and the slots executing once per second are processed on every fourth cycle.

- Each slot type has a different processing weight assigned to it. The slots processing slower than four times per second are distributed between the four cycles to equalize the processor loading (to whatever extent possible) of each cycle.

The processing order of the slots within a cycle is determined based on the point type as follows (from left to right):

RegPV → Fast RegPV → ProcMod → Logic → Fast Logic →
DigComp → Fast DigComp → RegCtl → Fast RegCtl

Within each point type, the slots are processed in the descending order of the slot number (that is, from highest slot number, down to one).
3.1.3 Determining Processing and Memory Capacity

The processing power of the PM control processor is measured in terms of "Processing Units (PUs)." Each control processor has an assured rate of 160 PUs per second. Each slot type consumes a certain amount of PUs subject to the scheduled frequency.

The relationship between the scheduled frequencies and the Processing Units for the slot types are contained in the following chart. Please note that slots use more Processing Units at faster frequencies.

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>PUs per second at Scheduled Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/4 sec</td>
</tr>
<tr>
<td>Digital Composite</td>
<td>0.4 PU</td>
</tr>
<tr>
<td>Logic</td>
<td>4 PU</td>
</tr>
<tr>
<td>Process Module</td>
<td>N/A</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>4 PU</td>
</tr>
<tr>
<td>Regulatory Control</td>
<td>4 PU</td>
</tr>
</tbody>
</table>

**Process Module Points**—When configuring each PM, you can choose how many processing units are allocated for its Process Module points.

- If parameter SEQPROC = 1_PU, one PU is allocated per Process Module point per scan and up to 40 Process Module points can be processed each quarter-second cycle.
- If parameter SEQPROC = 2_PU, two PUs are allocated per Process Module point per scan and up to 20 Process Module points can be processed each quarter-second cycle.

In batch applications where many small sequences are needed and you want all of them loaded at the same time, 1_PU is the appropriate choice for parameter SEQPROC.

Process module points in software releases before R300 always used two processing units, therefore, parameter SEQPROC should be set to 2_PU if updating from R230 and earlier versions.

**Memory Units**—PMM capacity is measured in terms of Memory Units. For the point data base and sequence programs, the maximum capacity is 3100 Memory Units allocated as follows:

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>Memory Units Per Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Composite</td>
<td>1</td>
</tr>
<tr>
<td>Logic</td>
<td>10</td>
</tr>
<tr>
<td>Process Module</td>
<td>10</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>10</td>
</tr>
<tr>
<td>Regulatory Control</td>
<td>10</td>
</tr>
<tr>
<td>Sequence Programs</td>
<td>1</td>
</tr>
<tr>
<td>Numerics</td>
<td>1/16*</td>
</tr>
<tr>
<td>Flags</td>
<td>-</td>
</tr>
</tbody>
</table>

*A block of 16 numerics = one memory unit.*
Any mix of the preceding slot types can be used, but the mix is subject to the following constraints:

1. Point mix used must not exceed 160 Processing Units or 3100 Memory Units per PM.
2. Absolute number of each slot type per PM must not exceed the maximum shown in the following chart (regardless of the available PUs):

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>Max. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Composite</td>
<td>255</td>
</tr>
<tr>
<td>Logic</td>
<td>80</td>
</tr>
<tr>
<td>Process Module</td>
<td>160</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>80</td>
</tr>
<tr>
<td>Regulatory Control</td>
<td>160</td>
</tr>
</tbody>
</table>

The following are two examples of possible configurations that show the PU calculations.

**Example 1:**

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>Slots</th>
<th>Freq</th>
<th>PUs/Slot</th>
<th>Total PUs/Slot Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory Control</td>
<td>160</td>
<td>1 sec</td>
<td>1 PU</td>
<td>160 X 1 = 160 PU</td>
</tr>
<tr>
<td>Digital Composite</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Logic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Process Module</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total PUs for this PM = 160 PUs

**Example 2:**

<table>
<thead>
<tr>
<th>Slot Type</th>
<th>Slots</th>
<th>Freq</th>
<th>PUs/Slot</th>
<th>Total PUs/Slot Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Composite</td>
<td>50</td>
<td>1/4 sec</td>
<td>0.4 PU</td>
<td>50 X 0.4 = 20 PUs</td>
</tr>
<tr>
<td>Logic</td>
<td>10</td>
<td>1/4 sec</td>
<td>4 PU</td>
<td>10 X 4 = 40 PUs</td>
</tr>
<tr>
<td>Process Module</td>
<td>10</td>
<td>1 sec</td>
<td>2 PU</td>
<td>10 X 2 = 20 PUs</td>
</tr>
<tr>
<td>Regulatory PV</td>
<td>10</td>
<td>1/2 sec</td>
<td>2 PU</td>
<td>10 X 2 = 20 PUs</td>
</tr>
<tr>
<td>Regulatory Control</td>
<td>30</td>
<td>1/2 sec</td>
<td>2 PU</td>
<td>30 X 2 = 60 PUs</td>
</tr>
</tbody>
</table>

Total PUs for this PM = 160 PUs

Invalid configurations are displayed as errors when the information is being loaded into the PM through the Universal Station.
3.1.3 Overrun Handling

The PM has the capability to handle most configurations of up-to-160 PU without encountering an overrun. Overruns occur when a specific task cannot be completed in the allowed time. The following three kinds of overruns are possible in the PMM:

- Point Processing
- I/O Link Access
- UCN Access (Peer-to-Peer Communication)

**Point Processing Overrun**—A point processing overrun occurs when the slots that are scheduled to be processed during any subcycle cannot be finished within the allocated time of 125 msec. When this occurs, all the points are processed to completion (nothing is aborted), but the following subcycle is delayed until the next 125 msec subcycle. Also, the current hour point processing-overrun counter is incremented by 1.

The primary cause of point processing overruns are several long sequence programs that are processing on the same subcycle. If a point processing overrun occurs for four seconds in a row (on any subcycle within each second), a point processing-overload soft failure is generated. The soft failure is reset when an overrun does not occur for eight seconds.

For each subcycle, the current hour and previous hour point processing-overrun counters are maintained in the PMM and displayed on the UCN Detailed Status Displays to help track down the cause of the overrun.

**I/O Link Access Overrun**—This type of overrun occurs when parameter read or write access requests, from slots residing in the PMM to I/O Processors in the same PM, are not completed within a cycle time. This indicates that too many parameter access requests were attempted through the I/O link within the last cycle (250 msec). When this occurs, point processing is delayed by 125 msec and the I/O link overrun counter is incremented by 1. This continues until the requested data becomes available. I/O link accesses to some parameters are not counted as I/O link accesses, and accesses to them are considered as being "unlimited." These are the digital input point’s PV (parameter PVFL) and BADPVFL, and the Digital Output point’s SO, and INITREQ parameters.

The anticipated average number of I/O link accesses (from PMM points within the same PM) is 120 parameters for each 250 msec cycle. Access overruns can be expected when the number of I/O link accesses exceeds 200 parameters for each 250 msec cycle. If an I/O link overrun occurs for four seconds in a row (on any cycle within each second), an I/O link access-overload soft failure is generated. The soft failure is reset when an overrun does not occur for eight seconds.

For each cycle, the current hour and previous hour I/O link access-overrun counters are maintained in the PMM and displayed on the UCN Detailed Status Displays to help track down the cause of the overrun.
UCN Access Overrun—This type of overrun occurs when parameter read or write access requests to other PMs (or other nodes) on the same UCN are not completed within the given time (0.5 seconds in R400, 0.75 seconds in R410 for the UCN scan table, 0.75 seconds in both for other functions). When this type of access overrun occurs, the UCN access-overrun counter is incremented by 1, but point processing is not delayed. The sequence programs that access data from other UCN devices remain suspended until a response becomes available (or a communication timeout occurs). For input connections at RegPV, RegCtl, and logic slots that require data from the UCN, the last fetched value is used until new data becomes available, or a time-out occurs.

If the UCN access overrun occurs for 8 seconds in a row (on any cycle within each second), a UCN access-overload soft failure is generated. The soft failure is reset when an overrun does not occur for 16 seconds.

For each subcycle, the current hour and previous hour UCN access-overrun counters are maintained in the PMM and appear on the UCN Detailed Status Displays to help track down the cause of the overrun.

Figure 3-1 illustrates the PM Scheduling Display—You may want to check this display for overruns, especially if your process module points contain a large number of statements per step (as long as all of the sequences in a subcycle average out to 20 statements per step, no overruns will occur). This display can be accessed through the PM Status Display/Detail Display target; then under CONTROL CONFIGURATION, choose SCHEDULE INFO.

Along the left side, the type of point and execution order appears. The four 1/4-second cycles and their subcycles divide the display into columns. The numbers in each column represent the point slots. All of the points in a subcycle run consecutively in descending order (compare to the drawing in 3.1.2.3). Overruns (if any) for the point processing executive (PPX) and the I/O Link (IOL) appear across the bottom for the cycle or subcycle affected.

Peer-to-peer UCN Overruns and Soft Failures—For Release 410 (and later) systems, 2 consecutive peer-to-peer timeouts are required to count as a UCN overrun. More than 1 UCN overrun in 8 consecutive seconds causes a soft failure. The soft failure automatically clears when there are no UCN overruns for 16 consecutive seconds. Peer-to-peer communication is described in subsection 3.4.
3.1.4 Performance Monitoring

Use the Toolkit displays to obtain performance statistics. These displays show the number of nodes requesting and responding, and the percent of time the PM Communications and Controller CPUs are not busy. They also show the maximum, minimum, and average request/response times for transactions between peer nodes and other statistics. Section 10 of the Engineer's Reference Manual explains how to use the Toolkit displays. A peer-to-peer communication efficiency statistic is displayed on the Control Configuration page of the PM Detail Display.

3.2 DATABASE CONSIDERATIONS

The point mix and the scan rate are configured as a part of the PM Box Data Point. On the Universal Station, this is the Node Specific Configuration display. When the PM Box Data Point information is loaded into the PMM, the point mix is validated against the absolute maximum allowed for each point type and the available memory and the scan rate is validated against the available processing resources. The PMM box state must be IDLE to make any changes to the point mix and scan rate configuration.

If changes are not required in the point mix, the PM Box Data Point can be loaded while in the RUN state. For example, a new I/O Processor can be added without interrupting control by simply loading the PM box data configuration (with the new I/O Processor added) while in the RUN state.

CAUTION

When the point mix or the scan rate is changed, the database of all the slots is defaulted to a null configuration and the database requires reconfiguration.

Point building follows box Configuration. Each point is configured to run in a slot inside the PMM. The first time through a power-up cycle (PMM box state transition from ALIVE to IDLE), the database of each slot (included in the default point mix) is defaulted to a null configuration. The user must build or load a point configuration into each slot. When a point is being deleted, the database of the slot containing the point is defaulted to the null configuration.
3.3 POINT EXECUTION STATE

Slot processing in the PMM is performed only when the PMM box state is RUN. Only those slots whose point execution state (PTEXECST) is Active are processed. The point’s execution state must be Inactive in order to modify any of the configuration parameters (for example, engineering unit range, PV or control algorithm ID, input/output connections, etc.). When a point is made Inactive, all the calculated variables (like PV, CV, alarms, etc.) are set to their default values ("NaN" for real numbers and OFF for Logical). The point execution state cannot be changed back to Active until all the configuration parameters are specified.

3.3.1 Run-Idle-Run Transition

When the PMM is switched from RUN to IDLE and back to RUN, the affect on data points is shown by the following:

<table>
<thead>
<tr>
<th>Table 3-1 — Effect of Run-Idle-Run Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic Blocks</td>
</tr>
<tr>
<td>CL Programs</td>
</tr>
<tr>
<td>Timers</td>
</tr>
<tr>
<td>Other Point Types</td>
</tr>
</tbody>
</table>

3.3.2 Warm/Cold Restart

The PM is started through the PM Status display. Cold/Warm startup refers to the behavior of algorithms under initialization. When going from the idle to run state, the operator can choose between warm and cold startup (for each PM).

- **Cold startup** — this usually requires operator intervention, that is, the operator must change the point states from manual to their normal operating mode. On a cold startup, all Regulatory Control points that output to the field go to manual mode. For Regulatory Control points that drive other Regulatory Control points (even in another PM), a cold start does not cause a change from the previous mode unless RAM memory was lost.

- **Warm startup** — if RAM memory has not been lost since previous operation, a warm startup is possible. If you choose warm startup, Regulatory Control points are back-initialized for a bumpless transfer to automatic control with their previous output value.
Some points behave differently during startup, regardless of the startup mode:

**Regulatory PV Totalizer points** — you can configure the point to continue or stop accumulation on restart (see parameter PVEQN).

**Process Module point** — you can configure sequence execution to restart from the beginning or remain off and be restarted by the operator (see parameter RSTROPT). During the first cycle, parameter RESTART indicates the type of startup. This allows a CL program to check its value and take appropriate action.

**Regulatory PV Ramp Soak** — Point is always set to Manual mode.

Table 3-2 summarizes the important status conditions for Warm/Cold restart functions.

<table>
<thead>
<tr>
<th>Point Type</th>
<th>Parameter</th>
<th>Status After Power Off/On</th>
<th>Status After Cold Start</th>
<th>Status After Warm Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory Control (except Ramp/Soak) Outputs to another RegCtl point</td>
<td>MODE</td>
<td>Manual</td>
<td>Last Mode$^1$</td>
<td>Last Mode. Back-initializes; goes on control</td>
</tr>
<tr>
<td>Regulatory PV Totalizer$^2$ PVEQN = A, B, C</td>
<td>PV PVSTS STATE</td>
<td>Cont. Totalizing Uncertn Running</td>
<td>NaN Bad Stopped</td>
<td>Cont. Totalizing Uncertn Running</td>
</tr>
<tr>
<td>Regulatory PV Totalizer PVEQN = D, E, F</td>
<td>PVSTS STATE</td>
<td>Bad Stopped</td>
<td>Bad Stopped</td>
<td>Bad Stopped</td>
</tr>
<tr>
<td>Process Module RSTROPT = Restart</td>
<td>SEQEXEC PROCMOD</td>
<td>Run Norm</td>
<td>Run Norm</td>
<td>Run Norm</td>
</tr>
<tr>
<td>Process Module RSTROPT = Off</td>
<td>SEQEXEC PROCMOD</td>
<td>Loaded Off</td>
<td>Loaded Off</td>
<td>Loaded Off</td>
</tr>
<tr>
<td>AO (DDC) or DO Output to IOP</td>
<td>STATE</td>
<td>Manual</td>
<td>Manual</td>
<td>Manual</td>
</tr>
<tr>
<td>Timer</td>
<td>PV STATE</td>
<td>Last Good Value$^3$ Stopped</td>
<td>Last Good Value$^3$ Stopped</td>
<td>Last Good Value$^3$ Stopped</td>
</tr>
</tbody>
</table>

1. Control is halted by the final point in the cascade which always outputs to an IOP.
2. Count may be inaccurate if rollover occurs in IOP.
3. The last good value can come from PM RAM Memory if battery power was continuously available; otherwise, from the last checkpoint stored on the History Module.
3.4 PEER-TO-PEER COMMUNICATION

Peer-to-peer communication allows information to be passed between nodes on the UCN and can be initiated from either the Process Manager, an Advanced Process Manager, a Logic Manager, or a Safety Manager. The PM provides the following two convenient mechanisms for implementing peer-to-peer communications functions:

- Input/Output Connection
- CL Read/Write Statement

Both communication mechanisms offer location-independent access to data from another UCN device using the "Tagname.Parameter" notation.

Refer to Table 3-3 for a summary of peer-to-peer communications.

Characteristics and configuration limits for input/output connection for each access are described below.

- **Input Connections**—The RegPV, RegCtl, and Logic slots can use standard input connections to obtain data from other UCN devices. When such a connection is configured, it is scanned at the rate of twice per second, regardless of the scan rate of the slot in which it is configured. The data obtained is saved internally and used (more than once if the slot is running faster than twice a second) until the next time that it needs data. Peer-to-peer data is requested .75 seconds before it is needed. The data obtained from another UCN device can, therefore, be up to .75 seconds old by the time it is used. A maximum of 50 input connections can be configured for each PMM.

  We recommend that input connections be used for continuous peer access that requires a 1/2 second update.

- **Output Connections**—The RegCtl and Logic slots can use standard output connections to provide outputs to other UCN devices. The output connections are processed when the slot is processed, thus outputs are updated four times per second, two times per second, or once per second, depending on the point processing rate. The number of output connections per PMM is not limited.

  We recommend that output connections be used for regulatory-control cascades between UCN devices.
Table 3-3 — Peer-to-Peer Summary

<table>
<thead>
<tr>
<th>Peer-to-Peer Mechanism</th>
<th>Configuration Limits (Per PM)</th>
<th>Handling of Failure/Recovery of Peer Node</th>
<th>Recommended Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Connections</td>
<td>50 values per 1/2 second</td>
<td>Analog — On failure, bad value (NaN) is substituted. Digital - Addressed by Logic Slot. On failure, ON, OFF, or last value is substituted based on user configuration. On recovery from failure, accessed values are then used.</td>
<td>Use for continuous (1/2 second) update of data required for RegPV, RegCtl or Logic Slots.</td>
</tr>
<tr>
<td>Output Connections</td>
<td>Not limited</td>
<td>Regulatory control cascade — primary initializes. Logic output — store does not occur. On recovery from failure, regulatory control clears initialization and resumes control. Subsequent output changes are stored on transition.</td>
<td>Use for regulatory control cascades between nodes.</td>
</tr>
<tr>
<td>CL Read Statement</td>
<td>16 values per Process Module Data Point per second</td>
<td>If requested read transaction not completed, CL program branches to specified error location. Program fails when error option not used. On failure recovery, program behavior is based on user code, or requires operator interaction if failed.</td>
<td>Use for on-demand data required by CL programs. Use for continuous (1 second) update of data required for RegPV, RegCtl or Logic Slots.</td>
</tr>
<tr>
<td>CL Write Statement</td>
<td>16 values per Process Module Data Point per second</td>
<td>Same as above.</td>
<td>Same as above Note: Use of Read or Write statements is based on user preference.</td>
</tr>
</tbody>
</table>

Characteristics and configuration limits for CL/PM read/write peer access are as follows:

- **CL/PM Program**—A user-written CL/PM sequence program executing in the PMM can use explicit read/write statements to read parameter values from other UCN devices and write parameter values to other UCN devices. Any time a read/write statement is executed, the sequence program is suspended until the following cycle when the response becomes available (normally one second).

It is recommended that the CL read/write technique be used for on-demand peer access, and for continuous peer access that requires a 1-second update.
Certain restrictions exist on the type of data that can be accessed through peer-to-peer communication. These restrictions vary with the point type. Table 3-4 shows the type of data that can be accessed for each point type or connection type.

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Allowed Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>RegCtl.CISRC</td>
<td>No restrictions</td>
</tr>
<tr>
<td>RegCtl.CODSTN</td>
<td>RegCtl.SP only</td>
</tr>
<tr>
<td>RegPV.PISRC</td>
<td>No restrictions</td>
</tr>
<tr>
<td>Logic.LISRC</td>
<td>No restrictions</td>
</tr>
<tr>
<td>Logic.LODSTN</td>
<td>No restrictions</td>
</tr>
<tr>
<td>DigComp.DISRC</td>
<td>No Peer-to-peer connections allowed</td>
</tr>
<tr>
<td>DigComp.DODSTN</td>
<td>No Peer-to-peer connections allowed</td>
</tr>
<tr>
<td>ProcModl Read Statement</td>
<td>No restrictions</td>
</tr>
<tr>
<td>ProcModl Write Statement</td>
<td>No restrictions</td>
</tr>
</tbody>
</table>

In addition to the configuration constraints described above, there are performance-related limits on parameter access that affect the overall peer-to-peer throughput capability. Actual performance for each PM varies depending on specific system configuration; however, any PM should be capable of handling a total load of up to 400 parameters per second.

In addition to the above parameter throughput-related constraints, the number of devices concurrently communicating to a single Process Manager is another factor that influences performance.

The interaction of the above constraints must be considered primarily in applications in which an extreme communication load is continuous. In this type of application, the following configuration recommendations maximize peer-to-peer throughput capability:

- Adopt a single approach for all peer-to-peer communications; use either input/output connections or CL read/write statements. If a 1-second update is adequate and cascade interconnection is not required, the CL read/write approach offers increased capability (quantity/throughput) for peer data access.

- For CL read/write approach, consistently use same method (either CL reads or CL writes).

- For CL read/write approach, the Process Module Data Points that are continually affecting peer-to-peer communication should be grouped on the same 1/4-second cycle.

**Performance**—Refer to Section 6 in the PM Implementation Guidelines manual for a discussion of Peer-to-Peer transaction performance.
3.5 HARDWARE REFERENCE ADDRESSING

The PM allows the referencing of parameters of I/O points (AO, DI, DO) on a hardware basis within the same PM using the standard input/output hardware connection reference syntax (user-written sequence programs can reference DI points). This type of addressing does not affect the point count in the NIM and these “untagged” references can be quickly built, but there are several disadvantages. Untagged points are not easily visible in the system so you must use the Command Processor Find Names function to see the connections. Note that operating displays cannot include untagged points.

The use of untagged references is not recommended, however, there might be a reason to use them or some may be present in an existing system. If you use them keep good records.

The hardware reference address point format is

`!MTmmSss.Parameter`

where: MT is the IOP type such as AO, DI, DO, or PI,
mm is the number of the IOP card (1-40) in the card file,
ss is the input or output slot number on the specified IOP card.
Parameter is the parameter whose value is to be written to by an output connection, or a parameter whose value is to be read by an input connection.

The following are examples of hardware reference addresses:

`AO Processor Output ==> !AO12S03.OP`

= parameter OP
of Slot #3
of AO Processor #12

`DI Processor PV ==> !DI05S07.PVFL`

= parameter PVFL
of Slot #7
of DI Processor #5

`DO Processor (Status or Latched) Output ==> !DO15S12.SO`

= parameter SO
of Slot #12
of DO Processor #15

`DO Processor ON Pulse Command ==> !DO15S12.ONPULSE`

= parameter ONPULSE
of Slot #12
of DO Processor #15

`DO Processor OFF Pulse Command ==> !DO15S12.OFFPULSE`

= parameter OFFPULSE
of Slot #12
of DO Processor #15

Standard status displays are available to show which points are associated with each hardware module.

*The AI address !AImmSss.Parameter is not supported because the analog input point does not have a useable default database.*
3.5.1 Find Names Function

You can use the Find Names function to provide the node number, module type, point type, and slot number for all connections. Refer to the Command Processor manual for information on the Find Names utility.

3.6 REDUNDANCY

The PM can contain optional redundant PMM modules and certain types of optional IOP modules (currently HLAI, AO, and STIM modules). During PM Node Specific configuration, the user specifies which modules are redundant and, for IOPs, the file/card locations of the redundant partners. Refer to Section 2 in the Process Manager Implementation Guidelines manual for more information.

If a redundant PMM module or synchronized redundant IOP module fails, switchover is automatic and transparent to the user (input and set output operations are unaffected). Data acquisition, alarming, and control strategies are automatically managed by the system.

The principal parameters that pertain to PM redundancy are—

<table>
<thead>
<tr>
<th>ACTPRIM</th>
<th>IOMFILEA/B</th>
<th>POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTACONN</td>
<td>IOREDOPT</td>
<td>SYNCHSTS</td>
</tr>
<tr>
<td>IOMCARDA/B</td>
<td>PKGOPT</td>
<td>WITHBIAS</td>
</tr>
</tbody>
</table>

Refer to these parameters in the Process Manager Parameter Reference Dictionary for additional information.
This section describes the functions available in the digital composite point. The description of the output portion of the point is provided first, followed by the description of the input portion. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

4.1 DIGITAL COMPOSITE POINT

The digital composite point is a multi-input/multi-output point that provides an interface to discrete devices such as motors, pumps, solenoid valves, and motor-operated valves. This point provides built-in structures for handling interlocks, and supports display of the interlock conditions in group, detail, and graphic displays. In addition, the digital composite point can be used with logic slots and other digital points to implement complex interlock schemes.

Some of the features of the digital composite point are as follows:

- Input and output states of the data point are totally independent of each other and can be configured as required by the user’s application. The inputs and outputs of the point can be linked to I/O points or to Boolean flags within the PM.

- Supports devices with two or three commandable states (motor-operated valves, reversing motors, etc.). Specific states can be defined as being momentary.

- Provides structured approach to handling interlock functions and includes indication to the operator of existence of interlock condition.

4.2 POINT STATES

4.2.1 Normal States

A digital composite point can have two or three normal states that allow the data point to interface with devices that have two or three operational states. The states of a digital composite point are as follows:

- State 1—this is the first active state.

- State 0—this is the inactive (middle) state. This is considered a safe state. If for any reason a valid output cannot be determined, the OP is forced to this state. See subsection 4.8 which discusses initialization manual.

- State 2—this is the second active state. (State 2 is applicable only when the entry for the NOSTATES parameter is 3, signifying that the data point has three states)
These states can best be described by showing how the digital composite data point is depicted in a Universal Station group display, as shown in Figure 4-1. On the display, each state is represented by a separate box. The state 0 box is the middle box, the state 1 box is the upper box, and state 2 box is the lower box. (The state 2 box does not appear if the point has been configured for two states where parameter NOSTATES = 2). The state descriptor for each box is an 8 character descriptor and appears at the top of the box. In Figure 4-1, the descriptors are FORWARD (for state 1), STOP (for state 0), and REVERSE (for state 2), which are specified by parameters STATETXT(0)-STATETXT(2).

The lower portion of each box is split, with the left box being the indicator for the input PV state, and the right box being the commanded-output state indicator. The condition of the PV input that causes the left box to light is determined by parameters D2D1_00 - D2D1_11. The condition that causes the right box to light is determined by OP being commanded to that state.

![Figure 4-1 — Digital Composite Point Display](image)
As an example, assume that the digital composite point shown in Figure 4-1 is connected through digital output points and digital input points to a motor control circuit and that the current state of the digital composite point is state 0 (STOP).

- In state 0, the PV indicator of the STOP box is lit, indicating that the motor is stopped because the proper PV input has been received from the field. All other indicators in the display are in the extinguished condition.

- When the operator touches the FORWARD box to place the motor in the forward running direction, the digital composite point output goes to State 1. Outputs from the digital composite point are provided as determined by the ST1_OPn parameter (where n=1..3). When the proper PV inputs are received from the field, the FORWARD box is lighted. This indicates to the operator that the motor is running. Also, the current state of the PV can be read by a logic slot or by a user program by accessing parameter PVFL(n) where n is 0, 1, or 2. If the PV is in State 0, PVFL(0) is on; otherwise, PVFL(0) is off. PVFL(1) and PV(FL2) operate in the same manner for States 1 and 2, respectively.

- Similarly, when the operator presses the STOP box, the operator is notified that the motor is stopped by the lighted PV indicator in the STOP box. The operator can then select the REVERSE box to start the motor running in the reverse direction.

### 4.2.2  Momentary States

The states of a digital composite point can be configured as being momentary by using the MOMSTATE parameter. The commanded states can be configured as momentary where the state acts like a doorbell (state remains active as long as a switch is pressed). The momentary states (MOMSTATE) parameter specifies which of the states are momentary as follows:

<table>
<thead>
<tr>
<th>Entry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mom_1</td>
<td>State 1 is momentary. When released from this state, it jumps back to State 0.</td>
</tr>
<tr>
<td>Mom_0</td>
<td>State 0 is momentary. When released from this state, it jumps back to State 1. Mom_0 can be selected only if the NOSTATES parameter = 2.</td>
</tr>
<tr>
<td>Mom_2</td>
<td>State 2 is momentary. When released from this state, it jumps back to State 0. Mom_2 can be selected only if NOSTATES parameter = 3.</td>
</tr>
<tr>
<td>Mom_1_2</td>
<td>States 1 and 2 are momentary. When released from any one of these states, it jumps back to State 0. Mom_1_2 can be selected only if NOSTATES parameter = 3.</td>
</tr>
</tbody>
</table>
4.2.3 Moving/Bad States

The digital composite data point has two states that represent the conditions when the current state of the device is "bad" (indeterminate) or the current state is "moving" (from one state to another). The bad state can result when the PV input signals from the process are in an inconsistent state (e.g., for a valve, the limit switches indicating open and closed are both simultaneously on). The moving state is encountered when the device is in transition from one state to another (e.g., a slow moving valve is changing from the open state to the closed state). The moving/bad state descriptor is located below the State 2 box on the display. In the example described above, the descriptor assigned for the BADPVTXT parameter would be the word FAULTY and the descriptor assigned for the MOVPVTXT parameter would be the word MOVING. These descriptors are configured once for each PM box data point and then are used for all digital composite points in the same PM.

4.3 MODE ATTRIBUTES

The digital composite point supports only the manual (MAN) mode with mode attributes (specified by parameter NMODATTR) of Operator and Program. If the mode attribute is Operator, only the Universal Station operator can provide the commanded output state, as shown in Figure 4-2. On the other hand, if the mode attribute is Program, only user programs (continuous or discontinuous) can provide the commanded output state. The operator mode attribute flag (OPRATRFL) is also provided for potential use by the interlocking logic.

The MODEPERM parameter is provided to optionally prevent the operator (as opposed to the supervisor or engineer) at the Universal Station from changing the mode attribute.

4.4 INTERLOCKS

Two kinds of interlocks, permissives and overrides, are provided in the output portion of a digital composite point. The states of the interlocks are typically controlled by output connections from logic slots that can write to the P0-P2 permissive interlock parameters, and I0-I2 override interlock parameters.
4.4.1 Permissive Interlocks

The permissive interlock parameters P0-P2 shown in Figure 4-2 are controlled by logic slot outputs, and the permissive interlocks determine whether the operator and user programs are allowed to change the output of a digital composite point to a specific state. A permissive interlock is provided for each of the three states. The permissive interlocks themselves never cause the output to change.

For the commanded output to be changed to the desired state, the corresponding permissive interlock parameter must be set to ON. As an example, if a logic-slot output has set parameter P1 to OFF, the commanded output of the digital composite point cannot be set to State 1. The permissive interlock parameters P0, P1, and P2 are all defaulted to ON, thereby allowing permission for all the states. They must be individually set to OFF by the logic slots to prevent access to the corresponding commanded output state.

4.4.2 Override Interlocks

The override interlock parameters I0-I2 shown in Figure 4-2 are also controlled by the logic slot outputs and can force the commanded output to a specific state regardless of the condition of the permissive interlocks. The operator and user programs cannot change the output state when any override interlock is in the ON condition. An override interlock is provided for each of the three output states.

When parameter I0 is set to ON by a logic slot output, the commanded output state is forced to State 0 (regardless of the condition of parameters I1 and I2). When I0 is OFF and I1 is ON, the commanded output is forced to State 1 (regardless of parameter I2). Finally, when I0 and I1 are OFF and I2 is ON, the commanded output is forced to State 2.

Override interlock parameters I0-I2 are all defaulted to OFF, disabling all the override interlocks. They must be set to ON to force the output to go to any specific state. If the override interlock forces the output to go to a momentary state, it stays in that state as long as the interlock remains ON and then switches back to the original state when the override interlock is reset to Off.

When all the override interlocks are OFF, the last value of the commanded output is maintained (except for momentary state) until changed by the operator, a user program, or another override interlock. The interlock logic restores the output value to the output devices (Digital Output IOPs) whenever the interlock value changes, even if the state asserted by the interlock is already in effect.

When the Digital Composite point is built, you can specify the tag name of the Logic point that is driving the interlocks as parameter LOGICSRC. The contents of this parameter then appears on the Group Display when the Digital Composite point is selected. After identifying the Logic point, an operator can call up the Detail Display for that point to find out about the interlocks.
Figure 4-2 — Digital Output, Functional Diagram
4.4.3 Configurable Interlock Bypass

The operator can have the ability to bypass the permissive and override interlocks for a digital composite point. To do so, the override parameter OROPT must be set to ON. The operator can then set (or reset) the parameter BYPASS from the Universal Station. Note that while BYPASS is ON, the mode attribute parameter can’t be changed. When the BYPASS parameter is reset, existing override interlocks (if any) take effect immediately. The group display shows whether interlocks are being bypassed. The organizational summary display lists all the points for which BYPASS = ON.

4.5 COMMANDED STATE (OP)

The command to go to a specific state results in outputs to the process that drive the actual state of the device to the commanded state. The commanded state is represented by the OP parameter in the digital composite point; the commanded state can be State 1 (ST1), State 0 (ST0), or State 2 (ST2). The OP parameter is available for configuration only if the number of digital output connections (NODOPTS) is configured to be greater than 0.

Up to nine Boolean parameters of the form STx_OPy (where x = 0, 1, or 2 for the state number and y = 1, 2, or 3 for the output number) allow the user to specify the state values that are to be stored by the output connections. For each of the three commanded states per output connection, the user must define the value (On or Off) of the state.

CL programs or Logic points can test the parameter INITREQ to see if they are allowed to command a certain state. If INITREQ(i) = ON, then CL programs or Logic points cannot change the output to STATE(i) (i = 0, 1, or 2).

The Status Output command parameter allows Logic points or CL programs (PM or AM) to manipulate outputs (subject to interlocks and the mode attribute). Logic or CL programs can set SOCMD(i) to ON to command State(i) where I = 0, 1, or 2. The same rules apply as storing the corresponding state to the OP parameter, i.e., the mode attribute must be PROGRAM, the corresponding permissive must be available, no override can be active, etc. The actual output (OP) is switched to the requested state only by an OFF to ON change of the corresponding SOCMD(i) flag. There is no priority scheme; the last one changing from OFF to ON controls the output.

CAUTION

Do not configure two different logic outputs to drive OPCMD and SOCMD of the same Digital Composite Point.
4.6 DIGITAL OUTPUTS

The user can specify the latched or pulsed output type for the digital composite point through the configurable output connections.

4.6.1 Latched Output

Configuring the digital composite point for a latched output is accomplished by specifying any parameter other than ONPULSE or OFFPULSE.

4.6.2 Pulsed Output

Configuring the digital composite point for a pulsed output is accomplished through the output connections by specifying the ONPULSE or OFFPULSE parameters as the destination points for the outputs. The width of the pulse is configured at the digital composite data point through the PULSEWTH parameter; it allows the user to specify a pulse width from 0 to 60 seconds as a real number. The selected pulse width applies to all of the output connections.

4.7 OUTPUT CONNECTIONS

The destinations of the outputs (and the output types) from a digital composite point are specified by the user through the DODSTN(1)-DODSTN(3) parameters. The categories of destinations that can be specified are as follows:

- Digital Output Point—Latched Output
- Digital Output Point—Pulsed Output
- Logic Slot Flag
- PM Box Flag
- Process Module Slot Flag

These destinations must be in the same PM box as the digital composite point that is being configured.
4.7.1 Digital Output Point—Latched Output

To assign the digital composite-point output to the latched output of a digital output point, the user can enter either of the following output connections for the respective DODSTN(n) output connection parameter:

Tagname.SO

or

!DOmmSss.SO

where: Tagname is the 8- or 16-character name assigned to the data point through the NAME parameter.

SO signifies the status output of the digital output point.

!DO signifies a digital output point. This is the start of the hardware-reference form of addressing the digital output.

mm is the IOP card number from 1-40 of the Digital Output IOP Card within the same PM.

the letter ‘S’ is a constant.

ss is the slot number in the range from 1-16 on the same Digital Output IOP Card.

4.7.2 Digital Output Point—Pulsed Output

Pulsed outputs can be either of two types: normally off pulsed-on, and normally on pulsed-off. To assign the digital composite-point output to the pulsed output of a digital output point, the user can enter the following information for the respective DODSTN(n) output connection parameter:

For a normally off pulsed-on output:

Tagname.ONPULSE

or

!DOmmSss.ONPULSE

where: Tag Name is the 8- or 16-character name assigned to the data point through the NAME parameter.

ONPULSE or OFFPULSE signifies the pulsed output of the digital output point.
For a normally on pulsed-off output:

- Tagname.OFFPULSE
- !DOmmSss.OFFPULSE

where: Tagname is the 8- or 16-character name assigned to the data point through the NAME parameter.

ONPULSE or OFFPULSE signifies the pulsed output of the digital output point.

Refer to paragraph 4.7.1 for descriptions of !DOmmSss

### 4.7.3 Logic Slot Flags

To assign the digital composite-point output to a logic-slot flag, the user can enter the following information for the respective DODSTN(n) output connection parameter:

- Tagname.FL(nn)

where: Tagname is the 8- or 16-character name assigned to the data point through the NAME parameter.

- FL signifies a logic-slot flag
- nn is the flag number to which the output of the digital composite is sent. The flag number has a range of 7-12: flag numbers 1-6 have dedicated uses and cannot be used as destinations by a digital composite point.

### 4.7.4 PM Box PV Flags

To assign the digital composite-point output to a PM box PV flag in the same PM box, the user can enter the following information for the respective DODSTN(n) output connection parameter:

- Tagname.PVFL or !BOX.FL(nnnn)

where: Tagname is the 8- or 16-character name assigned to the data point through the NAME parameter.

- PVFL signifies the PV flag
- !BOX specifies the same PM box in which the digital composite point resides.
- nnnn is the flag number that has a range from 1 to 1023.
4.8 INITIALIZATION MANUAL

A digital composite point that has at least one output connected to a DO IOP is forced into the initialization manual condition (INITMAN is On) when one of the following conditions exists:

- The associated DO IOP has failed or been powered off (digital composite point cannot communicate with the DO IOP), the DO IOP is in an idle condition, or in standby manual, or the FTA is missing.
- The associated DO IOP has its initialization request (INITREQ) flag set. The flag may be set because the point is inactive, the point is not configured as a status output type, or one of the output diagnostics has failed.
- The digital composite point is inactive.
- The PMM is in an idle condition.

INITMAN is displayed at the Universal Station for the particular digital composite point to inform the user that one of the above conditions has occurred. When the condition is corrected, INITMAN is set to Off.

When INITMAN transitions from On to Off, the digital composite point provides an output value OP as follows:

- If override interlocks are active and not bypassed, the OP value corresponds to the highest priority override interlock.
- Otherwise, in cases where feedback is configured, the stored OP value follows the PV state if the PV state is valid (that is, if the PV is not bad or moving).
- Otherwise, when the input is bad, the OP value is back-initialized from the output connections if there are no output connections to the ONPULSE/OFFPULSE parameters, and if a valid OP value can be constructed from the values of the output connections. For output connections to ONPULSE/OFFPULSE, OP is set to State 0.
- Otherwise, the OP is set to State 0.

4.9 DIGITAL INPUTS

When configuring digital inputs of the digital composite data point, the user can specify the input connections, PV states, PV source and options, alarming, and change-of-state events. The input portion of a digital composite point can be configured only if the user has entered 1 or 2 for the number-of-digital-inputs parameter (NODINPTS). A functional diagram of the input portion of the digital composite point is shown in Figure 4-3.
4.10 INPUT CONNECTIONS

The inputs to a digital composite point are specified by the user through digital input-source parameters DISRC(1)-DISRC(2). Inputs to the digital composite point are designated as Input 1 and Input 2, and they can be obtained from any of the following sources:

• Digital Input Point—PV
• Digital Output Point—SO
• Logic Slot Output
• Logic Slot Flag
• PM Box Flag PV
• Process Module Slot Flag

These sources must be in the same PM box as the digital composite point that is being configured.

The status of Input 1 is represented by parameter D1; Input 2 is represented by parameter D2. Input 2 can be configured only when the entry for the number-of-digital-inputs parameter (NODINPTS) is 2.

4.10.1 Digital Input Point—PV

To assign the PV of a digital input point to the PV input of a digital composite point in the same PM box, the user can enter the following information for the respective DISRC(n) input connection parameter:

Tagname.PVFL

or

!DImmSss.PVFL

where: Tagname is the 8- or 16-character name of the point that will provide the PV.

PVFL signifies the PV of the respective digital input point.

!DI signifies a digital input point. This is the start of the hardware reference address.

mm is the Digital Input IOP Card number from 1-40 within the same PM.

the letter ‘S’ is a constant.

ss is the slot number in the same Digital Input IOP Card in the range from 1-32.
Figure 4-3 — Digital Input, Functional Diagram
4.10.2 Logic Slot Output

To assign the logic slot output to the PV input of a digital composite point, the user can enter the following information for the respective DISRC(n) input connection parameter:

Tagname.SO(nn)

where: Tagname is the 8- or 16-character name assigned to the logic slot that is providing the output.

SO signifies the output of the logic block.

nn is the logic block number in the range from 1-16

4.10.3 Logic Slot Flags

To assign a logic slot flag to the input of a digital composite point, the user can enter the following information for the respective DISRC(n) input connection parameter:

Tagname.FL(nn)

where: Tagname is the 8- or 16-character name assigned to the the logic slot that is providing the flag.

FL signifies the logic-slot flag

nn is the flag number in the range from 1-12.

4.10.4 PM Box PV Flags

To assign a PM box PV flag to the input of a the digital composite point, the user can enter the following information for the respective DISRC(n) input connection parameter:

Tagname.PVFL

or

!BOX.FL(nnnn)

where: Tagname is the 8- or 16-character name assigned to the box PV flag

PVFL signifies the PV flag

!BOX specifies the PM box.

FL(nnnn) is the flag number that has a range from 1 to 1023.
4.10.5 Process Module Slot Flags

To assign a Process Module slot flag to the input of a digital composite point, enter the following information for the respective DISRC(n) input connection parameter:

\[ \text{Tagname.FL(nn)} \]

where: Tagname is the 8- or 16-character name assigned to the Process Module flag
FL(nn) signifies the flag

4.11 CURRENT INPUT STATE (PV)

The flexibility of the digital composite point allows the user to assign the states of the PV for each possible combination of digital inputs, so that the states correspond to the different applications in which this point type can be used. The PV parameter represents the current state of the interfaced device and is derived from inputs D1 and D2 that can be feedback signals from the process. Separate parameters are used to configure a single-input point and a dual-input point.

**NOTE**

The inputs to a digital composite point are usually the PVS from digital input points. The digital input points should be configured as component points that force the input direction to be direct (as opposed to reverse). The actual direct/reverse action can be configured by assigning the appropriate PV state to the input as described in the following paragraphs.

For a single-input point, there is only one input parameter (D1). D1 has two possible PV states (PVstate0 and PVstate1) that can be assigned to either of the following input conditions:

\[ D1 = 1 \text{ (D1 is ON; parameter D1_1)} \]
\[ D1 = 0 \text{ (D1 is OFF; parameter D1_0)} \]

The user has to assign only PVstate0 or PVstate1 to parameter D_1; the system automatically assigns the other PV state to parameter D1_0.
For a dual-input point, there are two input parameters (D2 and D1) that together have four possible combinations of input values as follows:

- $D2D1 = 00$ (D2 is OFF, D1 is OFF; parameter D2D1_00)
- $D2D1 = 01$ (D2 is OFF, D1 is ON; parameter D2D1_01)
- $D2D1 = 10$ (D2 is ON, D1 is OFF; parameter D2D1_10)
- $D2D1 = 11$ (D1 is ON, D2 is ON; parameter D2D1_11)

To these four combinations of input values, the user can assign any four of the following five PV states:

- $Pvstate1$
- $Pvstate0$
- $Pvstate2$
- $MovPV$
- $BadPV$

PVstates1, 0, and 2 cause the PV indicator to be lighted in the respective state box on the group display when the assigned D2D1 input conditions are satisfied. The MovPV and BadPV states cause the respective MOVPVTXT or BADPVTXT descriptor to appear below the state boxes on the group display.

4.12 PV Source

The PV source parameter (PVSOURCE) determines the source of the current PV state for the digital input portion of the digital composite data point. The possible sources of the current PV state are as follows:

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man (Manual)</td>
<td>Current PV state is provided by the operator from the Universal Station.</td>
</tr>
<tr>
<td>Auto (Automatic)</td>
<td>Current PV state is derived from Input 1 (D1) and Input 2 (D2).</td>
</tr>
<tr>
<td>Track</td>
<td>Current PV state is the commanded output state</td>
</tr>
<tr>
<td>Sub (Substituted)</td>
<td>Current PV state is provided by a user program</td>
</tr>
</tbody>
</table>
4.12.1 PV Source Option

During configuration, the user can specify the PV sources that can be used for this data point. Parameter PVSRCOPT allows the user to select the PV source as being only AUTO, or to select all the PV sources in the above listing as allowable sources of the PV. Note that the organizational summary display lists all the points for which PVSOURCE = TRACK.

4.13 ALARMING

The digital composite point can be configured to detect and report command disagree, uncommanded change, or off-normal alarms through the use of the ALMOPT parameter. The user has the option of specifying no alarming for the data point. Digital composite points also generate a bad PV alarm when any input is coming from a digital input point that has a bad PV flag (BADPVFL) status of ON.

These alarm options can be configured only if the digital composite point is configured to have inputs, or inputs and outputs. The BADPVPR parameter determines priority of the bad PV alarm.

4.13.1 Command Disagree and Uncommanded Change

This type of alarming is selected by entering CmdDis for the ALMOPT parameter. When the commanded-output state is changed and the actual input PV state does not change accordingly within a predefined feedback time, a command disagree alarm is generated. The feedback time (1 to 1000 seconds) is specified by the FBTIME parameter and the timer starts whenever the OP value changes. A command disagree alarm is also generated if OP changes are caused by the interlocks.

This alarm condition returns to normal when the input PV state and the commanded-output state are the same. If the commanded state is momentary, no alarm is generated. For example, a motor may have two PV states (RUN and STOP), but there may be three commanded output states (RUN, STOP, and JOG) where JOG is defined as a momentary state. Command-disagree alarming is performed for only the RUN and STOP commanded output states.

If a change does not occur in the commanded output state but the input PV state changes (and the PV is not bad), an uncommanded-change alarm is generated. This alarm condition returns to normal when the input PV state and the commanded state are the same. If the point state has been configured as being momentary, this type of alarm is not applicable.

You can set the priority of the command disagree alarm and the uncommanded change alarms with the command disagree priority parameter (CMDDISPR).

4.13.2 Off-Normal

Detection of off-normal alarms is configured by entering Offnorml for the ALMOPT parameter. The normal state of the PV input is defined by the user through the PVNORMAL parameter. When the PV input state is different than the state specified by the PVNORMAL parameter, the off-normal alarm is generated. The alarm condition returns to normal when the PV input state and the specified PV normal state are the same. The OFFNRMPR parameter sets the priority of the off-normal alarm.
4.14 CHANGE-OF-STATE EVENTS

Any transitions in the PV input state can be reported as events for journaling and for causing the event-initiated processing of points in the Application Module (AM). It is configured by entering EIP for the event-report-option parameter EVTTOPT. The user must enter the tag name of the AM or CM point using the EIPPCODE parameter. If only journaling is required, the EIPPCODE parameter can be set to a null tag name.

4.15 LOCAL MANUAL INDICATION

Field devices that are interfaced by a digital composite point often have a local HAND/OFF/AUTO (often called HAND/OFF/REMOTE) switch. Unless this switch is in AUTO position, the control system (PM) may not have any control over that device. The user can optionally feedback the switch position into the PM to obtain some display indication for the Universal Station operator. This indication is provided by the word LOCALMAN appearing at the bottom of the digital composite point on a group display. Further, when in local manual, any changes to the output by the operator, and user programs, are prohibited. The override interlocks are still active when the local manual condition is on.

To support HAND/OFF/AUTO switches, a Boolean flag called LOCALMAN is provided. The ON state indicates that the switch is not in AUTO position. The user can hard-wire the AUTO position of the HAND/OFF/AUTO switch through a digital input point. The state of the digital input state is then stored to the LOCALMAN flag from logic slot outputs or sequence programs.
LOGIC POINT
Section 5

This section defines the functions available in the logic point. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

5.1 LOGIC POINT

The logic point provides a configurable mix of logic capability that, together with a digital composite point, provides the basis for integrated logic functions. The logic point is also fully integrated with the regulatory functions in the PM. A logic point consists of logic blocks, flags, numerics, user-defined generic descriptors, input connections, and output connections as shown in Figure 5-1.

5.2 CONFIGURING THE LOGIC POINT

The logic point can have up to 12 input connections, 16 logic blocks, and 12 output connections. The actual number of these is specified through the entry made for LOGMIX parameter as shown in the following chart:

<table>
<thead>
<tr>
<th>LOGMIX Param. Entry</th>
<th>No. of Input Connections</th>
<th>No. of Logic Blocks</th>
<th>No. of Output Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>12_16_4</td>
<td>12</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>12_8_8</td>
<td>12</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>12_0_12</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

The 12_0_12 entry provides the user with a general-purpose data-transfer capability that can be used to read data from other points through input connections and to write this data to other data points and parameters as defined by the output connections, without using any logic blocks. Any input connection can write to any output connection in the logic point. In addition, an input connection can write to a maximum of 12 output connections, as desired.

This entry can also be used when the user desires to implement the internal flags and numerics in the logic point, without using any logic blocks.

5.2.1 Logic Input Connections

Inputs to the logic point are assigned by the user during configuration by using logic input connections. The user can specify up to 12 inputs that are assigned to logic-point inputs L(1) to L(12), as shown in Figure 5-1. The logic input connections can be specified using the "Tagname.Parameter" format, or the hardware reference address format by using the LISRC parameter.
The inputs to the logic point can be obtained from any of the following sources:

- Any Boolean, integer, enumeration, self-defining enumeration, or real parameter within this PMM or in another UCN node. Note that the integer, enumeration, or self-defining enumeration parameters are automatically converted to real values.

- Any parameter other than the DI point's PVFL from the IOPs in this PM. Maximum of four such input connections can be configured (these follow the same kind of restrictions that CL/PM has for prefetches).

- The PV flag parameter (PVFL) of a DI point from a DI IOP in this PM.

- The Bad PV flag parameter (BADPVFL) of a DI point from a DI IOP in this PM.

- The Status Output parameter (SO) from a DO point in this PM.

- The Initialization Request flag (INITREQ) from a DO point in this PM.

![Figure 5-1 — Logic Point](2067)
5.2.1 Effect of Communication and Configuration Errors on Logic Input Connections

Because the logic point can be used for implementing safety interlocks, special handling is provided for inputs, especially Boolean inputs, that cannot be obtained because of communication or configuration errors.

For example, an input obtained from a failed DI Processor can result in a communication error. Alternatively, an input can be coming from a digital composite point in another PM and the point mix in that PM can be changed such that the specified point no longer exists. This results in a configuration error. In order for the logic to be able to continue in spite of a configuration error, the following special features are provided:

- Bad Boolean Inputs—If a Boolean input is not successfully fetched, its value is defaulted based on the logic input bad handling option parameter (LIBADOPT) as follows:

  LIBADOPT = On  The On state is substituted for the unsuccessful input.
  
  LIBADOPT = Off The Off state is substituted for the unsuccessful input.
  
  LIBADOPT = Hold The previous value (the last successfully fetched value) is substituted for the unsuccessful input. On startup, the previous value is defaulted to the Off state. If required, the startup condition can be monitored by checking the startup flag.

- Bad Real Inputs—If a real input cannot be successfully fetched, its value is defaulted to NaN. If required, special action can be taken in the logic by checking it with the "check for bad" logic algorithm.

- Input Bad Flag—When an error is encountered in fetching the value of any input, flag FL(5) is set to On. Note that flag FL(5) is not set to On if a real input is successfully fetched but has a value of NaN.

5.2.2 Flags

Twelve flags, FL(1) to FL(12), are provided for each logic point. The states of flags FL(1) to FL(6) are controlled by the PM and cannot be changed by the user. Flags FL(7) to FL(12) are assigned by the user for controlling the path of the logic in the respective logic point. The flags are described in the following listing:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL(1)</td>
<td>Always Off.</td>
</tr>
<tr>
<td>FL(2)</td>
<td>Always On.</td>
</tr>
<tr>
<td>FL(3)</td>
<td>On only if this logic point is processing for the first time after becoming active.</td>
</tr>
</tbody>
</table>
5.2.3 FL(4) On only if this point is processing for the first time after the PMM box state has transitioned from Idle to Run, or the PMM has gone into the Run state following a power-up.

FL(5) On if at least one of the logic input connections was unsuccessful in fetching the specified source parameter.

FL(6) Used by the watchdog timer logic algorithm. It is set to On by the function or device being monitored to indicate that it is alive. The watchdog timer algorithm always sets this flag to Off. Flag FL(6) cannot be changed from the Universal Station.

FL(7)-FL(12) Can be changed as determined by the user. They can be changed from the Universal Station, other logic points, or user programs.

Flags FL(1) to FL(5) cannot be changed by the user, but the states of these flags can be used as inputs to the logic points and can also be read by user programs.

5.2.3 Numerics

Four numerics, NN(1) to NN(4), are provided with each logic point. The numerics can be used as reference values for the comparison logic algorithms, or they can be used as source parameters for the output connections when writing predefined analog constants to other points. The values of the numerics can be changed from the Universal Station, by other logic points, or by user programs. A bad numeric input typically has the value NaN.

5.2.4 Logic Blocks

The logic operations in a logic point are performed by the logic blocks. Up to 16 logic blocks can be configured by the user for each logic point. The actual number of logic blocks configured is determined by the logic mix described in paragraph 5.2. Each logic block consists of:

- Up to 4 inputs (specified by S1, S2, S3, S4.)
- One logic algorithm (specified by LOGALG)
- One Boolean output (specified by SO)

The parameters associated with a logic block are always qualified with an array index corresponding to the number of that logic block. For example, LOGALG(4) represents the algorithm configured in the logic block number 4, whose output is SO(4), and the inputs may be S1(4), S2(4), etc.

On the first time through configuration, the outputs of all logic blocks are set to OFF; however, on a subsequent restart (for example: IDLE to RUN transition of the PMM state, or INACTIVE to ACTIVE transition of the point execution state), all the outputs are held at their previous values.

Processing Order—The logic points defined for each PM are processed in decending order. Within each logic point, the inputs are calculated first, then the gates are processed, then the outputs are processed, each in ascending order.
5.2.5 Output Connections

Logic output connections are used to write the values of local parameters of a respective logic point to the configured destinations. Up to 12 output connections can be configured for each logic point. The actual number of output connections is determined by the LOGMIX parameter described in paragraph 5.2. The destinations are specified by parameter LODSTN by using the “Tagname.Parameter” format or the hardware reference address format.

The logic output connection can write the selected local parameters of a logic point to any of the following destinations:

- Any Boolean or real parameter in this PMM, or another UCN node.
- Any Boolean integer, enumeration, self-defining enumeration, or real parameter in the IOPs in this PM. A maximum of 12 such connections can be configured for each point.

The user must specify the local parameter within the logic point and the destination to which it is to be written. The local parameter to be written is specified as the logic output source (LOSRC(n), where n = 1 to 12). The source parameter for the output connection can be selected from any of the flags (specified as FL1, FL2, etc.), numerics (specified as N1, N2, etc.), external inputs (specified as L1, L2, etc.), or the output of any of the logic blocks (specified as SO1, SO2, etc.).

Associated with each output connection is a logic output enable flag, LOENBL(n). The parameter pointed to by LOENBL(n) must be ON for the corresponding output connection to write to the specified destination. If store-only-on-a-change is required, the appropriate condition to store can be determined by the CHDETECT logic algorithm and then used to manipulate the enable signal. The logic output enable flag can be obtained from any of the flags (specified as FL1, FL2, etc.), external inputs (specified as L1, L2, etc.), or the output of any of the logic blocks (specified as SO1, SO2, etc.).

5.2.6 Generic Descriptors

Up to 12 user-defined generic descriptors are provided with each logic point for identifying parameters of the logic point with custom names that are to be shown on Universal Station displays. Generic descriptors can be assigned to any of the following logic-point parameters:

- Flags (FL1, FL2, etc.)
- Numerics (N1, N2, etc.),
- External inputs (L1, L2, etc.),
- Outputs of any of the logic blocks (SO1, SO2, etc.).

Typically, the generic descriptors identify critical interlock signals, operator-adjusted parameters, etc.
The actual number of descriptors used is determined by the NODESC parameter for this logic point. For each descriptor, the parameter to which it is attached is defined by PRMDESC(n) parameter, and the corresponding 8-character descriptor is defined by GENDESC(n).

5.3 LOGIC BLOCK ALGORITHMS

Logic blocks perform logic functions. Each logic block can have up to four inputs and produce a single Boolean output, depending on the selected algorithm. The algorithm can require real or Boolean inputs. The real inputs can be obtained from any of the numerics (specified as NN1, NN2, etc.) or the external inputs (specified as L1, L2, etc.). Boolean inputs can be any of the flags (specified as FL1, FL2, etc.), external inputs (specified as L1, L2, etc.), or the output of any of the logic blocks (specified as SO1, SO2, etc.).

When one of the external inputs (L(1), L(2), .. L(12)) is used as an input to an algorithm, the value fetched can be real or Boolean. If the algorithm requires a real input and the fetched value is Boolean, it is treated as NaN. If the algorithm requires a Boolean input and the fetched value is real, it is treated as OFF. In either case, the bad input flag, FL(5), is not affected.

The following logic block algorithms are supported:

- Null (NULL)
- AND Gate (AND)
- OR Gate (OR)
- NOT Gate (NOT)
- NAND Gate (NAND)
- NOR Gate (NOR)
- XOR Gate (XOR)
- Qualified OR Gate With 2 Inputs ON (QOR2)
- Qualified OR Gate With 3 Inputs ON (QOR3)
- Switch (SWITCH)
- Compare Equal With Deadband (EQ)
- Compare Not Equal With Deadband (NE)
- Compare Greater Than With Deadband (GT)
- Compare Greater Than or Equal With Deadband (GE)
- Compare Less Than With Deadband (LT)
- Compare Less Than or Equal With Deadband (LE)
- Check for Bad (CHECKBAD)
- Fixed Size Pulse (PULSE)
- Pulse With Maximum Time Limit (MAXPULSE)
- Pulse With Minimum Time Limit (MINPULSE)
- Delay (DELAY)
- On Delay (ONDLY)
- Off Delay (OFFDLY)
- Watchdog Timer (WATCHDOG)
- Flipflop (FLIPFLOP)
- Change Detect (CHDETECT)
5.3.1 Null (Null)

This logic algorithm provides an output (SO) that is always set to OFF.

5.3.2 AND Gate (AND)

This algorithm provides a 3-input AND gate, with each input (S1, S2, and S3) having the capability of being optionally inverted, as required. The output SO is determined as follows:

\[
SO = (((S1REV = OFF) AND (S1 = ON)) OR ((S1REV = ON) AND (S1 = OFF))) \\
AND \\
(((S2REV = OFF) AND (S2 = ON)) OR ((S2REV = ON) AND (S2 = OFF))) \\
AND \\
(((S3REV = OFF) AND (S3 = ON)) OR ((S3REV = ON) AND (S3 = OFF)))
\]

REV = indicates if the input signal is reverse acting.

5.3.3 OR Gate (OR)

This logic algorithm provides a 3-input OR gate, with each input (S1, S2, and S3) having the capability of being optionally inverted, as required. The output SO is determined as follows:

\[
SO = (((S1REV = OFF) AND (S1 = ON)) OR ((S1REV = ON) AND (S1 = OFF))) \\
OR \\
(((S2REV = OFF) AND (S2 = ON)) OR ((S2REV = ON) AND (S2 = OFF))) \\
OR \\
(((S3REV = OFF) AND (S3 = ON)) OR ((S3REV = ON) AND (S3 = OFF)))
\]
5.3.4 NOT Gate (NOT)

This algorithm provides the Boolean inversion (NOT) function. The output SO is the inversion of the input S1 as follows:

\[
\text{IF } (S1 = \text{ON}) \text{ THEN } SO = \text{OFF} \\
\text{ELSE } SO = \text{ON}
\]

5.3.5 NAND Gate (NAND)

This algorithm provides a 3-input NAND gate, with each input (S1, S2, and S3) having the capability of being optionally inverted. The output SO is determined as follows:

\[
SO = \text{NOT} \left( ((S1_{\text{REV}} = \text{OFF}) \text{ AND } (S1 = \text{ON})) \text{ OR } ((S1_{\text{REV}} = \text{ON}) \text{ AND } (S1 = \text{OFF})) \right) \\
\text{AND} \\
( ((S2_{\text{REV}} = \text{OFF}) \text{ AND } (S2 = \text{ON})) \text{ OR } ((S2_{\text{REV}} = \text{ON}) \text{ AND } (S2 = \text{OFF})) \right) \\
\text{AND} \\
( ((S3_{\text{REV}} = \text{OFF}) \text{ AND } (S3 = \text{ON})) \text{ OR } ((S3_{\text{REV}} = \text{ON}) \text{ AND } (S3 = \text{OFF})) \right)
\]
5.3.6 NOR Gate (NOR)

This logic algorithm provides a 3-input NOR gate, with each input (S1, S2, and S3) having the capability of being optionally inverted. The output SO is determined as follows:

\[
SO = \text{NOT} \left( (((S1\text{REV} = \text{OFF}) \text{ AND } (S1 = \text{ON})) \text{ OR } ((S1\text{REV} = \text{ON}) \text{ AND } (S1 = \text{OFF}))) \text{ OR } (((S2\text{REV} = \text{OFF}) \text{ AND } (S2 = \text{ON})) \text{ OR } ((S2\text{REV} = \text{ON}) \text{ AND } (S2 = \text{OFF}))) \text{ OR } (((S3\text{REV} = \text{OFF}) \text{ AND } (S3 = \text{ON})) \text{ OR } ((S3\text{REV} = \text{ON}) \text{ AND } (S3 = \text{OFF}))) \right)
\]

5.3.7 XOR Gate (XOR)

This algorithm provides a 2-input exclusive-OR gate. The output SO is determined as follows:

\[
SO = \text{NOT} \left( S1 = S2 \right)
\]
5.3.8 Qualified OR Gate with 2 Inputs ON (QOR2)

This algorithm provides a 4-input qualified-OR function that requires at least two inputs to be ON before output SO is set to ON. The output is determined as follows:

```
IF (at least 2 inputs out of S1, S2, S3, and S4 are ON) THEN
  SO = ON
ELSE
  SO = OFF
```

5.3.9 Qualified OR Gate with 3 Inputs ON (QOR3)

This algorithm provides a 4-input qualified-OR function that requires at least three inputs to be ON before output S0 is set to ON. The output is determined as follows:

```
IF (at least 3 inputs out of S1, S2, S3, and S4 are ON) THEN
  SO = ON
ELSE
  SO = OFF
```
5.3.10 Switch (SWITCH)

This algorithm provides a 2-input switch. Output SO is determined as follows:

\[
\text{IF } (S3 = \text{ON}) \text{ THEN } \\
\text{SO} = S1 \\
\text{ELSE} \\
\text{SO} = S2
\]

5.3.11 Compare Equal with Deadband (EQ)

This algorithm compares two real inputs (R1 and R2) for being "almost equal" or within a specified deadband. Output SO is determined as follows:

\[
\text{IF } (\text{ABS}(R1 - R2) \leq \text{DEADBAND}) \text{ THEN } \\
\text{SO} = \text{ON} \\
\text{ELSE} \\
\text{SO} = \text{OFF}
\]

If R1 and/or R2 inputs are "NaN", then SO is not changed.
5.3.12 Compare Not Equal with Deadband (NE)

This algorithm compares two real inputs for NOT being "almost equal," or being outside of a prespecified deadband. Output SO is determined as follows:

\[
\text{NE} \quad \text{DEADBAND} \quad \text{R1} \quad \text{R2} \quad \text{SO}
\]

\[
\text{IF } (\text{ABS}(\text{R1} - \text{R2}) > \text{DEADBAND}) \text{ THEN} \\
\quad \text{SO} = \text{ON} \\
\text{ELSE} \\
\quad \text{SO} = \text{OFF}
\]

If R1 and/or R2 inputs are NaN, S0 is not changed.

5.3.13 Compare Greater Than with Deadband (GT)

This algorithm compares a real input (R1) for being greater than another real input (R2) with a predefined deadband. Output SO is determined as follows:

\[
\text{GT} \quad \text{DEADBAND} \quad \text{R1} \quad \text{R2} \quad \text{SO}
\]

\[
\text{IF } (\text{R1} > \text{R2}) \text{ THEN} \\
\quad \text{SO} = \text{ON} \\
\text{ELSE IF } (\text{R1} \leq (\text{R2} - \text{DEADBAND})) \text{ THEN} \\
\quad \text{SO} = \text{OFF} \\
\text{ELSE} \\
\quad \text{SO} \text{ is not changed.}
\]

If R1 and/or R2 inputs are NaN, S0 is not changed.
5.3.14 Compare Greater Than or Equal with Deadband (GE)

This algorithm compares a real input (R1) for being greater than or equal to another real input (R2) with a specified deadband. Output SO is determined as follows:

\[
\begin{align*}
R1 & \quad R2 \\
& \quad \text{DEADBAND} \\
& \quad \text{GE} \\
& \quad \text{SO}
\end{align*}
\]

\[
\begin{align*}
\text{IF } (R1 \geq R2) \text{ THEN} \\
\quad \text{SO} = \text{ON} \\
\text{ELSE IF } (R1 < (R2 - \text{DEADBAND})) \text{ THEN} \\
\quad \text{SO} = \text{OFF} \\
\text{ELSE} \\
\quad \text{SO is not changed.}
\end{align*}
\]

If R1 and/or R2 inputs are NaN, SO is not changed.

5.3.15 Compare Less Than with Deadband (LT)

This algorithm compares a real input (R1) for being less than another real input (R2) with a predefined deadband. Output SO is determined as follows:

\[
\begin{align*}
R1 & \quad R2 \\
& \quad \text{DEADBAND} \\
& \quad \text{LT} \\
& \quad \text{SO}
\end{align*}
\]

\[
\begin{align*}
\text{IF } (R1 < R2) \text{ THEN} \\
\quad \text{SO} = \text{ON} \\
\text{ELSE IF } (R1 \geq (R2 + \text{DEADBAND})) \text{ THEN} \\
\quad \text{SO} = \text{OFF} \\
\text{ELSE} \\
\quad \text{SO is not changed.}
\end{align*}
\]

If R1 and/or R2 inputs are NaN, SO is not changed.
5.3.16 Compare Less Than or Equal with Deadband (LE)

This logic algorithm compares a real input (R1) for being less than or equal to another real input (R2) with a predefined deadband. Output SO is determined as follows:

\[
\begin{align*}
&\text{IF } (R1 \leq R2) \text{ THEN} \\
&\quad \text{SO} = \text{ON} \\
&\text{ELSE IF } (R1 > (R2 + \text{DEADBAND})) \text{ THEN} \\
&\quad \text{SO} = \text{OFF} \\
&\text{ELSE} \\
&\quad \text{SO is not changed.}
\end{align*}
\]

If R1 and/or R2 inputs are NaN, SO is not changed.

5.3.17 Check for Bad (CHECKBAD)

This logic algorithm checks a real input (R1) for being bad (equal to NaN). Output SO is determined as follows:

\[
\begin{align*}
&\text{IF } (\text{R1} \text{ is } \text{"NaN"}) \text{ THEN} \\
&\quad \text{SO} = \text{ON} \\
&\text{ELSE} \\
&\quad \text{SO} = \text{OFF}
\end{align*}
\]
5.3.18 Fixed-Size Pulse (PULSE)

This logic algorithm provides a fixed-size output pulse at the SO output each time the S1 input transitions from the OFF state to the ON state. The output pulse width (in seconds) is specified by the DLYTIME parameter. If the delay time is less than or equal to one sample time (of the logic point), it is assumed to be equal to one sample time. Another output pulse cannot be generated until the generation of the preceding pulse has been completed.
5.3.19 Pulse with Maximum Time Limit (MAXPULSE)

This logic algorithm provides a pulse at the SO output each time the S1 input transitions from the OFF to the ON state. If the input stays ON longer than a predefined time, the output pulse is terminated. The maximum output pulse width (in seconds) is specified by the DLYTIME parameter. If the specified output pulse width is less than or equal to one sample time (of the logic point), it is assumed to be equal to one sample time.
5.3.20 Pulse with Minimum Time Limit (MINPULSE)

This algorithm generates a pulse at the SO output each time the S1 input transitions from the OFF to the ON state. If the S1 input stays ON for an interval that is less than the specified time, the output pulse is extended until the timed interval is over. The minimum output pulse width (in seconds) is specified by the DLYTIME parameter. If the specified output pulse width is less than, or equal to, one sample time (of the logic point), it is assumed to be equal to one sample time.

![MINPULSE Diagram]

5.3.21 Delay (DELAY)

This logic algorithm delays the input signal at the S1 input by one sample time. The SO output always follows the input after one sample time delay.

![DELAY Diagram]
5.3.22 On Delay (ONDLY)

This logic algorithm delays the input signal supplied at the S1 input when the input signal is going from the OFF to the ON state. (There is no delay provided when the input changes from the ON to the OFF state.) When the input state changes from OFF to ON, an internal timer starts counting down the delay time specified by the DLYTIME parameter (in seconds). When it times out, the S1 input is monitored again, and if it is still ON, the SO output is set to ON. When the input state transitions to OFF, the SO output is set to OFF immediately, and the timer is shut off (if it is running). If the specified delay time is less than or equal to one sample time (of the logic point), it is assumed to be equal to one sample time.
5.3.23 Off Delay (OFFDLY)

This logic algorithm delays the input signal supplied at the S1 input when the input signal is going from the ON to the OFF state. (There is no delay provided when the input changes from the OFF to the ON state.) When the input state changes from ON to OFF, an internal timer starts counting down the delay time specified by the DLYTIME parameter (in seconds). When it times out, the S1 input is monitored again, and if it is still OFF, the SO output is set to OFF. When the input state transitions to ON, the SO output is set to ON immediately, and the timer is shut off (if it is running). If the specified delay is less than or equal to one sample time (of the logic point), it is assumed to be equal to one sample time.

5.3.24 Watchdog Timer (WATCHDOG)

This logic algorithm provides a "time out" capability to monitor other system functions or remote devices. The function or device monitored must set the watchdog reset flag FL(6) (of this logic point) to ON within a time interval specified (in seconds) by the DLYTIME parameter, otherwise it is assumed to have failed, and the SO output of the algorithm is set to ON. If the specified delay time is less than or equal to one sample time (of the logic point), it is assumed to be equal to one sample time. When the watchdog timer algorithm runs and if the FL(6) flag is ON, the internal timer is set equal to DLYTIME, and FL(6) and the output SO are both set to OFF; however, if FL(6) is OFF, the internal timer is decremented, and if it becomes zero, the SO output is set to ON. Because this algorithm always uses the FL(6) flag of the logic point as the reset input, only one Watchdog Timer algorithm should be configured for each logic point.
5.3.25 Flip-Flop (FLIPFLOP)

This algorithm provides the flip-flop function. The SO output is determined by the states of inputs S1 and S2 as follows:

```
<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>OFF</td>
<td>Not changed</td>
</tr>
<tr>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>ON</td>
<td>ON</td>
<td>S3 input</td>
</tr>
</tbody>
</table>
```

5.3.26 Change Detect (CHDETECT)

This algorithm is used to detect changes in up-to-three inputs. The output SO is determined as follows:

```
SO = (S1 < > S1_last_time) OR (S2 < > S2_last_time) OR (S3 < > S3_last_time)
```
This section describes the functions available in the Process Module Data Point and the associated Box Flag, Box Numeric, and Box Timer Data Points. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

6.1 PROCESS MODULE DATA POINT

Control strategies frequently need the flexibility of user programs for continuous, batch, or hybrid applications. A Process Module Data Point is the resource for execution of user-created programs written in Honeywell's Control Language (CL/PM). CL/PM is a member of Honeywell's family of advanced process-engineer oriented languages and is a powerful tool for advanced continuous control, sequential control, and computations. CL programs are self-documenting, which is an important feature when future modifications of control strategies are anticipated. Total statement capacity depends on configuration. The maximum number of CL/PM statements = 3.2(3100-n) where n is the number of Memory Units used by data points (see subsection 3.1.3). Using the Universal Station or the Universal Work Station, individual programs can be easily modified and reloaded without affecting the execution of regulatory control, logic blocks, and other user programs.

The Process Module Data Point is the interface between the system and a CL/PM (sequence) program that resides in the Process Module Data Point. The Process Module Data Point shown in Figure 6-1 is the mechanism through which

- An operator, a CL/AM block, a user-written CM program, or another sequence program can start and stop a sequence program and monitor the current status of a sequence program.

- Sequence alarms (sequence errors, failures, and phase alarms) are reported to the system; an alarm priority can be assigned to sequence alarms.

- A sequence program can send information to an Advanced Control Point (ACP) in a Computing Module when implementing high-level control strategies.

6.1.1 CL/PM Sequence Program

To accomplish the desired sequence control, the sequence program can

- Monitor current process values such as temperatures, pressures, and flows and current states of devices such as valves and motors. The sequence program can access values from the local PM database, and from any other node such as PM, APM, HPM, LM or SM that is on the same UCN. A sequence program can read the values of almost all parameters in the PM database except for character-string descriptors such as PTDESC (Point Descriptor), and input/output connections.
Figure 6-1 — Process Module Data Point, Functional Diagram
• Control the process by using the accessed values to calculate new values and write them to the appropriate parameters. The sequence program can write values into the local PM database and into any other node such as PM, APM, HPM, LM or SM that is on the same UCN. A sequence program can write values to all parameters in the PM database except for calculated variables such as alarm flags and general configuration parameters such as PVALGID (PV Algorithm Identifier).

• Use up to 127 local flag variables and up-to-80 local numeric variables that reside in each Process Module Data Point for implementing batch operations. It can also use the local flags and numerics that reside in other Process Module Data Points. An additional 1023 flags, 2047 numerics, and 64 timer data points reside in the PM Box and are available to all sequence programs in the same PM.

• Start another sequence program or force an abnormal-condition handler in another Process Module Data Point as required.

• Issue predefined or computed messages to the operator at the Universal Station to inform the operator of current process conditions and to provide instructions. The operator can also override various portions of the sequence, as required.

6.1.2 Sequence Program/Unit Partitioning

The user's process is usually partitioned into process units where the operators have the responsibility to control one or more process units. To support this type of partitioning, the PM Process Module Data Points (sequence programs) can be partitioned on a process unit basis as shown in Figure 6-2. This is accomplished by using the following three elements:

• The set of CL/PM sequence programs that control individual process unit.

• The set of process monitoring and control elements that are used by the sequence program to control the operation of the process unit.

• The operating displays at the Universal Station such as the Module Summary Display (see Figure 6-3) which shows the current status of the process modules on a process unit basis, and the Module Group and Module Detail displays which allow the operator to start and stop the sequence programs, override various portions of the sequence programs, etc.

Wherever possible, process unit partitioning should be consistent with the inherent boundaries in the system, such as

• The beginning and end points of major separable segments of a process.

• The physical separations or classifications of process equipment components.
6.1.2

Figure 6-2 — Sequence Program Partitioning/Unit Partitioning
6.1.3 Writing the Sequence Programs

Sequence programs are written in CL/PM and compiled at a Universal Station. At compilation time, each sequence program is bound to a specific Process Module Data Point (i.e., a specific sequence slot) and is written to a separate object file. These files can be directly downline loaded through the NIM to the process module slots in the designated PM.

- To prepare CL/PM programs, refer to the *CL/PM Reference Manual* in the *Implementation/Process Manager - 2 Binder*.

- To compile a CL/PM program (binding it to a process module point) and load it into the PM, refer to the *CL/PM Data Entry* publication in the *Implementation/Process Manager - 2 binder*. 
6.1.3 Sequence Library

The Sequence Library contains the names of the sequence programs, phases, steps, subroutines, abnormal condition handlers, and self-defining enumeration states. The Sequence Library is divided into three sections, with each section having a maximum of 1000 entries. (The section is defined by the LIBRYNUM parameter.) A section of the library can be viewed by reconstituting the point, using $NxxLiby where xx is the UCN number on which the NIM resides and y is the section number of the library.

The library entries can be made automatically by the CL Compiler, or they can be entered manually by the user. If the manual entry method is to be used, the user should first enter the names on the NIM Library Configuration Form, PM88-540. The LIBRYTXT parameter defines the allowable character set for the library entries.

Library 1 is reserved for sequence names; Libraries 2 and 3 are reserved for all other names. If the CL Compiler completely fills up Libraries 2 and 3, the compiler will begin entering the overflow information into Library 1, beginning with index number 1,000 and working down towards index number 2.

The sequence library resides in the NIM, and it is available to all the PMs and APMs on the same UCN.

6.1.3.2 Local Flags and Numerics

Each Process Module Data Point contains 127 local flags and 80 local numerics; the flags are designated FL(1) to FL(127) and the numerics are designated NN(1) to NN(80).

The primary purpose of these flags and numerics is to provide storage for recipe data and intermediate results. They can be accessed by the sequence executing in the same process module in which they reside, or they can be accessed by any other sequence in the same PM. These flags and numerics can also be accessed by all system functions, such as CL programs in the AM, Universal Station displays, etc. They can be accessed as local variables by CL/PM by using the AT clause. Refer to the CL/PM Reference Manual.

The local variables are accessed by the various system elements using the "Tagname.Parameter" convention where the Tagname is the name of the process module in which they reside, and the "Parameter" is the parameter name such as FL(15) or NN(25). To store (write) into the local flags and numerics, the keylock position must equal or exceed the minimum access level specified in parameter SPLOCK.

Process module flags and numerics are set to the default values of OFF and NaN respectively, when the process module data point is deleted or when the PM database is initialized to default values. The PM database is set to default values on initial loading of the PM Box data point and when the SCANRATE parameter or point mix changes in subsequent loads of the PM Box data point. Process Module data point local flags and numerics are left unchanged during downloading of sequence programs or the process module data point itself to allow a record or history to exist between programs.

The Flag, Numeric, and Timer Data Points that reside in the PM box are a different set of variables from the local flags and numerics. These points are available to the sequence programs in this PM and to the other sequence programs in the PMs on the same UCN and, with some minor restrictions, to other system functions. They are described beginning with paragraph 6.2.
6.1.4 Sequence Program Structure

As shown in Figure 6-4, each sequence program consists of two main sections: the data declaration section and the execution section.

The data declaration section requires the user to provide optional CL/PM statements that relate user-defined names to PM flags and numerics, that declare the numeric constants, and that name the data points used in the program.

![Sequence Program Structure Diagram]

Figure 6-4 — Sequence Program Structure
The execution section consists of one-to-three parts:

- **A normal sequence** that is the main program. The normal sequence is the main program that provides control when conditions in the process are normal (e.g., the process is proceeding within acceptable limits and does not require special control actions). The main program is divided into "Phases," "Steps," and "Statements" as shown in Figure 6-4.

  *Phase*—A sequence program consists of a grouping of phases. A phase executes a major process function or marks a major process milestone, such as a charging phase or heat-up phase. Phase boundaries are key points of synchronization in the control program. A phase is identified in the sequence program by the PHASE statement, and consists of optional steps and statements.

  *Step*—A step executes a minor process function such as opening a valve with associated checks and verification, or checking a temperature. At least one step is executed each time the sequence is executed. A step is visible at a Universal Station as a process milestone. It is identified in the sequence program by a STEP statement, and consists of an ordered set of CL/PM statements. The step size is limited to a maximum of 255 statements.

  *Statement*—One CL/PM instruction. A statement performs an elementary action, such as commanding a valve to open, do arithmetic operations, fetch variables, etc.

- **Subroutines**—Subroutines simplify the program structure and are used for executing repetitive functions, thereby reducing the programming effort and memory requirements. Subroutines can be called by the normal sequence, other subroutines, or abnormal condition handlers. Two levels of nesting are supported for both normal and abnormal sequences. A runtime error is generated if the nesting level is violated.

  Subroutines are specific to one sequence program, i.e., subroutines defined outside of the program and maintained in subroutine libraries are not supported in the Process Manager.

- **Abnormal-Condition Handlers**—Abnormal-condition handlers provide corrective action when abnormal conditions are encountered. The conditions can be detected when the SEQEXEC value is Run, Pause, Fail, Error, or End. When such a condition is detected, the normal sequence is suspended and the appropriate abnormal-condition handler begins to execute. The types of abnormal-condition handlers are as follows:

  - **Hold**—For a condition that requires a partial shutdown.
  - **Shutdown**—For a condition that requires a systematic shutdown.
  - **Emergency Shutdown**—For a condition that requires a complete, sudden shutdown.
Abnormal-condition handlers are identified in the sequence program by the HANDLER statement, preceded by the name for the type of handler, and followed by the user-given handler name, such as in the following example:

```
HOLD HANDLER cooldown
```

Abnormal-condition handlers consist of steps and statements. Hold and Shutdown abnormal-condition handlers can be terminated by a restart section that is identified by the RESTART statement, followed by the handler's END statement. An Emergency Shutdown handler can be terminated by only the handler's END statement. Abnormal-condition handlers have priority over each other and over the normal sequences. The priorities are as follows:

- **Highest Priority** – Emergency Shutdown
  - Shutdown
  - Hold
- **Lowest Priority** – Normal Sequence

Note that the priority of a Restart Section is the same as the abnormal-condition handler that contains the Restart Section.

The abnormal condition handlers can be enabled or disabled anywhere within a Phase by using the ENB statement, which causes a suspend condition. The new conditions to be monitored take effect immediately. The abnormal condition can also be enabled or disabled by the phase header in the phase statement.

### 6.1.5 Sequence Execution

#### 6.1.5.1 Normal Execution

Execution of the normal sequence can be initiated by one of the following:

- Universal Station operator from the Process Module Detail Display.

- Another sequence, executing in another process module by using the INITIATE statement. Generally, this other sequence is a master or supervisory sequence; that is, a sequence program that initiates, monitors, and controls other sequences.

- CL Block in an AM which changes the PROCMOD parameter value in the PM to Strt (Start).

- User-written program in a CM which changes the PROCMOD parameter value in the PM to Strt (Start).

To manipulate the PROCMOD parameter successfully, the value of PROCMOD must be Off, and the value of SEQEXEC must be Loaded. The keylock position must equal or exceed the minimum access level specified in parameter CTLLOCK. The value of PROCMOD can be changed to START from any keylock position regardless of the access level specified in CTLLOCK.
6.1.5.2 Execution of Abnormal-Condition Handlers

Enabled abnormal-condition handlers can be initiated by one of the following:

- Request from a Universal Station operator.
- Predefined process condition detected by the sequence program at every pre-emption point, such as before executing a step.
- Activation by a statement in the sequence (for example, INITIATE HOLD).
- INITIATE statement from another sequence.
- CL block in an AM.
- User-written program in a CM.

6.1.6 Process Module Operating State

The process module operational state represents the operational condition of a process module. The module state is represented through the PROCMOD parameter and the allowable states are listed and described in Table 6-1. A state diagram is provided in Figure 6-5.
6.1.7 Sequence Execution Mode

The sequence execution mode defines the manner in which the sequence program is executed. The sequence execution mode is established through the SEQMODE parameter, and the allowable modes are listed and described in Table 6-2.

Figure 6-5 — Process Module Operating States
### Table 6-1 — Process Module Operating States*

<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Process module slot is not being processed. A sequence program can be assigned to a process module but it cannot be executed. The sequence execution mode is not applicable to this module state.</td>
</tr>
<tr>
<td>Norm (Normal)</td>
<td>The normal sequence program is running in the process module slot.</td>
</tr>
<tr>
<td>Hold</td>
<td>Process module is executing the hold abnormal-condition handler. Hold sequence may be initiated by one of the items listed in paragraph 6.1.5.2.</td>
</tr>
<tr>
<td>Shdn (Shutdown)</td>
<td>Process module is executing the Shutdown abnormal-condition handler. Shutdown sequence can be initiated by one of the items listed in paragraph 6.1.5.2. Shutdown has priority over Hold.</td>
</tr>
<tr>
<td>Emsd (Emergency Shutdown)</td>
<td>Process module is executing the Emergency Shutdown abnormal-condition handler. Emergency Shutdown sequence can be initiated by one of the items listed in paragraph 6.1.5.2.</td>
</tr>
</tbody>
</table>

* Parameter PROCMOD also contains the Strt (Start) and Stop states, which are transitional states that can be controlled by one of the items listed in paragraph 6.1.5.2.

### Table 6-2 — Sequence Execution Modes

<table>
<thead>
<tr>
<th>Execution Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto (Automatic)</td>
<td>Normal mode of operation. Sequence runs from beginning to end without operator intervention.</td>
</tr>
<tr>
<td>SemiAuto (Semi-Automatic)</td>
<td>Sequence stops at all PAUSE statements in the sequence. Sequence can be restarted by the operator.</td>
</tr>
<tr>
<td>SnglStep (Single-Step)</td>
<td>Normally used for debugging. Sequence is executed one step at a time. Sequence can be restarted by the operator.</td>
</tr>
</tbody>
</table>
6.1.8 Sequence Execution State

The sequence execution state represents the current state of the sequence program. These states are defined through parameter SEQEXEC and are listed and described in Table 6-3. Figure 6-6 shows the possible state transitions of the sequence.

Figure 6-6 — Sequence Execution States
### Table 6-3 — Sequence Execution States

<table>
<thead>
<tr>
<th>Execution State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL (Not Loaded)</td>
<td>Initial state in which sequence has not been assigned to a process module. This state is automatically entered from the DLL state when loading has been aborted.</td>
</tr>
<tr>
<td>DLL (Down-Line Loading)</td>
<td>Transient state during which the loading of the sequence into the process module slot is in progress.</td>
</tr>
<tr>
<td>Loaded</td>
<td>Sequence program has been loaded into the process module slot. This state is automatically entered from the DLL state when loading has been completed.</td>
</tr>
<tr>
<td>Run</td>
<td>Sequence program is running.</td>
</tr>
<tr>
<td>Pause</td>
<td>Execution of the sequence is suspended because of the execution of a PAUSE statement, or the completion of a step when in the single-step mode. Sequence execution can be resumed by the operator.</td>
</tr>
<tr>
<td>Fail</td>
<td>Sequence execution is suspended because of the detection of one of the failure conditions listed below. A system message that describes the failure condition is generated. Sequence execution can be resumed by the operator.</td>
</tr>
</tbody>
</table>

#### Failure Code Definition

<table>
<thead>
<tr>
<th>Failure Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>165</td>
<td>Sequence has been stopped by the operator.</td>
</tr>
<tr>
<td>166</td>
<td>Attempt to start an abnormal-condition handler that has not been enabled and no lower-priority abnormal-condition-handler is enabled. Possibly using INITIATE. Suggestions: Use INITIATE with a When Error clause.</td>
</tr>
<tr>
<td>167</td>
<td>Not used.</td>
</tr>
<tr>
<td>168</td>
<td>Not used.</td>
</tr>
<tr>
<td>169</td>
<td>An attempt was made to start a sequence that was not loaded into the process module slot.</td>
</tr>
<tr>
<td>170</td>
<td>Communication error detected in READ/WRITE statement. Possible cause: a READ/WRITE statement without a When Error Path fails a bad read. Note that a post store reports its own failure code. Suggestions: • determine validity of the attempted fetch or store. • check actual presence of point.</td>
</tr>
</tbody>
</table>
### Table 6-3 — Sequence Execution States (Continued)

<table>
<thead>
<tr>
<th>Execution State</th>
<th>Description</th>
</tr>
</thead>
</table>
| Fail (continued) | 171 Communication error detected during an I/O Link access. This error is generated for all post-store problems. Possible cause:  
• IO Link poststore failed.  
• DI scan PV status is bad. Suggestions:  
• check I/O Link for reasons for bad post-store, or bad PV in DI scan. |
|                  | 172 Range error has been detected. Possible cause:  
• box timer set point value greater than 32000.  
• illegal stores to Digital Composite parameters. |
|                  | 173 Store failure because of "rights" error. For example, an attempt was made to write to a parameter when the point was not in the proper mode. Possible cause:  
• Other points reject stores.  
• attempt to write to box timer set-point or time base when state is in RUN.  
• attempt to start timer when PV is greater than SP value.  
• attempt to INITIATE a lower priority handler, while in a higher priority handler.  
Suggestion: check state of point not accepting the store. |
|                  | 174 An interlock error condition has been detected. (Not used). |
| Error            | 175 –255 Reserved for future use. |
|                  | Sequence execution is suspended because of the detection of one of the error conditions listed below. A system message that describes the error condition is generated. Sequence execution can be resumed by the operator. |

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Not used</td>
</tr>
</tbody>
</table>
| 102        | Array index error  
Possible cause: violated array index bound check. Suggestions: check array bounds defined in the LOCAL statement or in the subroutine header. |
Table 6-3 — Sequence Execution States (Continued)

<table>
<thead>
<tr>
<th>Execution State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error (Continued)</td>
<td><strong>Error Code</strong></td>
</tr>
<tr>
<td>103</td>
<td>Illegal generated code</td>
</tr>
<tr>
<td>Possible cause:</td>
<td></td>
</tr>
<tr>
<td>• could not find variable operator code in the reference list</td>
<td></td>
</tr>
<tr>
<td>• invalid statement header</td>
<td></td>
</tr>
<tr>
<td>• unsupported built-in function call.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>Illegal generated code referencing a parameter or variable.</td>
</tr>
<tr>
<td>Possible cause:</td>
<td></td>
</tr>
<tr>
<td>• bad box timer parameter code</td>
<td></td>
</tr>
<tr>
<td>• local numeric/flag index out of range</td>
<td></td>
</tr>
<tr>
<td>• invalid time base.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>Interpreter stack overflow</td>
</tr>
<tr>
<td>Possible cause: Not enough stack depth.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>GOTO destination error</td>
</tr>
<tr>
<td>Possible cause: Invalid destination.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>Key-level error</td>
</tr>
<tr>
<td>Possible cause:</td>
<td></td>
</tr>
<tr>
<td>• tried store to read only parameter</td>
<td></td>
</tr>
<tr>
<td>• tried store with access level invalid</td>
<td></td>
</tr>
<tr>
<td>• system error</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>Configuration mismatch error</td>
</tr>
<tr>
<td>Possible cause:</td>
<td></td>
</tr>
<tr>
<td>• may be system error</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>I/O Link prefetch overflow</td>
</tr>
<tr>
<td>Possible cause: exceeded 12 I/O Link prefetches per step.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: insert a new STEP in the code if several IOL references are made within this step.</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>Subroutine nesting level error</td>
</tr>
<tr>
<td>Possible cause: nesting of subroutine calls is more than two levels deep.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: reduce nesting level of subroutine call to no more than two. Note that a subroutine called from a normal or abnormal program can call only one more level of subroutine.</td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Illegal value error</td>
</tr>
<tr>
<td>Possible cause: illegal value detected when doing READ/WRITE or SET.</td>
<td></td>
</tr>
<tr>
<td>Suggestions: contact Honeywell Technical Assistance Center.</td>
<td></td>
</tr>
<tr>
<td>Execution State</td>
<td>Error Code</td>
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<td>-----------------------</td>
<td>------------</td>
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<tr>
<td>Error (Continued)</td>
<td>112</td>
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<tr>
<td></td>
<td>117 - 164</td>
</tr>
<tr>
<td>End</td>
<td></td>
</tr>
</tbody>
</table>
6.1.9 Sequence Overrides

The process module displays at the Universal Station allow the user to perform phase, step, and statement overrides when the sequence execution state is Fail, Error, or Pause. An attempt to access the override function from anywhere other than the Universal Station results in an error code of 107 (key-level error). The overrides are not restricted by the value in CNTLOCK if the sequence execution state is Fail or Error.

• **Phase Override**—Allows the user to skip execution of one phase after another, in forward or reverse order. Phase override works only in the sequence for which it is invoked; it is implemented through the OVERPHAS parameter.

• **Step Override**—Allows the user to skip execution of one step after another, in forward or reverse order. Step override works only in the phase for which it is invoked; it is implemented through the OVERSTEP parameter.

• **Statement Override**—Allows user at a Universal Station to skip execution of one statement after another, in forward or reverse order. Statement override works only in the step for which it is invoked; it is implemented through the OVERSTAT parameter.

6.1.10 Sequence Alarms

Sequence alarms are generated when

• The process-module operational state is changed to Hold (HOLD), Shutdown (SHDN), or Emergency Shutdown (EMSD) as indicated by a change in the PROCMOD parameter. The PROCMOD parameter can be changed by entry into an abnormal condition handler or externally by operator, AM, etc. The PROCMOD parameter has a key level of Operator and can be written to from the LCN (by an operator, a CL/AM program, etc.) or by a CL/PM program.

• The sequence execution state is changed to Fail, Error, or End as indicated by a change in the SEQEXEC parameter. The SEQEXEC parameter has a key level of View only and cannot be changed from the LCN or by a CL/PM program.

• The phase timer has elapsed as determined by the PHASETIM parameter.

6.1.10.1 Sequence Alarm Priorities

The priority of the sequence alarm can be configured for each process module through the SEQPRI parameter. The entry for this parameter can be Emergency, High, Low, JnlPrint, Printer, Journal, or NoAction.
6.1.11 Sequence Messages

6.1.11.1 Sequence Status Messages

Sequence-status messages are issued when the:

- Process-module operational state is changed
- Sequence-execution mode is changed
- Sequence-execution state is changed
- Sequence begins a new phase.
- A sequence message is issued.

6.1.11.2 Operator Messages

Two types of programmed operator messages can be generated by the sequence program as listed below.

- **Message with feedback**—A SEND statement with the confirmation option (WAIT) causes the sequence to be suspended until the message has been confirmed by the user at the Universal Station.

- **Message without feedback**—This message is a 1-way communication from the sequence to a destination, such as the Universal Station.

These messages can be displayed at the Universal Station and/or logged on the printer, depending on how the user codes the message statement.

It is good practice to confirm any outstanding messages after a sequence failure before rerunning the sequence and before loading a new sequence.
6.1.12 Restart Option

The restart option determines how the sequence program is started following a warm restart. A Warm restart is considered as being a transition from Idle to Run, or a short power interruption that does not change the PM database. The following restart options are available:

- **Restart**—When the sequence-execution state is Run, the sequence program is started from the very beginning; otherwise, the process module operational state is changed to Off and the sequence-execution state is changed to Loaded (or Not Loaded if a sequence has not been loaded). If an abnormal handler is executing when the warm start occurs, execution begins from the beginning of the normal sequence and not from the abnormal handler. A sequence-state change event is issued to report the transition from Hold, Shutdown, or Emergency Shutdown to Normal.

- **Off**—The process module operational state is changed to Off and the sequence-execution state is changed to Loaded (or Not Loaded if a sequence has not been loaded).

6.2 BOX FLAG DATA POINT

A Box Flag Data Point is a 2-state (On and Off) point that is used for storing a Boolean value. The value can be supplied by the operator, by the sequence program, by an output connection from another PM point, by any PM box on the same UCN, or by a node on the LCN. There are 1023 Flag Data Points (slots) available in a PM box and they can be configured as Full or Component points as determined through the PNTFORM parameter.

Flag data points are not scheduled and only off-normal alarms are processed. Their states change when they are accessed by other functions such as an operator or a user-written program.

Flag points do not require a tag name. They can be accessed by !BOX.fl(i) or $NMxxNyy.fl(i). A functional diagram of the Flag Data Point is shown in Figure 6-7.

As shown in this figure, the input to the flag point is provided by parameter PVFL, which can be On or Off. PVFL will set the the flag-point PV state to the same state as PVFL. The PV is then available as an output from the flag point and its current state can be accessed by other points in the PM and in the system.

PVFL will also light the STATE1 and STATE0 boxes on the Universal Station Displays, depending on its state. If PVFL is On, the STATE1 (upper) box will be lighted; if PVFL is Off, the STATE0 (lower) box will be lighted.
6.2.1 Alarming

The first 128 flag points (slots) can be configured for off-normal alarming. An alarm will be generated when the PV of the flag point is changed from STATE0 (Off) to STATE1 (On).

Alarming is available only if the flag point has been configured as a Full point.

Figure 6-7 — Box Flag Data Point, Functional Diagram
6.3 BOX NUMERIC DATA POINT

Box Numeric Data Points are used to store numeric values that can be used for batch/recipe operations, or they can be used as a scratch pad to store the intermediate results of calculations. The values in a numeric point are real numbers that have been entered by the operator, or by a sequence program, or other system element. Box Numeric Data Points are full points and cannot be configured as component points.

Up to 2047 Numeric slots can be configured as part of each PM box. Numeric slots do not require a tag name. They can be accessed by !BOX.nn(i) or $NMxxNyy.nn(i). These points are accessible to the sequences in the same PM box, to any PM box on the same UCN, and to any node on the LCN.

Numeric data points are not scheduled and are not processed. Their parameter values change when they are accessed by a system activity, such as by an operator or a sequence program.

6.4 BOX TIMER DATA POINT

The Box Timer Data Point allows the operator and the sequence program to time the process events, as required. This type of data point keeps track of the elapsed time after the timer has been started and provides an indication when the elapsed time has reached the predefined limit. Box Timer Data Points are component points and cannot be configured as full points.

There are 64 Timer Data Points in each PM Box, and like box numeric and flag points, timer data points do not require a tag name. These points are accessible to the sequences in the same PM box, to any PM box on the same UCN, and to any node on the LCN. A functional diagram of the Timer Data Point is shown in Figure 6-8.

To use a Timer Data Point, an operator at a Universal Station or the sequence program loads a preset time value (the length of time that the timer is to run in seconds or minutes) into parameter SP. Once the preset value is entered, the timer is started by setting parameter COMMAND to Start. (The timer can also be stopped, reset, or reset and restarted through the COMMAND parameter.)

The time value in PV starts at zero and increments toward the preset time value when the timer is processed. (The timer is processed once each second.) The RV parameter indicates the time remaining until the timer reaches its limit (SP - PV). When PV = SP, the status parameter SO is set to On to indicate that the time limit has been reached. The values in PV and SP can range from 0 to 32000 seconds or minutes, as configured.
Figure 6-8 — Box Timer Data Point, Functional Diagram
This section describes the functions available in the Regulatory PV (RegPV) point. The functions are described first and are followed by detailed descriptions of the algorithms. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

7.1 REGULATORY PV POINT

While standard I/O functions such as engineering unit conversion and alarming are handled directly by the I/O Processors, Regulatory PV (RegPV) points provide an easy-to-use configurable approach for implementing PV calculations and compensation functions. PV processing provides a menu of selectable algorithms such as mass flow, totalization, and variable dead-time compensation.

The RegPV data point supports the following PV algorithms:

- Data Acquisition (DataAcq)
- Flow Compensation (FlowComp)
- Middle of 3 Selector (Mid0f3)
- High Low Average Selector (HiLoAvg)
- Summer (Summer)
- Variable Dead Time with Lead Lag (VDTLDLag)
- Totalizer (Totalizr)
- General Linearization (GenLin)
- Calculator (Calcultr)

Detailed descriptions of these algorithms can be found in this section beginning with paragraph 7.7.

Figure 7-1 is a functional diagram of the RegPV point.
Figure 7-1 — Regulatory PV Point, Functional Diagram
7.2 PV INPUT CONNECTIONS

PV input connections are used to specify the source(s) for the inputs to PV algorithms. A maximum of six PV input connections can be configured for an algorithm, as required by the individual PV algorithm. The user can implement the input connections by using the "Tagname.Parameter" format.

When using the "Tagname.Parameter" format, the user must enter the tag name of the data point and the name of the parameter within that data point. The source parameter must contain a real number, integer, or Boolean quantity. The values provided by the input connection parameters are assigned to destination parameters within the RegPV point by the PIDSTN parameter. The destination parameters for these sources default to one for each input to the configured PV algorithm.

One input connection must be configured for each algorithm input, otherwise the point cannot be made active.

7.3 PV ALGORITHM CALCULATION

The configured PV algorithm accepts the values received through the PV input connections and produces the calculated PV value (PVCALC) plus its value status (PVAUTOST). The PV algorithms are described beginning with paragraph 7.7.

7.4 PV RANGE CHECK AND FILTERING

The PV range is configured in PVEULO and PVEUHI in a range from 0% to 100.0% of the engineering-units range. This is usually the normal operating range for the PV but it can extend into a configurable extended range, as defined by PVEXEULO and PVEXEUHI. The extended range is forced to be equal to or greater than the range defined by PVEULO and PVEUHI. PVCALC is generally constrained within PVEXEULO and PVEXEUHI, but the checks and constraints depend on the PV source, as follows:

- If PVSOURCE is Auto—(1) If PVAUTOST contains Bad, PVSTS is Bad and no PV-range checks are made. (2) If PVAUTO is outside the extended range and PV clamping (PVCLAMP) is not configured, the PV becomes a bad value and PVSTS is Bad; however, if PV clamping is configured, the PV becomes equal to the value of the violated range and PVSTS becomes Uncertn. In either case, the appropriate PV-range violation flag is set (PVEXLOFL or PVEXHIFL).

- If PVSOURCE is Man—Any value from the Universal Station that is outside the extended range is not accepted. PVSTS is already uncertain because the source is Man.

- If PVSOURCE contains Sub—If a program stores a PV value outside the extended range, the appropriate PVEXLOFL or PVEXHIFL flag is set. PVSTS is already uncertain because the source is Sub.

If clamping of the output is specified by the PVCLAMP parameter, PV filtering is performed before the range check. If the value entered for PV filtering through the TF parameter is other than the default value of 0.0, a single-lag filter is applied to the PVCALC value to remove noise. If a filter value is not specified, PVAUTO contains the same value as PVCALC.

Data-point parameter LASTPV always holds the last good value of the PV.
7.4.1 PV Value Status

The value in the PV value-status parameter, PVSTS, is determined as follows:

- **Normal**
  - PVSOURCE = Auto, PVAUTOST = Normal, and the PV value is within the range defined by PVEULO and PVEUHI.

- **Uncertn**
  1) PVSOURCE = Man or Sub and the PV value does not equal NaN (i.e., is a valid, real number), or,
  2) PVSOURCE = Auto, and PVAUTOST = Uncertn. Note that PVAUTOST contains Uncertn if at least one of the required algorithm inputs is Uncertn and none of the required algorithm inputs is Bad, or,
  3) PVSOURCE = Auto and the value in PVAUTO is outside the engineering-units range and is clamped.

- **Bad**
  - The PV value is NaN. This results from one of the following:
    1) PVSOURCE = Auto and PVAUTO = NaN.
    2) PVSOURCE = Auto, the value in PVAUTO is out-of-range, and has not been clamped.
    3) PVSOURCE = Sub or Man and the PV is stored as NaN.

7.5 PV SOURCE SELECTION

The source of the PV can be PV processing, a Universal Station, or a user-written program, as shown in Figure 7-1. It is specified by the PVSOURCE parameter, whose value can be changed by an operator, a supervisor, an engineer, or a user-written program. The PVSOURCE parameter is configurable only if Full has been entered for the PNTFORM parameter. PVSOURCE can have one of the values:

- **Auto**—PV is received from PV processing through the PV filtering function. The value is in PVAUTO and its status is contained in PVAUTOST. During normal operation, the PV source is Auto, and the PV and its value status (PVSTS) become equal to PVAUTO and PVAUTOST, respectively, before PV range checks are made. When the PV source is changed from Auto to Man or Sub, the PV remains at the last value until it is changed by the operator (Man) or a program (Sub), so it doesn't "bump." In Man or Sub, the status in PVSTS is Uncertn. When the PV source is changed from Man or Sub to Auto, the PV immediately goes to the PVAUTO value. This might cause a bump in the value unless it is changed gradually to the value in PVAUTO before changing the source.

- **Man**—The PV is entered by an operator, supervisor, or engineer at a Universal Station.

- **Sub**—The PV is entered by a user-written program. A program can store a bad value in PV, and if it does, PVSTS goes Bad.

You can prevent PV source changes by configuring OnlyAuto in PVSRCOPT. This fixes the source as Auto and the parameter PVSOURCE is removed from the point. Configuring All in PVSRCOPT allows normal PV source selection.
7.6 PV ALARM DETECTION

The PV alarming function can be implemented only when Full has been entered for the PNTFORM parameter. The following types of alarms are detected during PV alarm processing:

- PV High/Low
- PV High-High/Low-Low
- PV Rate-of-Change Positive/Negative
- PV Significant Change
- BadPV

PV source selection has no effect on alarm processing. For more detailed alarm information, refer to paragraph 4.3 in *System Control Functions*.

7.7 PV ALGORITHMS

The PV Algorithms in the PM are described in the sections that follow. Each of the PV algorithm descriptions has the same form and the same headings:

- TYPE AND NAME
- FUNCTION
- USE
- OPTIONS, EQUATIONS, AND SPECIAL FEATURES

Each of the algorithm descriptions mentions several parameters associated with the algorithm. The parameter names consist of CAPITAL letters. References to parameters not named in the descriptions are provided after the descriptions. Further information on all data-point parameters, including the data type, range, and access keys, is provided in the *Process Manager Parameter Reference Dictionary*. 
7.7.1 Data Acquisition (DATAACQ)

7.7.1.1 Function

This algorithm normally accepts the input and places it, unchanged, in PVCALC. All of the other PV algorithms alter the input(s) in some way. See Figure 7-2.

7.7.1.2 Use

The most common use of this algorithm is to provide a PV that has been through PV Input Processing, PV Algorithm Processing, PV Filtering, and PV Source Selection (see Figure 7-1). The value in PVCALC is filtered, and becomes PV, if the PV source is Auto.

The input can be a measured process-variable, or the calculated PV or calculated output of another data point.

The input to this algorithm and its output are in engineering units.

7.7.1.3 Options and Special Features

This algorithm has no options nor special features.

7.7.1.4 Equation

This algorithm has one equation form. The operation is simply the replacement of the data point’s calculated PV (PVCALC) with the value of the input:

\[ \text{PVCALC} = \text{P1} \]

Where P1 contains the first input value and PVCALC contains the value that becomes the PV when PVSOURCE = Auto.

The parameters associated with this algorithm are P1, PVCALC, and P1STS. Refer to the Process Manager Parameter Reference Dictionary.
7.7.2 Flow Compensation (FLOWCOMP)

7.7.2.1 Function

This algorithm compensates a flow measurement for variations in temperature, absolute pressure, specific gravity, or molecular weight. The measured flow can be that of a gas, a vapor, or a liquid. An extended equation is provided for industrial steam-flow compensation, which includes factors that compensate for steam quality and compressibility. See Figure 7-3.

7.7.2.2 Use

The uncompensated-flow input is typically a square-rooted, differential pressure measurement. Other direct-flow measurements can also be used. The square root should be extracted before the input to the data point, and the input value must be in engineering units. For process-connected inputs, the square root can be extracted in the IOP; conversion to EUs also takes place in the IOP.

The compensation is calculated from temperature, pressure, specific gravity, molecular weight, steam quality, or steam compressibility. Choice of inputs depends on the type of the equation selected. All of these inputs are obtained through PV input-connections.

![Functional Diagram, Flow Compensation PV Algorithm](1305)

Simplified Equation

\[ \text{PVCalc} = F \times \text{COMPTERM} \]

Where \( F \) is uncompensated flow and \( \text{COMPTERM} \) has five forms

- A: Liquids
- B: Gasses, Vapors
- C: Gasses, Vapors (Specific Gravity)
- D: Volumetric Flow of Gasses and Vapors
- E: Steam

Figure 7-3 — Functional Diagram, Flow Compensation PV Algorithm
7.7.2.3 Options and Special Features

Five Forms of Flow Compensation

Parameter PVEQN specifies one of five different equations for this algorithm. The equation causes the compensation term (COMPTERM) to differ according to the application, as follows (see 7.7.2.4 for the actual equations):

**Equation A**

Primarily used for mass-flow or volumetric-flow compensation for liquids. Actual (measured or calculated) specific gravity is used as a compensation input.

**Equation B**

Primarily used for mass-flow compensation of gas or vapor flows. Actual absolute temperature and pressure are used as compensation inputs.

**Equation C**

Used for mass-flow compensation of gas or vapor flows. Actual specific gravity (measured or calculated), absolute temperature, and pressure are used as compensation inputs.

**Equation D**

Principally used for volumetric-flow compensation for gas or vapor flows. Actual temperature, pressure, and molecular weight are used as compensation inputs. The molecular weight can be calculated by the Calculator algorithm, or a user written program in the AM or Computing Module (CM50/CM60).

**Equation E**

Used for mass-flow compensation of steam flows in industrial applications. Actual temperature, pressure, specific gravity, steam compressibility, and steam quality are used as compensation inputs. This equation can also be used for "custody transfer" of gases or liquids.

**Restart or Point Activation**

On a cold or warm restart, or when this data point is activated, PVCALC is recalculated the next time the FLOWCOMP data point is processed.

**Error Handling**

If the status of any of the input values is bad, PVCALC contains NaN and the PVAUTOST becomes Bad. If there are no bad inputs but the status of one or more of the inputs is "uncertain," the PVAUTOST becomes Uncertn.
Special Notes

Refer to 7.7.2.4, Equations, for more detail on the inputs and parameters mentioned in these notes.

Zero Pressure Reference—Parameter P0 (see definition of this parameter under 7.7.2.4) compensates for ambient atmospheric pressure. Most pressure sensors measure pressure relative to the atmospheric pressure. If the pressure measurement is actually absolute, P0 must be set to a value of zero. The usual zero reference is a value for sea level. If the pressure sensor is at a significantly different elevation than sea level, P0 should be set to a more appropriate value. For example, Denver, Colorado has an average atmospheric pressure of about 12.2 psia. Standard sea-level atmospheric pressure is 14.696 psia. P0 contains the absolute value of ambient atmospheric pressure.

Units of Measure—The absolute value of either U.S. Customary Units or SI (metric) units can be used. All inputs and parameters must be in engineering units of one system or the other. The typical value for P0 (see definition of this parameter under 7.7.2.4) in U.S. Customary Units is 14.696 psia and in SI units it is 101.325 kPa. The typical T0 value is 459.69°F in U.S. Customary Units and 273.15°C in SI units.

Compensation Term Value—Typically, the COMPTERM value is near 1. It should never be zero or negative. The COMPO and COMPHI limits are used to prevent unrealistic values of COMPTERM caused by incorrect inputs. Should the calculated value of COMPTERM go beyond one of these limits, the value is held (clamped) at that limit. You should estimate the range of COMPTERM by considering the most extreme input-conditions you expect. Also, you should set the PV range for this data point, by considering the largest compensated-flow value expected.

Custody Transfer—Equation E can be used for "custody transfer" of gases or liquids. To do so, set parameter RX (see definition of this parameter under 7.7.2.4) equal to one and specify the input connection to X to come from RX in this data point.

Compensating for Assumed Design Conditions

Equation A can be used for either mass or volumetric compensation of liquid flows. The use depends on whether the measurement of uncompensated flow is a mass measurement or a volumetric measurement, and on the desired uncompensated-flow units. Here are three ways to use Equation A:

- **Converting an uncompensated mass-flow to compensated mass-flow**: C1 and C2 (see 7.7.2.4) are configured as 1.0.

- **Converting an uncompensated, standard volumetric-flow to compensated mass-flow**: C1 is configured to equal the design density, referenced to standard conditions. C2 is configured as 1.0.
• **Converting uncompensated, standard volumetric-flow to compensated, standard volumetric-flow:** If the variations in standard density caused by fluid-composition changes are significant, C2 is manipulated as follows:

If the measured value of specific gravity at flow conditions is available, the actual specific gravity, referred to standard conditions, is calculated from that measurement by another data point and input to C2 through a general input connection. If actual specific gravity is measured by a lab, a numeric data-point could be used to hold the value and input to C1 through a general input connection. For the latter case, another data point uses the lab value to calculate specific gravity at flow conditions and the result is input G.

### 7.7.2.4 Equations

You configure PVEQN for data point that uses the Flow Compensation algorithm to specify one of five equations. The equations select the compensation term. The basic equation is

\[
PVCALC = C \cdot \frac{C_1}{C_2} \cdot F \cdot COMPTERM
\]

Where:

- **PVCALC** = The output of this algorithm. It is selected as the PV for this data point when the PVSOURCE is Auto.
- **C** = Scale factor. The default value is 1.0.
- **C1, C2** = Constants for correcting for assumed design conditions. See **Compensating for Assumed Designed Conditions** under 7.7.2.3. Default value for each is 1.0.
- **F** = The uncompensated flow input. A square-rooted, differential pressure input.
- **COMPTERM** = The compensation term. This term differs in each of the five flow-compensation equations, A through E. Its value lies between the COMPOLO and COMPHI limits, which are specified by the process engineer. If either limit parameter contains NaN, the corresponding limit check is not made.
The five forms of COMPTERM are as follows:

![NOTE]

The equations shown below are performed using absolute values for pressure and temperature. You must convert temperatures and pressures to absolute values in order to use this algorithm.

The COMPTERM computation depends on the value of the PVCHAR parameter. If PVCHAR = SqrRoot, then COMPTERM is as shown. If PVCHAR = Linear, then COMPTERM is determined without the square root function.

Equation A: \[ \text{COMPTERM} = \sqrt{\frac{G}{RG}} \] (Liquids)

Equation B: \[ \text{COMPTERM} = \sqrt{\frac{P+P_0}{RP} \ast \frac{RT}{T+T_0}} \] (Gases & Vapors)

Equation C: \[ \text{COMPTERM} = \sqrt{\frac{P+P_0}{RP} \ast \frac{RT}{T+T_0} \ast \frac{G}{RG}} \] (Gases & Vapors w/Specific Gravity)

Equation D: \[ \text{COMPTERM} = \sqrt{\frac{P+P_0}{RP} \ast \frac{RT}{T+T_0} \ast \frac{RG}{G}} \] (Volumetric Flow of Gases & Vapors)

Equation E: \[ \text{COMPTERM} = \sqrt{\frac{P+P_0}{RP} \ast \frac{RT}{T+T_0} \ast \frac{X}{RX} \ast \frac{Q}{RQ}} \] (Steam)

Where the following (in engineering units) are received through input connections

- \( G \) = Measured or calculated specific gravity or molecular weight.
- \( P \) = Measured actual gage pressure.
- \( T \) = Measured actual temperature.
- \( X \) = Measured actual steam compressibility.
- \( Q \) = Measured actual steam-quality factor.

And the following parameters are specified by the process engineer

- \( RG \) = Design specific gravity or reference molecular weight, in the same engineering units as \( G \) (Default value = 1.0).
- \( RP \) = Design pressure, converted to an absolute value (Default value = 1.0).
RQ = Design steam quality factor, in the same units as Q (Default value = 1.0)

RT = Design temperature, converted to an absolute value (Default value = 1.0).

P0 = Factor to convert gauge pressure to an absolute value. Typically 14.696 psia or 101.325 kPa. Enter the absolute value of the number. See 7.7.2.3 - Special Notes. Default value = 0. If the measured pressure is already an absolute value, enter 0.

T0 = Factor to convert Celsius and Fahrenheit temperatures to an absolute value. Typically 459.69°F or 273.15°C (use the absolute value of the number when entering a value in T0). See Special Notes. Default value = 0. If the measured temperature is already an absolute value, enter 0.

RX = Reference steam compressibility, in the same engineering units as X. Default value = 1.0.

Other parameters associated with this algorithm are as follows (refer to the Process Manager Parameter Reference Dictionary):

- COMPHILM
- COMPLOLM
- COMPTERM
- FSTS
- GSTS
- PSTS
- PVCALC
- PVEQN
- QSTS
- TSTS
- XSTS
7.7.3 Middle of Three Selector (MIDOF3)

7.7.3.1 Function

This algorithm provides a calculated PV (PVCALC) that is normally the middle value of three values from the PV input connections. PVAUTOST is Bad, only if all three inputs to this algorithm are bad. If at least one input is valid (normal or uncertain), the algorithm provides a valid value in PVCALC.

When configured with only two inputs, this algorithm serves as a high/low selector or input averaging block. These functions are selected by choosing the corresponding control equation (A, B or C as shown below).

If only one valid input value is available, it is selected. If only two valid input values are available, the selected value can be the highest or the lowest, or the average of the two, as specified when you select the equation to be used by this algorithm. See Figure 7-4.

Normal Operation: PVCALC = Middle value for three input values.

With only two valid inputs:

Equation A: PVCALC = Highest of the two inputs

Equation B: PVCALC = Lowest of the two inputs

Equation C: PVCALC = Average of the two inputs

With only one valid input: PVCALC = Value of the input

SELINP = The selected input, Select P1 through Select P3, except with only two valid inputs and Equation C, SELINP contains None.

Figure 7-4 — Functional Diagram, Middle-of-Three Selector PV Algorithm

7.7.3.2 Use

This algorithm is used to provide a reasonably secure PVCALC when inputs are available from three redundant inputs, one or more of which may occasionally fail or provide erratic values. The Low Selector, High Selector, Average PV algorithm provides a somewhat similar function with up to six input connections (see 7.7.4).
7.7.3 Options and Features

Normal Operation with Three Valid Inputs

Normal operation occurs if there are no inputs with a bad-value status. Inputs are treated as valid if their value status is either normal or uncertain.

If no two inputs have equal values,

\[ \text{PVCALC} = \text{the middle value of the three inputs, P1, P2 and P3} \]
\[ \text{and} \]
\[ \text{SELINP} = \text{the selected input, SelectP1 through SelectP3} \]

If there are two inputs with equal values or if all three input values are equal,

\[ \text{PVCALC} = \text{the value for which there is at least one other equal} \]
\[ \text{and} \]
\[ \text{SELINP} = \text{the lowest-number input with and equal value, SelectP1 through SelectP3.} \]

Error Handling

PVAUTO becomes Uncertn only when the selected input is uncertain, or for equation C, when one of the inputs used for averaging is uncertain.

The PVAUTO status is bad and PVCALC becomes NaN when the status of all three inputs is bad.

7.7.3.4 Equations

If three valid inputs are present, the equations have no meaning and the algorithm functions normally, as described under Normal Operation with Three Valid Inputs. The equations specify what the algorithm is to do if one or more inputs has a bad-value status. The equations function as follows:

- With one bad input

  **Equation A**

  \[ \text{PVCALC} = \text{Highest of the two input values} \]
  \[ \text{SELINP} = \text{The selected input, SelectP1 through SelectP3} \]

  **Equation B**

  \[ \text{PVCALC} = \text{Lowest of the two input values} \]
  \[ \text{SELINP} = \text{The selected input, SelectP1 through SelectP3} \]
**Equation C**

\[
PVCALC = \text{The average of the two input values} \\
SELINP = \text{None}
\]

- With two bad inputs

**Equations A, B and C**

\[
PVCALC = \text{the value of the valid input} \\
SELINP = \text{The selected input, SelectP1 through SelectP3}
\]

- With three bad inputs

**Equations A, B, and C**

\[
PVCALC = \text{NaN} \\
SELINP = \text{None}
\]

Where:

- **PVCALC** = The output of this algorithm. It is selected as the PV for the data point when the PVSOURCE is Auto.
- **P1, P2, and P3** = The input values. The default value is NaN.
- **SELINP** = The selected input, SelectP1 through SelectP3. If no input is selected or if PVCALC contains an average value, SELINP contains None.

Other parameters associated with the MIDOF3 algorithm are as follows:

- **P1STS**
- **P3STS**
- **P2STS**
- **PVEQN**

Refer to the *Process Manager Parameter Reference Dictionary* for more information.
7.7.4 High Selector, Low Selector, Average (HILOAVG)

7.7.4.1 Function

This algorithm does one of the following:

- Selects the input with the highest value
- Selects the input with the lowest value
- Calculates the average value of all valid inputs

It can accept up to six inputs. Valid inputs are those with a status that is "Normal" or "Uncertain." When the input selection functions are used, the number of the input that is selected is contained in a accessible parameter (SELINP). See Figure 7-5.

7.7.4.2 Use

One example of the use of this algorithm is shown at the top of Figure 7-5. In this example, the high value-selector version of the algorithm is used to detect hot spots in a boiler or a reactor.

Either the high value-selector version or the low value-selector version can be used to detect production bottlenecks. For example, this algorithm might be used to notify the process operator that production is currently constrained by the speed of a gas compressor. One of the selector options might also be used to select the "safest" PV for control.

One use of the averaging option is in balancing furnace passes. In this application, the algorithm calculates the average of the outlet temperatures of the passes.

7.7.4.3 Options and Special Features

Forced Selection

The data point can be configured to allow the Universal Station operator, a user-written program, or a general-input connection to force selection of one of the inputs.

- If the FRCPERM parameter is configured as On, the forced-selection function is enabled and an operator or a user-written program can force the selection.
- IF FRCPERM is configured as Off, the forced-selection function is disabled.

The FSELIN parameter specifies the input to be selected, when selection is forced (SelectP1 through SelectP6).
Example: Temperature Inputs from Six Points in a Boiler

Which is the hottest spot in the boiler?

PVCALC = Highest of the Input Values

\[ PVCALC = \text{HILOAVG} \]

PVCALC = Lowest of the Input Values

\[ PVCALC = \text{HILOAVG} \]

PVCALC = Average of All Valid Input Values

\[ PVCALC = \frac{P_1 + \ldots + P_N}{N} \]

Where \( N \) = the number of configured inputs

Figure 7-5 — Functional Diagram, HI LO Average Selector PV Algorithm
7.7.4 Error Handling

Except when forced selection is in effect (Forced Selection), inputs with a bad status are ignored and they do not make the PVAUTOST is Bad. For example, if the algorithm is configured as a 4-input high-selector and one of the inputs goes bad, the algorithm functions as a 3-input high-selector.

If the number of valid inputs (PVSTS is Normal or Uncertn) is less than the minimum number specified in parameter NMIN, PVCALC becomes NaN and the PVAUTOST is Bad.

PVAUTOST is changed to Uncertn under any of the following conditions:

- An input selection is forced and the status of that input is not bad (is normal or uncertain).
- Forced selection is not in effect, at least as many inputs as specified by NMIN are normal or uncertain, and the status of the selected one (Equation A or B) is uncertain.
- Equation C (averaging) is chosen, at least as many inputs as specified by NMIN are not bad (normal or uncertain), and the status of any of them is uncertain.

PVCALC becomes NaN and PVAUTOST becomes Bad under either of the following conditions:

- The selection of an input is forced and the status of that input is bad.
- Forced selection is not in effect, and there are fewer inputs with a status other than bad than are specified by NMIN.

Restart or Point Activation

On a cold or warm restart, or when this data point is activated, PVCALC is simply recalculated the next time this data point is processed.
7.7.4 Equations

Equation A selects the highest input value. Equation B selects the lowest input value. Equation C calculates the average of all valid inputs.

**Equation A—High Selector**

If FRCPERM and FORCE are both On,

\[ PVCALC = \text{the value of the input indicated by FSELIN} \]
\[ SELINP = \text{FSELIN} \]

If either FRCPERM or FORCE is Off,

\[ PVCALC = \text{the highest valid input.} \]
\[ SELINP = \text{the selected input, SelectP1 through SelectP8.} \]

**Equation B—Low Selector**

If FRCPERM and FORCE are both On,

\[ PVCALC = \text{the value of the input indicated by FSELIN} \]
\[ SELINP = \text{FSELIN} \]

If either FRCPERM or FORCE is Off,

\[ PVCALC = \text{the lowest valid input.} \]
\[ SELINP = \text{the selected input, SelectP1 through SelectP8.} \]

**Equation C—Average**

If FRCPERM and FORCE are both On,

\[ PVCALC = \text{the value of the input indicated by FSELIN} \]
\[ SELINP = \text{FSELIN} \]

If either FRCPERM or FORCE is Off,

\[ PVCALC = \frac{\text{Sum of the valid inputs}}{N} \]
\[ SELINP = \text{None} \]

Other parameters associated with the HILOAVG algorithm are as follows (refer to the Process Manager Parameter Reference Dictionary):

NMIN  PVEQN  PnSTS  SELINP
7.7.5 Summer (SUMMER)

7.7.5.1 Function

This algorithm calculates a PV (PVCALC) that is the sum of up to six input values. The input values can be scaled, the combined inputs can be scaled, and a bias value can be added to the result. See Figure 7-6.

EQUATION B, simplified:

\[ PVCALC = P_1 + P_2 + \ldots + P_6 \]

7.7.5.2 Use

A typical use is the calculation of the rate at which a component of a raw product is entering a process unit, which is found by summing the proportion of the component in each of several input streams and multiplying by the stream flow rates. This algorithm can also be used to calculate a net heat loss by finding the difference between the heat inputs and heat outputs (the difference can be obtained by using a negative scale factor, for example, \(-1.0\)).

Other possible uses are mass-balance, heat-balance, and inventory calculations.

This equation can be used to scale and bias a single variable; see 7.7.5.4 Equation A.
7.7.5.3 Options and Special Features

Ensuring Adequate PV Range

Because the input values can be either positive or negative, as can the scale factors and bias values, the results in PVCALC can have a broad range of values. You should evaluate the worst-case values you expect to be in use, to establish the PV range. When you configure the data point, be sure to specify a PV range adequate to cover all expected values.

Error Handling

If there are no inputs with a bad status and the status of at least one input is uncertain, PVAUTOSt is Uncertn.

If the status of at least one input is bad, the PVAUTOSt becomes Bad and PVCALC contains NaN.

Restart or Point Activation

On any type of restart or when this data point is activated, PVCALC is normally calculated.

7.7.5.4 Equations

You can select one of two equations when you configure a data point that uses the Summer PV algorithm:

Equation A

\[ PVCALC = C \times P1 + D \]

Equation B

\[ PVCALC = C \times ((C1 \times P1) + (C2 \times P2) + \ldots + (Cn \times Pn)) + D \]

\((Pn \leq 6)\)

Where:

\[ \begin{align*}
    PVCALC & = \text{The output of this algorithm. It is selected as the PV for this data point when the PV source is AUTOmatic.} \\
    C & = \text{The overall scale factor. Default = 1.0.} \\
    C1 \text{ through } Cn & = \text{The scale factors for P1 through Pn. Default = 1.0.} \\
    P1 \text{ through } Pn & = \text{The PV input values. Equation B is limited to six inputs. Default for all values is NaN.} \\
    D & = \text{The overall bias. Default = 0.} \\
    n & = \text{The number of PV inputs used. Default = 2.}
\end{align*} \]

Other parameters associated with the SUMMER algorithm are: N, PnSTS and PVEQN. Refer to the Process Manager Parameter Reference Dictionary for more information.
### 7.7.6 Variable Dead Time with Lead-Lag Compensation (VDTLDLG)

#### 7.7.6.1 Function

This algorithm provides a calculated PV (PVCALC) in which value changes may be delayed from the time that the corresponding change occurred in the P1 input. Dynamic lead-lag compensation to the PV can also be provided. Lag compensation is available in combination with the delay or with no delay. The delay time can be fixed or can be varied as the value of an input varies. See Figure 7-7.

![Functional Diagram, Variable Dead time with Lead Lag PV Algo](image)

**Equation A:** One Lead and Two Lag Compensations

**Equation B:** Fixed Dead Time

**Equation C:** Variable Dead Time

**Equation D:** Variable Dead Time with Two Lag Compensations

#### 7.7.6.2 Use

This algorithm is used for feedforward control and in process simulations. For additional use information, see Equations C and D, under 7.7.6.4.

This algorithm can be used as the PV algorithm in a data point that uses the PID Feedforward control algorithm (see 8.13.2), Figure 8-7.

In a typical feedforward application, the PV provided by this algorithm serves as the feedforward PV. An operator can "cut out" this feedforward component by switching the PVSOURCE to Man.
7.7.6 Options and Special Features

Four Combinations of Delay and Lead-Lag Compensation

You select the combinations of delay, lead compensation, and lag compensation by selecting Equation A, Equation B, Equation C, or Equation D when configuring the data point. The equations function as follows:

- **Equation A, Lead-Lag**—A change in the input value (P1) is subjected to one lead compensation and two lag compensations. If you specify a time constant of zero in the Lead Compensation time constant, TLD, Lag Compensation time constants, TLG1, or TLG2, the corresponding lead or lag compensation is suppressed. If you don't suppress the lead compensation, you must use at least one lag compensation.

- **Equation B, Fixed Dead Time**—A change in the input value (P1) is delayed by a user-specified time. This data point must be made inactive in order to change the dead-time value (TD).

- **Equation C, Variable Dead Time**—A change in the input value (P1) is delayed by a time period the duration of which varies as the inverse of P2-input value variations. The variable time period is determined by P2, the C1 and C2 scale factors, and bias values D1 and D2. The delay (or dead time) typically represents a delay in the process that depends on some variable in the process, such as flow, feed rate, or a conveyor-belt speed.

Equations C and D have a cutoff feature that can simulate situations like a conveyor belt stopping. If the flow or speed value, represented by the P2 input, drops below a limit that you configure in the CUTOFFLM parameter, the value of the delayed P1 signal (DP1) goes to zero. (DP1 is not an external parameter.) When P2 again exceeds the CUTOFFLM value, DP1 resumes as a normal, delayed output. If you don't want this feature, configure CUTOFFLM as NaN. Note that DP1 is subject to scale factor C and bias value D. See 7.7.6.4.

Equation C can be used to produce a fixed delay time that can be changed while the data point is active.

- **Equation D, Variable Dead Time with Two Lags**—A change in the input value (P1) is delayed as with Equation C and then receives lag compensation as specified by one or two time constants (TLG1, TLG2). This equation is useful for simulating a portion of a process that can be represented by a dead time and one or two lags. The cutoff feature applies as for Equation C.
7.7.6

Dead-Time (Delay-Time) Calculation

The delay of the input values is accomplished by a process that has the effect of shifting the values through a table in the PM's memory. Values are shifted from one location in the table to the next, at intervals calculated to provide the desired delay. This is illustrated in Figure 7-8.

![Variable Delay Time Functional Diagram](image)

From the process or another data point, P1, new table input at each NRATE*TS interval. Updated each time the point is processed. New interpolated value each time the data point is processed (at each TS interval).

For an example of the delay-table operation, suppose that the P1-input value has been constant at 5.0 units for an hour. Assume that the specified delay time, TD, is 15 minutes and that the data point is processed every second; Time Sample (TS = 1/60) min. as determined by the SCANRATE parameter. At this time, the output of the interpolator is 5.0 units, all of the locations in the table contain a value of 5.0 units, and P1 contains a value of 5.0 units.

Now suppose that the input to P1 suddenly changes to 6.0 units. The interval at which new values are shifted through the table and the number of table locations in use have been set up so that it takes 15 minutes for the new value of 6.0 units to appear at the output of the interpolator.
Three sample calculations follow. The first shows how a fixed delay time is determined (Equation B), the second shows how a variable delay time is determined, and the third shows how a change in the P2 input changes the variable delay time.

Fixed Delay Time Example

1. The value in TS is 0.5 minutes and TD has been specified as 15 minutes.

2. NRATE, the table shift-rate factor, is calculated as follows:

\[
NRATE = \frac{TD}{(TS \times 30)} = \frac{15}{(0.5 \times 30)} = 1
\]

3. NLOC, the number of table locations to be used, is

\[
NLOC = \frac{TD}{(TS \times NRATE)} = \frac{15}{(0.5 \times 1)} = 30 \text{ locations}
\]

4. The actual delay time is then recomputed as

\[
TD = NLOC \times NRATE \times TS = 30 \times 1 \times 0.5 = 15 \text{ minutes}
\]

If the calculated values of NRATE and NLOC had resulted in fractions, the results would have been rounded up to the nearest larger integer and the actual delay time would have been slightly more than specified.

Where the TD is less than 30 times TS, NRATE always has a value of 1. In such cases, the delayed output is a true, but delayed, representation of the corresponding input value.

Where the NRATE value is greater than 1, the output signal is interpolated to approximate the earlier change in the input, by using the last output value and the value in the last location in the table. This is an excellent approximation for typically smooth changes in process values.
Variable Delay-Time Example

1. The value in $TS$ is $\frac{1}{60}$ minutes. $NLOC = 30$.

2. Each time the data point is processed, a new variable delay time is calculated as
   \[ TD_{NEW} = \frac{C_1}{(C_2 \times P_2) + D_2} + D_1. \]

   Assume the $P_2$ input is 20.0 units and its scale factor is 0.05. Scale factor $C_1$ is 30.0. The biases, $D_1$ and $D_2$ both equal 0.
   \[ TD_{NEW} = \frac{30.0}{(0.05 \times 20.0) + 0} + 0 = 30 \text{ minutes}. \]

3. \[ NRATE = \frac{TD_{NEW}}{(TS \times NLOC)} = \frac{30}{(\frac{1}{60} \times 30)} = 60 \]
   $NLOC$ is configurable (range 2 - 30; in this example it is configured as 30)

4. Actual delay time is calculated as
   \[ TD = NLOC \times NRATE \times TS = 30 \times 60 \times \frac{1}{60} = 30 \text{ minutes}. \]
   $NLOC$ is configurable (range 2 - 30; in this example it is configured as 30)

Now suppose the $P_2$ input changes to 23.4 units.

Second Variable Delay-Time Example

1. The value in $TS$ is $\frac{1}{60}$ minutes.

2. \[ TD_{NEW} = \frac{C_1}{(C_2 \times P_2) + D_2} + D_1 = \frac{30.0}{(0.05 \times 23.4) + 0} + 0 = 25.641 \text{ minutes}. \]

3. \[ NRATE = \frac{TD_{NEW}}{(TS \times NLOC)} = \frac{25.641}{\frac{1}{60} \times 30} = 51.282 \]
   This is rounded to the nearest integer (not necessarily the next larger integer, as for a fixed delay time), so
   \[ NRATE = 51. \]
4. Actual delay time then is

\[ TD = NLOC \times NRATE \times TS = 30 \times 51 \times \frac{1}{60} = 25.5 \text{ minutes.} \]

NLOC is configurable (range 2 - 30; in this example it is configured as 30)

In the Second Delay Time Example, the exact delay specified by the input was 25.641 minutes.

**Changing Dead-Time (Delay-Time) Parameters**

Variable delay-time parameters C1, C2, D1, and D2 in Equations C and D can be changed at a Universal Station while the data point is active. Note that the D1 value allows a supervisor or engineer to add a fixed delay time to the total variable delay time.

The C1 and C2 parameters are used to specify the time scale of the P2 value. D1 can be used to offset that scale. Note that the P2 value is inversely proportional to the variable time delay. Where P2 represents a flow rate or speed, when the flow or speed decreases, the time delay increases to simulate the effect of the reduced flow or speed.

**Restrictions on Delay Time**

The minimum fixed delay time (Equation B) is equal to TS, the processing interval in minutes. Delay values greater than 32,000*TS are rejected.

For Equations C and D the minimum step-change in the TD value is equal to NLOC*TS. This is also the value of the smallest dead time (delay time). If the TDNEW value is less than zero, it is clamped to zero. Also, if TDNEW exceeds 32,000*TS, it is clamped to 32,000*TS.

**Time-Constant Recommendations**

We recommend that the processing rate of a data point that uses this algorithm and Equation A or D must be at least ten times greater than the lead or lag break-point frequencies, so, divided by lead break-point frequency) be less than or equal to 10, so,

- TLG1 should be equal to or greater than \(2 \times TS\)
- TLG2 should be equal to or greater than \(2 \times TS\)
- |TLD| should be equal to or greater than \(10 \times TS\)

Both positive and negative lead times can be specified, so it is the absolute value of TLD that must be equal to or greater than \(10 \times TS\).

We recommend that the rate amplitude (lag break-point frequency divided by the lead break-point frequency) be less than or equal to 10 so,

- |TLD| should be equal to or less than \(10 \times TLG1\).
Using Equation C or D for a Fixed Delay Time

You can use these variable delay-time equations to attain a fixed delay time by setting the value of C1 to 0 and adjusting the value of D1 to get the desired delay value. This permits changes of delay time from a Universal Station while the data point is active, but the resolution may be much less than using a fixed delay time (Equation B), where the delay can be changed only by making the point inactive and then active again.

Restart or Point Activation

On a cold start, a warm start, and when the data point is activated, the lead-lag dynamics are set to the steady state, and all values in the delay table are set to the current value of the P1 input. PVCALC is calculated as follows:

\[ \text{PVCALC} = C \times P1 + D \]

Error Handling

For Equations C and D, if neither input has a bad-value status, but one or both has an uncertain-value status, PVAUTOST is Uncertn. Equations A and B don't use the P2 input, so for them, PVAUTOST is Uncertn only if the P1-value status (P1STS) is Uncertn.

For Equations C and D, if either input has a bad-value status, PVCALC becomes NaN and the PVAUTOST is Bad. For Equations A and B, when P1STS is Bad, it causes PVCALC to contain NaN and the PVAUTOST to be Bad.

When the input-value status is again normal or uncertain, the data point is initialized as for a cold start under Restart or Point Activation, and the PVAUTO-value status becomes normal, or uncertain, as appropriate.

7.7.6.4 Equations

You can select one of four equations when you configure a data point that uses the Variable Dead Time with Lead-Lag Compensation PV algorithm:

**Equation A—Lead Compensation with Two Lag Compensations**

\[ \text{PVCALC}(s) = [C \times \frac{1 + \text{TLD} \times s}{(1 + \text{TLG1} \times s) \times (1 + \text{TLG2} \times s)}] \times P1(s) + D \]

**Equation B—Fixed Delay Time**

\[ \text{DP1_t} = P1t - \text{TD} \]

\[ \text{PVCALC}(s) = C \times \text{DP1} + D \]
Equation C—Variable Delay Time

If CUTOFFLM does not contain NaN and if P2 is less than CUTOFFLM, DP1 = 0. Otherwise, calculate DP1 as follows:

$$DP1_t = P1_{t-TD}$$

$$TD = \frac{C1}{C2 * P2 + D2}$$

$$PVCALC(s) = C * DP1 + D$$

Equation D—Variable Delay Time with Two Lag Compensations

$$TD = \frac{C1}{C2 * P2 + D2} + D1$$

$$DP1_t = P1_{t-TD}$$

$$PVCALC(s) = [C * \left( \frac{1}{(1 + TLG1 * s) * (1 + TLG2 * s)} \right) * DP1(s)] + D$$

Where:

- PVCALC = The output of this algorithm. It is selected as the PV for this data point when the PV source is AUTOmatic.
- C = The overall scale factor. Default value = 1.0.
- C1 = Scale factor, TDNEW denominator. Default value = 1.0.
- C2 = Scale factor for P2. Default value = 1.0.
- CUTOFFLM = Cutoff (zero-flow or zero-belt speed) limit. Default = 0.0.
- D = Overall bias. Default value = 0.
- DP1 = The delayed P1 value. Not accessible to Universal Stations nor to user-written programs.
- D1 = Bias value for the variable delay time. Default value = 0.
- D2 = Bias for P2. Default value = 0.
- P1 = The input value to which the delay and lead-lag compensation are applied.
7.7.6

P2 = The input value that changes the variable delay when Equation C or Equation D is used.

s = The Laplace operator (notation only, not a parameter)

t = The present time (notation only, not a parameter)

t-TD = The present time minus the actual dead (delay) time (notation only, not a parameter).

TD = The fixed time delay in minutes for Equation B. The actual variable delay time in minutes for Equations C and D. Default = 0.

TDNEW = The calculated new (ideal) delay time in minutes for Equations C and D.

TLD = Lead-compensation time constant in minutes. 0 = no lead. Default = 0.

TLG1 = Lag-compensation time constant 1 in minutes. 0 = no lag. Default = 0.

TLG2 = Lag-compensation time constant 2 in minutes. 0 = no lag. Default = 0.

Other parameters associated with the VDTLQLG algorithm is as follows (refer to the Process Manager Parameter Reference Dictionary):

PVEQN NLOC (equations C and D)
7.7.7 Totalizer (TOTALIZR)

7.7.7.1 Function

This algorithm provides a time-scaled accumulation of an input value. The input value is typically a flow measurement. Either analog or pulse input can be selected through parameter ACCTYPE. The time-base can be seconds, minutes, or hours.

The accumulation can be started, stopped, and reset by commands from a Universal Station operator or from a user-written program. An operator or user-written program can establish a target value for the accumulation. Status indicators are available to indicate that the accumulation is near the target value, nearer to the target value, and is complete (has reached or exceeded the target value).

For situations where the flow transmitter may not be precisely calibrated near the zero-flow value, a zero-flow cutoff feature is provided that avoids accumulating negative flow values. When the flow is below a user-specified cutoff value, the input value is clamped to zero.
7.7.7  Use

The Totalizer PV algorithm accumulates periodic measurements over time. It is principally used to accumulate total flows, or in applications such as the measurement of ingredients that are blended. The accumulated value can be used for control or just as process history.

An example of TOTALIZR’s use in control is determining how full a tank is, so that the flow into the tank can be shut off before it overflows. In such an application, the PI input to TOTALIZR would be the PV of PID-flow controller.

7.7.7.3 Options and Special Features

Typical Operation

The events in an operation that uses TOTALIZR might be as follows (see Figure 7-10):

• The target value, which represents the desired total volume, is specified to the AVTV parameter in the TOTALIZR point, by an operator at a Universal Station or by a user-written program.

NOTE

AVTV is displayed as the setpoint (SP).

• An operator or a user-written program issues a Reset command (using the COMMAND parameter) to the TOTALIZR point. This sets any accumulation value equal to RESETVAL.

• A Start command is issued to the TOTALIZR point. A logic slot or user program sets the setpoint to some value.

• When the first "slowdown" or "near-target" flag (ADEV1FL) comes on, it is read by logic or user program and reduces the setpoint.

• When the second "slowdown" or "near-target" flag (ADEV2FL) comes on, it is read by logic or user program and reduces the setpoint.

• When the accumulation reaches the target value (AVTV), filling is complete and the complete flag (AVTVFL) comes on. It is read by logic or user program and sets the setpoint = 0.
**Time-Base and Engineering-Units Scaling**

The user specifies the time base in seconds, minutes, or hours, in parameter TIMEBASE. This is the time base in which the flow measurement is made. For example, liters per second. This parameter only applies when ACCTYPE = ANALOG.

Scale factor, C, can be used to convert from one set of engineering units to another, for example, from gallons per minute to barrels per minute.
Commands, States and Command Flags

Commands can be issued to the data point that is using TOTALIZR from a Universal Station or by a user-written program. These commands are written in the TOTALIZR point's COMMAND parameter.

The commands are as follows:

- **None**—No action.
- **Start**—Start the accumulation. STATE changes to Running.
- **Stop**—Stop the accumulation. STATE changes to Stopped.
- **Reset**—Reset the accumulated value to a user-specified value. This value is specified in parameter RESETVAL. If the accumulator is running, it continues from the reset value.

Command Flags

In addition to the above (enumerated) commands, explicit command flags are provided to reset, start, or stop the totalizer.

- **RESETFL** — Off to On transition causes the totalizer to be reset. (See *Accumulated Value Before Reset* for additional information.)
- **STARTFL** — Off to On transition causes the STATE of totalizer to be Running.
- **STOPFL** — Off to On transition causes the STATE of totalizer to be changed to Stopped.

The above flags are program-access level, so they can be written to by a Logic Point or a user-written program.

Accumulated Value Before Reset

The reset command sets the PVCALC parameter equal to the reset value (RESETVAL). The value of PVCALC just prior to being reset is saved as the old accumulation value (OLDAV). This allows other system functions using the totalized value to be able to reset the totalizer without losing any "accumulation."
Range of Values, Clamping Option

The accumulated value has a normal range of PVEULO to PVEUHI, where PVEUHI defines the point where the bar graph is at the 100% level, and PVEULO is the point where the bar graph is at the 0% level.

This algorithm will continue to totalize past PVEUHI until it reaches the value of PVEXEUHI. When it reaches PVEXEUHI, the following occurs:

- If NoClamp was selected, the PV is set to BadPV and displayed as NAN.
- If Clamp was selected, the PV is flagged as uncertain and clamped to PVEXEUHI.

In either case, the algorithm continues to accumulate a value in PVCALC until it is reset, regardless of the selection of NoClamp/Clamp.

Using Scientific Notation

Values are accumulated as integers, but displayed as real numbers. You can enter values using scientific notation; for example, 1,000,000 can be entered as 1E6. If the accumulated value exceeds the limit of displayable characters, it will be displayed in scientific notation.

Near-Zero Cutoff

To prevent accumulation of negative flow values, where the flow transmitter may not be precisely calibrated near zero flow, you can specify a cutoff value in parameter CUTOFFLM. When the P1 value is below CUTOFFLM, it is replaced by zero. You can eliminate this feature by specifying NaN in CUTOFFLM.

Target-Value Flags

The target value can be specified by an operator or a user-written program that is stored in AVTV. This feature can be disabled by storing NaN in AVTV.

When the accumulated value in PVCALC is greater than or equal to AVTV, the target-value-reached flag, AVTVFL, goes to On, indicating that the accumulation is complete.

Even if the accumulator has stopped, this check is made on each processing pass.

You can specify two other trip points in AVDEV1TP and AVDEV2TP, as deviations from AVTV. Each of them is associated with a flag:

AVDEV1FL trips when

\[ PVCALC \geq AVTV - AVDEV1TP \]

AVDEV2FL trips when

\[ PVCALC \geq AVTV - AVDEV2TP \]

When the PVAUTOST of the accumulated value is Bad, AVTVFL, AVDEV1FL, and AVDEV2FL are all Off.
Bad-Input and Warm-Restart Options

You can configure equations A through F for this algorithm, but instead of specifying the calculation, they specify combinations of the following five options:

- **Use Zero**—When the accumulator is running, if the input status P1STS (or P2STS for Pulse IOP) is Bad, the input value is replaced by zero and the accumulation continues with a PVAUTOST of Uncertn.

When the input status is Normal, PVAUTOST remains Uncertn until a reset command is received. No special action by the operator is required.

- **Use Last Good Value**—When the accumulator is running, if the input status is bad, the input value is replaced by the last good value and the accumulation continues with PVAUTOST as Uncertn. When the input status is Normal, PVAUTOST remains Uncertn until a Reset command is received. No special action by the operator is required.

- **Set PVAUTOST Bad and Stop**—When the accumulator is running and the input status is bad, the value in PVCALC becomes NaN, PVAUTOST goes Bad, and the accumulator is stopped. If the PVSOURCE is Auto, a bad-PV alarm is generated. When the input status is again Normal, PVAUTOST remains Bad until the accumulator is started again. To restart the accumulation, the operator should estimate its value and use the Reset command (see Commands, States and Command Flags under 7.7.7.3) to establish that value, then use the Start command to restart the accumulation. The last accumulated value before the status went bad is in LASTPV.

- **Continue After a Warm Restart**—On a warm restart when the accumulator is running, the accumulation continues from the last PVCALC value. The PVAUTOST goes to uncertain (UNCERTN) and remains so until a Reset command is received.

When the Pulse Input IOP is used (ACCTYPE = PULSE), accumulation continues with the accumulated value count (AV) obtained from the IOP. The totalizer assumes that exactly one rollover of the IOP count has occurred, if necessary. The PVAUTOST goes to UNCERTN and remains so until a Reset command is received.

- **Set PVAUTOST Bad and Stop After a Warm Restart**—On a warm restart when the accumulator is running, the value in PVCALC becomes NaN, PVAUTOST goes Bad, and the accumulation is stopped. The operator must intervene to restart the accumulator.

These options are selected as follows:

<table>
<thead>
<tr>
<th>Equation</th>
<th>Bad Input Handling</th>
<th>Warm Restart</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Use Zero</td>
<td>Continue</td>
</tr>
<tr>
<td>B</td>
<td>Use Last Good Value</td>
<td>Continue</td>
</tr>
<tr>
<td>C</td>
<td>Set Bad and Stop</td>
<td>Continue</td>
</tr>
<tr>
<td>D</td>
<td>Use zero</td>
<td>Set Bad and Stop</td>
</tr>
<tr>
<td>E</td>
<td>Use Last Good Value</td>
<td>Set Bad and Stop</td>
</tr>
<tr>
<td>F</td>
<td>Set Bad and Stop</td>
<td>Set Bad and Stop</td>
</tr>
</tbody>
</table>

If the accumulator is stopped, the input status is ignored. If the accumulator is stopped on a warm restart, no special action by the operator is required.
7.7.7

Restart or Point Activation

When the TOTALIZR data point is activated, the PVCALC value becomes NaN, PVAUTOST goes Bad and the accumulator state is Stopped. If the PVSOURCE is Auto, this causes a bad-PV alarm and the operator must re-establish normal operation.

The processing that takes place for a warm restart is described under **Bad Input and Warm-Restart Options**.

Error Handling

PVAUTOST is Uncertn when

- The input status (P1STS or P2STS) is Uncertn.

- The input status is Bad and the "use zero" or "use last value" (Equation A, B, D, or E) is configured (see **Bad-Input and Warm-Restart Options**).

- The data point is in a warm restart and the continue option (Equations A, B, or C) is configured (see **Bad-Input and Warm-Restart Options**).

A Reset command is needed to return PVAUTOST status to Normal, provided the input status is Normal.

PVCALC contains NaN and the PVAUTOST is bad when

- The input status is Bad and the "set bad and stop" (Equation C or F) is configured.

- The data point is in a warm restart and is configured for "set bad and stop" (Equations D, E, or F) is configured.

A Reset command is needed to return PVAUTOST to Normal, provided the input status is Normal.
7.7.7.4 Equations

Configure one of Equations A through F for a TOTALIZR data point equation specifying the operating bad-input and warm-restart options according to **Bad-Input and Warm-Restart Options**.

**Analog Operation**

For all equations, when the accumulator is running, the accumulated value in PVCALC is calculated as follows:

\[
PVCALC(i) = PVCALC(i-1) + C \times \text{(TIME-SCALE)} \times Pn
\]

Where:

- \( PVCALC(i) \) = The output of this algorithm from the current pass. It is selected as the PV for this data point when PVSOURCE is Auto.
- \( PVCALC(i-1) \) = The accumulated value at the end of the last processing pass for this point.
- \( C \) = The scale factor. Can be used to convert from eng. units to different eng. units. Default value = 1.0
- \( \text{(Time-scale)} \) = \( TS \times 60 \) if TIMEBASE contains Seconds.
  \( TS \) if TIMEBASE contains Minutes.
  \( TS / 60 \) if TIMEBASE contains Hours.
- \( TS \) = The data-point processing interval in minutes.
- \( Pn \) = The input value. Typically a flow rate.

**Pulse Input**—See the discussion on pulse input operation.

7.7.7.5 Pulse Input Operation

If **pulse** is selected via parameter ACCTYPE, operation is the same, except input from the Pulse IOP is supported as described below (refer also to the Pulse IOP description in Section 2.7).

As Figure 7-9 indicates, P1/P2 input is from the Pulse IOP. Normally the P2 input (AV) is used (see PV/AV Selection). AV is the accumulated value from the pulse IOP. It is a 32 bit unsigned integer and used to determine volume. This method is more precise than if the Pulse IOP rate value is used. Error handling selected by Equations A through F reference the P2 input status.

The PV Totalizer algorithm contains a single user-configurable constant (C) —

\[
PVCALC = C \times \text{DELTA_AV} + PVCALC_{LAST\_SAMPLE}
\]
7.7.7 Configuration

When configuring the PV Totalizer algorithm for pulse operation, select ACCTYPE = PULSE. Then, define the pulse input source, P1SRC(1) to be the PV parameter of the PI IOP. The PMM software uses the entity specified for P1SRC(1) to establish the algorithm’s second input (P2) except that it uses the parameter ID of AV.

7.7.7.6.1 PV/AV Selection

Either of the parameters AV or PV is available at the input of the Regulatory PV Totalizer algorithm. Normally AV is used, but only if all the following conditions are true:

- The Pulse IOP is running
- The Point is active
- The IOP PV is not in lo cutoff
- The IOP PV is not clamped
- The IOP PV source is AUTO
- There are no soft failures against the IOP slot

7.7.7.7 Parameters

Other parameters associated with the TOTALIZR algorithm are as follows (refer to the Process Manager Parameter Reference Dictionary):

- P1STS (analog input)
- P2STS (pulse input)
- PVCALC
- PVEQN
- AVTV
- ACCTYPE

7.7.8 General Linearization (GENLIN)

7.7.8.1 Function

This algorithm calculates a PV that is a function of the input. The function can be any that can be represented by up-to-12 continuous, linear segments. You specify the base value and slope of each segment. The input is compared with the input range of each segment and the output is set at the intersection of the input with the appropriate segment. See Figures 7-11 and 7-12.
7.7.8.2 Use

This algorithm is typically used to provide a linearized PV (in engineering units) for a sensor with a nonlinear characteristic. This algorithm can also be used to characterize functions of a single variable, such as heat transfer vs flow rate, or efficiency as a function of load. The algorithm is particularly useful when the relationship of the input to engineering units is empirically determined.

This algorithm supplements the standard linearization functions that are provided in the IOPs for standard temperature sensors and differential flow meters.

7.7.8.3 Options and Special Features

Restart or Point Activation

On a cold or warm restart, or when a data point using this algorithm is activated, PVCALC is recalculated the next time this data point is processed.

Error Handling

If P1STS is Uncertn, PVAUTOST status becomes Uncertn.

If P1STS is Bad or if any of the segment coordinates (INᵢ or OUTᵢ) contains NaN, PVAUTOST becomes Bad.

If any of the segment coordinate values (INᵢ or OUTᵢ) contains NaN, a configuration alarm is generated.

Changing Parameters through a Universal Station

The SEGTOT, INᵢ, and OUTᵢ parameters can be changed through a Universal Station only if the data point that uses the GenLin algorithm is made inactive.

Parameter—Value Restrictions

The input coordinate value parameters must be specified in ascending order from the smallest value to the largest.
Solution A (P1 = IN2):

\[ \text{PVCALC} = \text{OUT2} = 45.0 \]

Solution B (P1 > IN1):

\[ \text{PVCALC} = \frac{\text{OUT0} - \text{OUT0}}{\text{IN1} - \text{IN0}} \times (\text{P1} - \text{IN0}) + \text{OUT0} = \frac{20 - 0}{30 - 0} \times (20 - 0) + 0 = 13.33 \]

Solution C (P1 intersects any but 1st and last segment):

\[ \text{PVCALC} = \frac{\text{OUT(i+1)} - \text{OUTi}}{\text{IN(i+1)} - \text{INi}} \times (\text{P1} - \text{INi}) + \text{OUTi} = \frac{45 - 20}{55 - 30} \times (45 - 30) + 20 = 35.0 \]

Solution D (P1 intersects the last segment):

\[ \text{PVCALC} = \frac{\text{OUTsegtot} - \text{OUT(segtot - 1)}}{\text{INsegtot} - \text{IN(segtot - 1)}} \times [\text{P1} - \text{IN(segtot - 1)] + \text{OUT(segtot - 1)} = \frac{100 - 45}{85 - 55} \times (70 - 55) + 45 = 72.5 \]

Figure 7-12 — Example of GENLIN Algorithm Operation
**Extension of First and Last Segments**

The first and last segments are treated as if they indefinitely extended, so if P1 is less than \( IN_0 \) or greater than \( IN_{\text{seg}t\text{ot}} \) (see 7.7.8.4), PVCALC is computed by assuming that the slope of the appropriate segment continues to the intersection point.

**7.7.8.4 Equation**

Each time this algorithm is processed the input value P1 is compared with each segment, starting with the first and continuing until a segment is found that intersects with the input. When that segment is found, PVCALC is calculated as follows:

- If the P1 value is exactly equal to the input value at the beginning of any segment (\( P1 = IN_i \), for i in a range from 0 to the value in \( \text{SEGTOT} \)),

\[
PVCALC = OUT_i
\]

- If P1 intersects the first segment (\( P1 < IN_1 \)),

\[
PVCALC = \frac{OUT_1 - OUT_0}{IN_1 - IN_0} \times (P1 - IN_0) + OUT_0
\]

- If P1 intersects any segment except the first one or the last one (\( IN_i < P1 < IN_{(i+1)} \) for any i from 1 to \( \text{seg}t\text{ot}-2 \)),

\[
PVCALC = \frac{OUT_{(i+1)} - OUT_i}{IN_{(i+1)} - IN_1} \times (P1 - IN_1) + OUT_1
\]

- If P1 intersects the last segment (\( P1 > IN_{(\text{seg}t\text{ot}-1)} \)),

\[
PVCALC = \frac{OUT_{\text{seg}t\text{ot}} - OUT_{(\text{seg}t\text{ot}-1)}}{IN_{\text{seg}t\text{ot}} - IN_{(\text{seg}t\text{ot}-1)}} \times (P1 - IN_{(\text{seg}t\text{ot}-1)}) + OUT_{(\text{seg}t\text{ot}-1)}
\]

Where:

- \( PVCALC \) = The output of this algorithm. It is selected as the PV for this data point when the PV source is AUTOmatic.
- \( P1 \) = The input value.
- \( IN(i) \) = Input value at the beginning of the intersecting segment.
- \( IN(i+1) \) = Input value at the end of the intersecting segment.
- \( OUT(i) \) = Output value at the beginning of the intersecting segment.
- \( OUT(i+1) \) = Output value at the end of the intersecting segment.
- \( \text{seg}t\text{ot} \) = A subscript indicating the user-entered value in \( \text{SEGTOT} \).

Other parameters associated with the GenLin algorithm are as follows (refer to the Process Manager Parameter Reference Dictionary).

\[ P1STS\quad PVCALC\quad \text{SEGTOT} \]
7.7.9 Calculator (CALCULTR)

The calculator algorithm allows the user to write an equation to compute the PV and up to four intermediate results. The result from evaluating the expression is stored into PVCALC, which is then processed like any other PV algorithm. See Figure 7-13.

Accepts up to six inputs (POINT.PARAMETER).
Equation may be up to 40 characters long.
Up to 4 intermediate results
FORTRAN-like syntax rules
High Select; Low Select; Average Select and Middle of 3 Select support

Figure 7-13 — Functional Diagram, PV Algorithm CALCULTR

7.7.9.1 Function

The equation is specified at the time of point building and is loaded from the DEB without additional steps such as compilation or linking. Up-to-six inputs can be configured and stored into the destination parameters P1, P2 . . . P6.

The following general guidelines apply.

- The equation can be up to 40 characters long.
- FORTRAN-like syntax rules apply.
- Up to 5 levels of nesting of expressions.
- Free format reals and mixed real and integer calculations permitted.
- Up to four intermediate results.
- The result of any expression that has no "equate" associated with it is stored into PVCALC.
- On point activation or warm restart PVCALC is initialized to the P1 input.
• The following operators are supported:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Associated Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divide</td>
<td>/</td>
</tr>
<tr>
<td>Multiply</td>
<td>*</td>
</tr>
<tr>
<td>Subtract</td>
<td>-</td>
</tr>
<tr>
<td>Add</td>
<td>+</td>
</tr>
</tbody>
</table>

• The following arithmetic functions are supported:

<table>
<thead>
<tr>
<th>Function</th>
<th>Associated Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td>ABS</td>
</tr>
<tr>
<td>Square</td>
<td>SQR</td>
</tr>
<tr>
<td>Square Root</td>
<td>SQRT</td>
</tr>
<tr>
<td>Natural Logarithm</td>
<td>LN</td>
</tr>
<tr>
<td>Base_10 Logarithm</td>
<td>LOG</td>
</tr>
<tr>
<td>Exponent</td>
<td>EXP</td>
</tr>
<tr>
<td>Sine</td>
<td>SIN</td>
</tr>
<tr>
<td>Cosine</td>
<td>COS</td>
</tr>
<tr>
<td>Tangent</td>
<td>TAN</td>
</tr>
<tr>
<td>Arc-tangent</td>
<td>ATAN</td>
</tr>
</tbody>
</table>

• In addition, the following special functions are supported:

<table>
<thead>
<tr>
<th>Function</th>
<th>Associated Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Select</td>
<td>MAX</td>
</tr>
<tr>
<td>Low Select</td>
<td>MIN</td>
</tr>
<tr>
<td>Average Select</td>
<td>AVG</td>
</tr>
<tr>
<td>Middle of 3</td>
<td>MID3</td>
</tr>
</tbody>
</table>

• Arithmetic assignment statement:

Equate =

• Other

Separator ;

7.7.9.2 Use

This algorithm can be used to perform any calculation or arithmetic function on up to six inputs, using up to four intermediate results. Additionally is can be used as a selector algorithm as noted above (see also 7.7.9.3 Options and Special Features).
7.7.9 Options and Special Features

- The user can configure up to six inputs, using the "Tagname.Parameter" format for PISCR(n). The destination inputs can be assigned, using PIDSTN(n) for P1 through P6.

- Up to four intermediate results can be calculated, for example:

\[ C_1 = <\text{expr}_1>; \quad C_2 = <\text{expr}_2>; \quad C_3 = <\text{expr}_3>; \quad C_4 = <\text{expr}_4>; <\text{expr}_5> \]

The result of expr_5 is stored in PVCALC (because it has no equate associated with it). There is no restriction on the order in which the sub equations and the expression for PVCALC are specified.

If C1-C4 are expressions, they are recalculated every time the algorithm is processed.

- If it is necessary, or desirable, to key user configurable constants into the equation, C1-C4 can be useful. C1-C4 can then be entered or modified by an operator through the detail displays, or by logic slots, or user program.

- The equation can comprise up to 40 characters including the subequations.

- Can be loaded from the DEB without extra linking and compiling.

- FORTRAN syntax rules apply; up to five levels of nesting of expressions.

- HI, LO, and AVG functions may have any number of inputs including constants.

Error Handling of Bad-Inputs and Uncertain Values

If the calculated value of PVCALC is "bad," PVAUTOST is marked Bad. If the final value of PVCALC is a normal number, PVAUTOST is marked Uncertn if any input that is used in the calculation is uncertain or bad; otherwise it is set equal to Normal.

If the HI, LO, and AVG functions have bad inputs, they are ignored in the computation; if all inputs are bad, the result is marked bad. On MID3 function, if only one input is bad, the result is set equal to the average of the other two.
7.7.9.4 Equations

The equation can be up to 40 characters long. It is entered into the Parameter Entry Display in the port for the parameter CALCEXP. You can configure up to four intermediate expressions. The result of an expression not having an "equate" associated with it is stored in PVCALC.

Examples of use of this algorithm's equation:

\[(180.0/(.15*P1)) + (P2+P3*\text{LOG}(P4))\]
\[C1=P1*P2;C2=P4*\text{MAX}(0,C1,100);\text{SQRT}(C2*10)\]
\[\text{MAX} \; (\text{MID3}(P1,P2,P3), \; \text{MID3}(P4,P5,P6))\]
\[(P1 * P2)/C1\]
This section describes the functions available in the Regulatory Control point. The functions are described first, and then are followed by detailed descriptions of the algorithms. Definitions of the parameters mentioned in this section can be found in the Process Manager Parameter Reference Dictionary.

8.1 REGULATORY CONTROL POINT

Regulatory Control (RegCtl) points are used to perform standard control functions by executing the algorithms that have been configured. Each control algorithm includes a wide range of configurable options to allow implementation of complex control strategies by a simple menu-select process. For example, initialization and windup protection are inherently provided for all point interconnections. Also, the capability to ramp a setpoint (by operator entry of a target value and ramp time) is configurable. Predefined and custom displays are available to support these control strategies. These standard support functions significantly simplify the implementation and use of sophisticated multiloop control strategies. Increasingly advanced control strategies become practical as a result of the ease of PM configuration.

The RegCtl point supports the following algorithms:

- PID (Pid)
- PID with Feedforward (PidFf)
- PID with External Reset Feedback (PidErfb)
- Position Proportional (PosProp)
- Ratio Control (RatioCtl)
- Ramp Soak (RampSoaK)
- Override Selector (ORSel)
- Auto Manual (AutoMan)
- Incremental Summer (IncrSum)
- Switch (Switch)
- Null (Null)

Detailed descriptions of these algorithms can be found in this section beginning with paragraph 8.13.

Figure 8-1 is a functional diagram of the RegCtl point.

8.2 CONTROL INPUT CONNECTIONS

Control input connections are typically used to assign "noninitializable" inputs to the configured control algorithm. They can be used to assign initializable inputs, but if initialization and windup protection are required, a control output connection from the primary point must be used.
The number of control input connections (NOCINPTS) and the destination parameter (CIDSTN) for each connection are defaulted based on the noninitializable inputs required by the control algorithm. (Refer to the individual control algorithm configuration form for the destination parameters within each algorithm.) The control input connection-source parameter CISRC allows the user to specify the source of the input using the "Tagname.Parameter" format.

The inputs can be obtained from any source parameter that is a real number, an integer, or a Boolean state. (Boolean states are treated as real numbers by the algorithm. The Off state is equal to a real number of 0.0; the on state is equal to 1.0.) For all RegCtl algorithms except PIDERFB, the point's control output connections are also considered input connections because the RegCtl point reads the output status before writing to it. A RegCtl point can have a maximum of four input connections that obtain inputs from I/O Processors in the same PM.

Generally, initializable inputs are stored with control output connections at the primary data point, and no input connections are required; however, in some cases it may be required to obtain initializable inputs with input connections (for example, when initialization and windup protection are not needed). To achieve this, the number of control inputs is allowed to be increased based on the initializable inputs of the control algorithm.

### 8.3 PV SOURCE SELECTION (Pid, PosProp, and RatioCtl Algorithms)

The source of the PV can be an analog input point, a PV algorithm, a Universal Station, or a user-written program. It is specified by the PVSOURCE parameter, whose value can be changed by an operator, a supervisor, an engineer, or a user-written program. The PVSOURCE parameter is configurable only if the data point has been configured as a full point. PVSOURCE can have one of the following values:

- **Auto**—PV is received from an analog input point or a PV algorithm. The value is in PVAUTO and its status is contained in PVAUTOST. During normal operation, the PV source is Auto, and the PV and its value status (PVSTS) become equal to PVAUTO and PVAUTOST, respectively, before PV range checks are made. When the PV source is changed from Auto to Man or Sub, the PV remains at the last value until it is changed by the operator (Man) or a program (Sub), so it doesn't "bump." In Man or Sub, the status in PVSTS is Uncertn. When the PV source is changed from Man or Sub to Auto, the PV immediately goes to the PVAUTO value. This might cause a bump in the value unless it is changed gradually to the value in PVAUTO before changing the source.

- **Man**—The PV is entered by an operator, supervisor, or engineer at a Universal Station.

- **Sub**—The PV is entered by a user-written program. A program can store a bad value in PV, and if it does, PVSTS becomes Bad.

You can prevent PV source changes by entering OnlyAuto for the PVSRCOPT parameter. This fixes the source as AUTO and the parameter PVSOURCE is removed from the point. Configuring All in PVSRCOPT allows normal PV source selection.
Figure 8-1 — Regulatory Control Point, Functional Diagram
8.4 MODES

The following operating modes are applicable to the RegCtl point (refer to Figure 8-2):

- **Manual (Man)**—provides the operator or the discontinuous program with direct control over the output value of the data point, regardless of any automatic control strategy.

- **Automatic (Auto)**—output value is computed by the configured RegCtl algorithm, and the setpoint comes from the local setpoint (LSP) location in the RegCtl point. An operator or a discontinuous program can change the setpoint value.

- **Cascade (Cas)**—data point receives its setpoint value from a primary data point.

- **Backup Cascade (Bcas)**—local cascade mode where the RegCtl point receives its setpoint from a primary data point even though the entry for the RCASOPT parameter is Spc, DdcRsp, or Rsp (where the AM provides the setpoint). In this way, should the AM or the NIM fail, the control strategy will shed to the local cascade mode.

Separate flags are provided to indicate if the current mode is manual (MANMODFL), auto (AUTMODFL), or if the mode attribute is Oper (OPRATRFL). The modes and mode attributes can be used in conjunction with the logic slots to implement interlocks.

8.4.1 Mode Attribute

The mode attribute denotes who has the authority to change certain parameters of a data point, and is established through parameter MODATTR. The mode attributes are as follows:

- **Operator**—Operator can supply the setpoint, output value, mode, ratio, and bias for a data point (operator-access level).

- **Program**—Program can supply the setpoint, output value, mode, ratio, and bias for a data point (program-access level).

- **None**—The mode does not have an attribute.

At a Universal Station, the mode attribute is displayed next to the mode of the data point. If the mode attribute is program, a "P-" is displayed to the left of MODE. If the mode attribute is Operator, blanks are displayed to the left of MODE.

An access level of Ccont (Continuous Control) allows supervisory control from an LCN module, such as the AM, to change the setpoint, output value, and mode of a data point.
Figure 8-2 — Mode Structure
8.4.2 Normal Mode

The normal mode is the mode that is copied into the MODE parameter when the operator presses the NORM button at the Universal Station. Also at that time, the content of the NMODATTR parameter is copied into the MODATTR parameter. This then becomes the mode for the data point. The possible entries for the normal mode are None, Man, Auto, Cas, and Bcas.

8.4.3 Normal Mode Attribute

The normal mode attribute is the attribute that is copied into the MODATTR parameter when the NORM button is pressed. The possible entries for the NMODATTR parameter are Operator, Program, and None.

8.4.4 Remote Cascade Handling (PID Algorithms)

The PM supports supervisory or DDC control for the PID algorithms from any remote device such as a computer (through the CG) or the AM. If the remote cascade connection is coming from a regulatory data point in the AM, it handles everything automatically; however, in all other cases (including the continuous CL programs in the AM directly writing to the PM), the user must ensure that the following conditions are handled:

- Remote device must use the continuous control access-level (Ccont) parameter for writing to the SP, OP, and MODE parameters.
- Remote device must also handle mode changes for closing the cascade.
- Initialization to ensure bumpless mode transfers.
- Windup protection.

8.4.4.1 Remote Cascade Options

The following remote cascade options are provided by the RCASOPT parameter:

- **Supervisory Control (Spc)**—This option is configured by setting RCASOPT to Spc. The AM control strategy writes to the setpoint of the RegCtl point, subject to the setpoint limits, when the RegCtl point is in Cas mode.

- **Direct Digital Control (Ddc)**—This option is configured by setting RCASOPT to Ddc. The AM control strategy writes to the OP output of the RegCtl point, when the RegCtl point is in Cas mode. The output limits are not applicable in this case. The SP cannot be written by the AM control strategy to the RegCtl point. If the control algorithm is a PID type and is configured for PV tracking, the SP is set equal to the PV when in Cas mode.
• Direct Digital Control with Remote Setpoint (DdcRsp)—This option is available for only PID-type algorithms. It is configured by setting RCASOPT to DdcRsp. The AM control strategy writes directly to the OP output of the RegCtl point when it is in Cas mode. The output limits are not applicable. The AM can also write to the SP of the RegCtl point subject to the setpoint limits. PV tracking is not performed in Cas mode. This option is used primarily when a single PID controller in the PM is used to back up a higher level control strategy running in the AM. The higher level control strategy writes to the OP and also provides the SP for the backup control strategy.

• Remote Setpoint (Rsp)—This option is available for only PID-type algorithms and is configured by setting RCASOPT to Rsp. The AM control strategy writes to the SP via an AM general output connection, subject to the setpoint limits, when the RegCtl point is in the Auto mode and it is being initialized by its secondary (i.e. INITMAN flag is On). PV tracking is not performed in Auto mode when INITMAN is On, if Rsp is selected.

The Rsp option is used primarily in a cascade control strategy where a RegCtl point is used to backup a higher level control strategy running in the AM, and the higher-level control strategy provides the SP for the backup control strategy. In the backup strategy, the primary PID would be configured for the Rsp option (allowing the AM to specify the backup SP), and the secondary would be typically configured for Ddc or Spc control.

8.4.4.2 Remote Cascade Request

When the RCASOPT parameter for the RegCtl point is configured for Spc, Ddc, or DdcRsp and the operator at the Universal Station or a discontinuous user program (for example, a sequence program) tries to change the mode to Cas, the remote cascade request flag (CASREQ) is set to On, but the actual mode is left unchanged. The actual mode is changed to Cas only when

• The AM control strategy explicitly writes the mode to Cas (it should do this only after seeing a remote cascade request from the secondary), or

• If Spc is entered for the RCASOPT parameter, and the AM control strategy writes to the setpoint, or

• If Ddc or DdcRsp is entered for the RCASOPT parameter, and the AM control strategy writes to the output value OP of the RegCtl point.

After CASREQ has been set to On, any mode change causes CASREQ to be set to Off.
8.4.4.3 Remote Cascade Shed

The remote cascade shed mechanism in the PM allows the user to substitute the local backup control strategy in the PM for the AM control strategy if the AM or NIM fails.

When a RegCtl point that is configured for Spc, Ddc, or DdcRsp control is in Cas mode and the SP (if Spc) or the OP (if Ddc or DdcRsp) is not updated by the AM within a predefined time, the AM or the NIM is assumed to have failed. The backup control strategy is substituted by means of changing the mode to a preconfigured backup mode. The maximum time allowed between updates is specified by SHEDTIME (in seconds) and the backup mode is specified by SHEDMODE. Shedding to the backup mode can be disabled by setting SHEDTIME to 0.

When the mode is shed to the preconfigured shed mode, the remote cascade shed flag (RCASSHED) is set to On (mainly for indication at the Universal Station). Any subsequent mode changes automatically set the RCASSHED to Off. The remote cascade request flag is also set to On, which allows the AM to resume control at a later time without operator intervention.

8.5 SAFETY SHUTDOWN

This option allows the user to implement safety interlocks that effectively shut down a single control loop. When the shutdown flag (SHUTDOWN) is set to On by a user-written program, the mode and the mode attribute are changed to Man and Oper, respectively, and the OP output is set equal to a predefined safe output value (SAFEOP). Further, the external-mode-switching enable state (ESWENBST) is disabled, if it is currently enabled. As long as the shutdown flag is On, the MODE, MODATTR, ESWENBST, and OP parameter values cannot be changed. When the shutdown flag is set to Off, the control loop must be manually restarted.

A Logic Point or CL program must be used to reset the Safety Shutdown Flag (from ON to OFF).

If the point is already red tagged when the shutdown flag is turned On, the output value is not changed. Typically, the safe output value can be configured as 0% (if the valve is fully closed) or 100% (if valve fully open). In some cases it may be important to just hold the last value. This can be achieved by setting the SAFEOP parameter to NaN.

The shutdown flag cannot be initiated from the Universal Station.

8.6 EXTERNAL MODE SWITCHING

External mode switching (EMS) is typically used to establish mode interlocks or, under certain process conditions, to restrict the use of a mode that invokes a higher level of control. External mode switching is an option and can be configured by entering Ems for the EXTSWOPT parameter. Mode changes made through external mode switching have no effect on the mode attribute of the data point, or on the normal mode and normal mode attribute of the point. When a mode change is made, the last values of the normal mode and normal mode attribute parameters stay in effect.
Each regulatory data point has three parameters (ESWMAN, ESWAUTO, and ESWCAS) that are used as flags to indicate the mode to which the point has been switched.

When external mode switching is enabled by the operator or the program by setting the ESWENBST parameter to Enable, the operator and the program are prevented from changing the mode of the data point when the point is in the ESWMAN, ESWAUTO, or ESWCAS mode as indicated on Table 8-1; however, the operator or the program can disable external mode switching at any time by entering Disable for the ESWENBST parameter.

### Table 8-1 — Mode-Switching Operation

<table>
<thead>
<tr>
<th>EXTSWOPT = Ems</th>
<th>ESW (Note 1)</th>
<th>Parameters' Effective New Mode</th>
<th>Can Mode Be Changed By Operator or Program?</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN AUTO CAS</td>
<td></td>
<td>Last Mode Requested</td>
<td>Yes</td>
</tr>
<tr>
<td>F F F</td>
<td></td>
<td>Previous Mode (Note 2)</td>
<td>No</td>
</tr>
<tr>
<td>T X X</td>
<td>Man</td>
<td>Auto (Note 3)</td>
<td>Cas (Note 3)</td>
</tr>
<tr>
<td>F F T</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. MAN is ESWMAN, AUTO is ESWAUTO, and CAS is ESWCAS, T = True, F = False, and X = don't care.
2. Previous Mode is the mode when the point was last processed.
3. If the effective new mode is not legal for the control algorithm, the mode doesn't change.

### 8.7 SETPOINT HANDLING

Setpoint handling takes place only if the configured control algorithm requires a setpoint. Setpoint-handling functions are as follows:

- Setpoint (SP) limits
- SP Target-Value processing
- PV Tracking
- Deviation Alarming
- Advisory Deviation-alarm processing
- Ratio and bias options
- Setpoint Restrictions
8.7.1 Setpoint (SP) Limits (Pid, PosProp, & RatioCtl Algorithms)

Setpoint limit parameters SPHIILM and SPLOLM prevent setpoint values from exceeding user-configured high and low limit values. These limits are configured in the same engineering units as the SP and must be within the SP range plus extensions. Crossover of setpoint limits is not allowed. The configured setpoint limits also apply to the advisory-target value.

Setpoint limits are observed in initialization calculations. If the limits are violated by the SP value, antireset windup-status propagation is invoked.

8.7.2 SP Target-Value Processing (Pid, PosProp, & RatioCtl Algorithms)

This option allows a Universal Station operator or a user-written program to "ramp" the setpoint from the current value to a new value over a period of time. The option is configured through the Data Entity Builder by entering TV in setpoint option parameter SPOPT. If an operator is to ramp the SP, the mode attribute in MODATTR must be Oper; and if a user-written program is to ramp the SP, the mode attribute must be Prog.

To use the SP target-value option, the operator

1. Enters the desired new SP value in SPTV.
2. Enters the ramp time (in minutes) in RAMPTIME.

**NOTE**

Step 1 or 2 causes the TVPROC parameter to go to Preset if the point is in the Auto mode, INITMAN is Off, and TVPROC is Off.

3. Enters Run in TVPROC.
4. The SP begins moving linearly toward the new value and the value in RAMPTIME decreases with time. When RAMPTIME = 0, SP reaches the new value and the status in TVPROC changes to Off.
TVPROC can be changed to the Run state only from the Preset state. While TVPROC contains either Preset or Run, SP high and low limits, and the SP high and low engineering-unit ranges can't be changed. The following applies to TVPROC if it is in the Run state:

1. If MODE is changed to Man, state goes to Preset.
2. If MODE is changed to Cas, state goes to Off.
3. If INITMAN is true, state goes to Preset.
4. A store to SP forces the state to Off.
5. If SPTV > SP and the antireset-windup ARWNET parameter indicates that SP is wound Hi or HiLo, the SP stops changing. When ARWNET indicates that SP is no longer wound Hi or HiLo, SP ramping continues from the stop position. Note that when SP is ramping, ARWNET is not shown on the Group or Detail Displays. SP can normally be inferred from the output windup status. ARWNET can be accessed from a custom display.
6. If SPTV < SP and the output becomes wound Lo or HiLo, the SP stops changing.
7. If none of the above is true, the SP is ramped to SPTV.

8.7.3 PV Tracking (Pid Algorithms)

PV tracking is configured by entering Track for the PVTRACK parameter. During PV tracking, SP is set equal to PV whenever the cascade is broken by an operator or a program action, or the RegCtl point is a secondary (in a local cascade strategy) and the cascade is momentarily interrupted by a 1-shot initialization.

PV tracking occurs under the following conditions:

- Mode is Man.
- Mode is Cas and RCASOPT is Ddc.
- INITMAN is On, and either the mode is not Auto, or RCASOPT is not Rsp.
- RegCtl point is being processed for the first time after becoming active.
- RegCtl point is a secondary within a local cascade-control strategy (inside the same PM), and it is going through a 1-shot control initialization. One-shot control initialization occurs when
  - the control initialization-request flag CTRLINIT is On
  - the point is being processed for the first time after the PM state has changed to Run
  - just recovering from a bad PV
  - this slot has only one disposable secondary that just underwent 1-shot initialization.

Note that PV tracking (even if configured) is not done on return from a Bad PV.
8.7.4 Deviation and Advisory Deviation Alarming

8.7.4.1 Deviation Alarming (Pid, PosProp, PIDPosPr, RampSoak, and RatioCtl Algorithms)

Deviation (PV-SP) high and low alarms can be configured by using the alarm trip points provided by the DEVHITP and DEVLOTP parameters. In addition, alarm priorities can be established for these trip points by using the DEVHIPR and DEVLOPR parameters. Parameters DEVHIFL and DEVLOFL are used as flags to indicate that a deviation (high or low) alarm has been detected. This alarm returns to normal when the deviation (PV-SP) is less than or equal to the configured trip point minus a deadband equal to 10% of the trip point value.

8.7.4.2 Advisory Deviation Alarming (Pid, PosProp, & RatioCtl Algorithms)

This option allows an operator to manually change the SP to a predetermined value. The predetermined value is usually calculated by a user-written program that stores the value in advisory setpoint parameter ADVSP rather than storing it directly in SP. Advisory-deviation alarming is selected by entering Asp for setpoint option parameter SPOPT.

This alarm type is available if the RegCtl point has been configured as a full point. When this option is selected, an alarm is generated if the difference between the PV and the value in ADVSP is greater than the trip-point value in ADVDEVTP. This alarm returns to normal when the difference between the PV and ADVSP is less than or equal to the value in ADVDEVTP minus a deadband equal to 10% of the trip-point value.

The following conditions must be true if advisory-deviation alarming is to function:

- SPOPT = Asp
- ADVDEVTP <> NaN
- ASPROC = Enable
- PV alarm status in PVVALST <> Bad
- Alarm-enable status in ALENBST <> Inhibit

If the advisory-deviation alarm is present and the value of one of the above-listed configuration parameters is changed, the advisory-deviation alarm is reset.

If parameter ASPPROC = Disable, the value in ADVSP equals the value in SP.

8.7.5 Bad Output Alarm

The Regulatory Control point’s Bad Output Alarm option (when enabled) generates a process alarm if one or more of the configured output connections to Analog Output or Digital Output points are broken. Broken means data cannot be pushed to a point. This alarm is cleared when all connections to the AO or DO points are good, or when the Bad Output Alarm Option is disabled.
8.7.6 Ratio and Bias Options (Pid Algorithms)

NOTE

If SP target value processing or advisory deviation alarming is configured for a RegCtl point, the ratio/bias options cannot be configured for the same data point.

The ratio and bias options are configured by entering one of the following values in ratio and bias option parameter RBOPT:

- **FixRatBi**—Fixed Ratio and Bias
- **AutoRat**—Auto Ratio and Bias
- **AutoBi**—Fixed Ratio and Auto Bias

If one of these options is configured, the SP is modified before being used by the PID algorithm as follows:

\[
\text{SP\_Store\_Value} \times \text{RATIO} + \text{BIAS}
\]

Where SP\_Store\_Value is the setpoint before the modification.

You can configure limits for both the RATIO and the BIAS values in the following parameters:

- **RTHILM**—Ratio high limit
- **RTLLOLM**—Ratio low limit
- **BSHILM**—Bias high limit
- **BSLOLM**—Bias low limit

In normal operation (in Cas mode and INITMAN is Off), all three options work alike. RATIO and BIAS can be changed by a Universal Station operator or by user-written programs (depending on whether MODATTR contains Oper or Prog). During initialization...
of this point, however, RATIO and BIAS can be changed only if they are not being initialized, based on the value in RBOPT, as follows:

- **FixRatBi**—The initialization value calculated for this point's primary is
  \[ \text{RINITVAL} = \frac{(\text{SP} - \text{BIAS})}{\text{RATIO}} \]

- **AutoRat**—RATIO is initialized as follows:
  \[ \text{RATIO} = \frac{(\text{SP} - \text{BIAS})}{\text{Store Value}} \]

If RATIO attempts to go outside one of its limits, it is clamped at the limit, and INITVAL is calculated as follows:

\[ \text{INITVAL} = \frac{(\text{SP} - \text{BIAS})}{\text{RATIO}} \]

- **AutoBi**—BIAS is initialized as follows:
  \[ \text{BIAS} = \text{SP} - (\text{Store Value} \times \text{RATIO}) \]

If BIAS attempts to go outside one of its limits, it is clamped at the limit, and INITVAL is calculated as follows:

\[ \text{INITVAL} = \frac{(\text{SP} - \text{BIAS})}{\text{RATIO}} \]

### 8.7.6.1 Bias Limits

Two user-setable Hi and Lo limits on the SP-related bias parameter are provided. Whenever operator or program entries are outside the limits, the entries are clamped to the closest limit. Crossover of limits is inhibited.

You can configure high and low limits for the BIAS value that can be applied to the setpoint for PID algorithms. A Universal Station user with a Supervisor key can change these limits. An operator is prohibited from entering a value exceeding these limits. A user-written program is clamped to the exceeded limit. Crossover of these limits is prohibited.
8.7.6 Ratio Limits

You can configure high and low limits for the RATIO value that can be applied to the setpoint for Pid Algorithms. A Universal Station user with a Supervisor key can change these limits. An operator is not allowed to enter a value that exceeds these limits. If a user-written program attempts to store a value outside the limits, it is clamped to the limit. Crossover of these limits is prohibited.

8.7.7 SP Access Restrictions

The activities that can write a value to the SP are defined by Table 8-2.

8.8 ALARM DETECTION

Alarms for a RegCtl point can be configured only when the point has been configured as a full point. The following alarm types are supported by the RegCtl points:

- PV High/Low*
- PV High-High/Low-Low*
- PV Rate-of-Change Positive/Negative*
- PV Significant Change*
- BadPV*
- Bad Control
- Deviation High/Low
- Advisory deviation

For detailed alarm information, refer to paragraph 4.3 in System Control Functions.

* Applicable to only Pid, PosProp, and RatioCtl algorithms.
8.9 CONTROL OUTPUT PROCESSING

The primary task of control output processing is to make the control algorithm calculation available to the rest of the system (displays, printers, CL programs, other data points, etc.) in percent or EUs, as needed. Control algorithms produce outputs in percent or in engineering units.

Control output processing performs the following functions:

- Provides the output value in percent and EUs for displays, printing, CL programs, and for interpoint communications.
- Processes control output connections that send the output to the secondary data point after conversion to EUs.
- Constrains the output to the configured limits.
- Generates and propagates windup status as a result of a violation an output limit.

The following parameters contain significant output-processing information. All of them are accessible for displays and printing and all can be accessed by a program written in CL.

\[
\begin{align*}
CV &= \text{The result (calculated value) of calculation of the control algorithm, can be in percent or EU depending upon the control algorithm.} \\
OP &= \text{The final control output, expressed as % of EU Range of the output.} \\
OPEU &= \text{Final control output in Engineering Units.} \\
CVEUHI &= \text{Output EU Range corresponding to 100\% value of OP.} \\
CVEULO &= \text{Output EU Range corresponding to 0\% value of OP.}
\end{align*}
\]

8.9.1 Initial Control Processing

During initial control processing, initialization data is fetched from the secondary points indicated by each control output connection.

The output engineering-unit range in CVEULO and CVEUHI is determined, based on the EU range of the secondary pointed to by the first active control output connection. If this connection has a communication or configuration error, the output range is set to bad and the point is aborted. If this happens, the CI connections and CO connections, scheduled for execution after initial control processing are not processed.
### Table 8-2 — Setpoint Access Restrictions

<table>
<thead>
<tr>
<th>MODE</th>
<th>BOX-IDLE or POINT INACTIVE or INITMAN</th>
<th>RCASOPT</th>
<th>PID ALGO.</th>
<th>NON-PID ALGO.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ATTRB</td>
<td>PVTRK = ON</td>
<td>PVTRK = OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OPR</td>
<td>PRG</td>
<td>OPR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MODE ATTRB</td>
<td>MODE ATTRB</td>
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<td></td>
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<td>PRG</td>
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<tr>
<td></td>
<td></td>
<td>OPR</td>
<td>PRG</td>
<td>OPR</td>
</tr>
</tbody>
</table>

**NOTEs:**
- \( I \Rightarrow \) SP is being initialized, no change permitted.
- \( Opr \Rightarrow \) Operator from group or detail display.
- \( Prg \Rightarrow \) Discontinuous CL programs or sequence programs.
- \( PC \Rightarrow \) PM cascade. Mainly the output connections from another control slot in this PM or another PM.
- \( RC \Rightarrow \) Remote cascade. These include: continuous CL programs on LCN, output connections from regulatory points in the AM, or user computers on the LCN.
- \( NCH \Rightarrow \) No change permitted.
- \( * \Rightarrow \) Target value processor state (TVPROC) must be off.
8.9.2 Normal Computation

1. CV is calculated by the control algorithm.

2. OP is calculated from CV, with the units based on the range defined by CVEULO and CVEUHI. Note that the values in CVEULO and CVEUHI are determined by the engineering-units range of the secondary point to which the first active connection is made.

3. OP is checked for minimum output change, output rate-of-change, output high-limit, and output low-limit. If any of the limits is exceeded, the OP value is adjusted or clamped as applicable.

4. The windup status is set.

5. Each control output connection is processed as follows:

   If the control output connection is disposable,

   The corresponding value in the secondary point is made equal to OP, if the destination parameter is OP, otherwise it is made equal to OPEU.

   The OP or OPEU value is transferred to the secondary's destination parameter, subject to applicable limits on the destination parameter (e.g., SP limits).

In MANual Mode

1. OP is set (in percent) by an operator or by a user-written program, depending on the attribute.

2. Each control output connection receives normal processing, as described above. Remaining process is as defined under "Normal Computation."

When initializing because of a request from a secondary data-point

1. If all of the control output connections are indisposable, CV is initialized to its last value. When the first disposable control output connection becomes available, the CV is back-calculated (% to EU conversion if the destination parameter is OP) from the destination parameter of the secondary.

2. OP is calculated from CV, based on CVEULO and CVEUHI.

8.9.2 Output High and Low Limits

You can configure high- and low-limit values for the RegCtl point output using parameters OPHILM and OPLOLM. These limits are expressed as a percentage of the output range and the limit values can range from -6.9% to 106.9%. A Universal Station user with a Supervisory key can change these limits. Crossover of these limits is not permitted.

When an output limit is reached or exceeded, windup status is propagated up through cascade strategies.
8.9.3 Output Rate-of-Change Limits

You can configure a maximum rate of change in percent-per-minute for output values of RegCtl points using the OPROCLM parameter. The effect of this limit is to reduce excessive rates of change in the output, to the limit. The smallest limit can't be less than 0.1 percent-per-minute. The default value for the limit is NaN, which eliminates the limit check.

Typically, the output rate-of-change limit is used to match the slew rate of the final control element to the control dynamics.

Use caution when setting the value of OPROCLM. This value should be set before loop tuning has taken place. When done this way, tuning accommodates any slow down in response time caused by rate limiting. If OPROCLM is changed after a loop has been tuned, it is possible for poor loop dynamics or even instability to result.

Note that when a choice is available, rate limiting should be applied to PID algorithms (PID, PIDFF, and PIDERFB) rather than regulatory control algorithms of other types. The PID algorithms support special processing to prevent windup of the CV during rate limiting. Other algorithms cannot provide this special processing.

8.9.4 Output Minimum-Change Limit

You can configure a minimum output-change value for RegCtl points using parameter OPMCHLM. This value is a percentage of the output-value range. If the absolute difference between the output value at one processing pass and the next doesn't equal or exceed the minimum change, the earlier value is maintained. A Universal Station user with a Supervisory key can change the minimum output-change value.

The default minimum output-change value is NaN, which eliminates the minimum change check.

This feature is used to minimize "wear and tear" on the final control device.

8.9.5 Output Limiting in Manual Mode

No output limits, output rate-of-change or output minimum-change limits are observed while in manual mode. An indication is given to the operator if a manually entered or program-entered output value exceeds the output limits. Output values written by CL programs are clamped to the HI and LO output limits.
8.9.6 Control Output Connections

Control output connections are used to establish initializable cascade connections between the output of the RegCtl point output and other points. Control output connections are accomplished through parameter CODSTN. To assign the RegCtl output to the parameter of another data point, the user can choose from one of the following two output connection conventions (Tagname.Parameter or hardware reference address):

- Tagname.Parameter
- !MTmmSss.Parameter

where:
- MT is the IOP type (AO or DO)
- mm is the IOP number in the PM file, from 1 to 40
- ss is the slot number from 1 to 8 for analog outputs, and from 1 to 16 for digital outputs
- Parameter is the parameter in the AO or DO point to which this output value is to be written.

Up to four output connections can be configured for a RegCtl point. Initialization and wind-up protection are supported for multioutput configurations.

The RegCtl data point can write the output value to only the following destination parameters:

- SP, RATIO, X1, X2, X3, and X4 parameters of another RegCtl data point in the same PM. When a control output connection is made to the RATIO parameter, the ratio high and low limits on the secondary are used as its engineering unit range. Also the secondary should be configured for a ratio bias option of auto ratio and placed in Program Cascade mode for the initialization to work correctly.

- SP parameter of a RegCtl point in another PM, APM, or HPM on the same UCN.

**NOTE**

An output connection of this type counts as one input and one output for the purpose of limiting the number of input/output connections going across PMs.

- OP parameter of an analog output point in the same PM. The component form of the output connection can be used to connect to an AO point that has been configured as a component point. The following restrictions apply:
  - The number of control input connections fetching data from the I/O Processors must be less than four.
  - The analog output slot must be configured as a component point.
  - The output destinations cannot be a mix of IOPs and RegCtl points.
• OP parameter of a digital output point that has been configured for pulse-width modulation in the same PM. The following restrictions apply:
  – The number of control input connections fetching data from the I/O Processors must be less than four.

• Any addressable parameter of any accessible slot if the configured control algorithm is PidERFB.

**CAUTION**
Up to four output connections are permitted from a Regulatory Control point but the control output destinations must be all IOPs (AOs or pulse width modulated DOs) or all Regulatory Control inputs. The outputs cannot be a mix of IOPs and Regulatory Control inputs.

### 8.9.7 Output High/Low Alarms

With R510 and later software, an Output High or Output Low alarm is set when a Regulatory Control point's output value (OP) exceeds the configured high or low alarm limit. The alarm is removed when the value of OP returns toward normal past a configurable deadband.

The following parameters deal with the Output Alarms and are configurable for each point:

- **OPHITP/OPLOTP** contain the Output High/Low Alarm trip points
- **OPHIPR/OPLOPR** contain the Output High/Low Alarm priorities
- **OPHAFL/OPLAFL** contain the Output High/Low Alarm flags
- **OPALDB** contains a deadband for the Output Alarms

The output alarms are only available for Regulatory Control points configured as full points and are disabled if the trip points are not specified.

### 8.10 INITIALIZATION

Initialization provides meaningful initial values in the data point parameters before processing is started or restarted. Separate mechanisms are provided to initialize PV-related parameters and control-related parameters.
8.10.1 PV Initialization

The principal purpose of PV initialization is to set up starting values the first time the point is processed or the first time it is processed after recovering from a BadPV value status. PV initialization is useful for only functions involved in history collection or for dynamically varying values. Stated another way, PV initialization is required where the new value depends on the previous value.

The following events cause PV initialization:

- Point's execution state is changed to Active.
- PM undergoes a warm or cold restart.
- PVAUTOST recovers from Bad value status.

PV initialization consists of the following functions:

- PVCALC is calculated from the PV inputs, using the steady-state portion of the equation. For calculations that don't involve time, the normal equation is used.
- PVAUTO is made equal to PVCALC. If PV filtering is configured, the filter dynamics are initialized to steady state.
- No other PV processing is affected by PV initialization.

8.10.2 Control Initialization

Control initialization allows normal control strategies to be re-established after they have been interrupted without "bumps" in the output to the process, and without the need for manual balancing of values to avoid such bumps.

Control initialization compensates for changes that may have occurred since the normal control strategy was last operating. For example, a Universal Station operator might have taken over control of the output to the process, so that it now has a value that is different than normal processing would calculate. The initialization procedures automatically readjust either the bias value in the data point(s) or an input to the data point(s) so that when normal control is reestablished, the output to the process does not move or "bump."

For the control algorithms, the new value is back-calculated for an input that absorbs any output change. This value and an initialization request are sent to the primary data point that provides the input. Thus, the primary absorbs the change and it must take similar action with its own primary, if it has one, so that the whole strategy can absorb the change.

By configuring a control connection from one point (primary) to an initializable input to another point (secondary) an initialization path is created. It is along this initialization path that a value is transferred for use by a primary to absorb external process-upsets that may have occurred at the secondary.

Two or more active paths from a single primary to multiple secondaries are referred to as "fan out" connections. Where there are two or more control output connections from a primary to two or more secondaries and all of these outputs are indisposible, the primary goes into the initialization state.
The value that is to be protected from a bump (the value to back-calculate from) is obtained at the point's output or at the secondary's initializable input. When "fan out" connections to more than one output are used, the Regulatory Control output is initialized from the first disposable secondary.

**General Mechanism**—At each point-processing pass, the following information is retrieved from all secondaries to which the data point has control output connections. The data that is retrieved to support initialization is

- Initialization Request
- Initialization Value

An initialization request from the secondary causes the control output connection on the primary to go to an "output indisposible" state, a condition where a newly generated output to the secondary has no effect on the secondary. A control output connection also has "output indisposible" status if an error has been detected when the initialization request and initialization value should have been received.

When all connections from a primary are in the "output indisposible" state, the primary is forced to the initialized state. This causes the primary to set its initialization request. In turn, this may cause the control output connection of a preceding primary to assume the "output indisposible" state and may force that primary to be initialized as well. In this manner, the initialization state is propagated upstream to all interconnected primaries.

During the initialization state, each point remains in that state until a disposable output connection is found. For points with one control output connection, the primary sets its output value to the initialization value received from its secondary while in the initialized state. For points with more than one control output connection, on the first processing pass when a disposable output connection is available, the primary sets its output value to the initialization value received from its secondary.

When initialization is being performed for a control strategy, each data point's output is readjusted by back-calculating an initializable input or by an internal (bias) adjustment. When each point resumes normal calculations, the new output and the input value at its secondary are balanced and no bump occurs.

Indisposible outputs are not the only factor for triggering initialization. It is possible to force a back-calculation by writing to a point's output while it is in MANual mode, or a user program or a logic slot can set the control initialization flag in a point. For these cases, the point does not go to the initialization state but its primary may, because the point sent an initialization request to the primary.

Special handling is provided for connections to local I/O (e.g., Analog Outputs or Digital Pulse Width Modulated Outputs). In the event that communication with the local output module is lost, the mode automatically goes to MANual to permit the operator to take control. When communication with the module is restored, back initialization to the output value occurs automatically. The operator can then return the strategy to the desired mode. This handling is triggered by loss of communications on the I/O link, failure of the I/O processor, or an I/O processor-detected power outage.
Conditions that Cause Control Initialization—The need to initialize a data point is indicated by external upsets that directly affect the point or it is indicated by an initialization request from a secondary data point.

Control initialization is caused by any of the following:

- A user program or logic slot has requested initialization (see "Initialization Forced by a Program," below).
- The point is active for the first time (an inactive to active transition).
- The point is executing the first time after a warm PM restart.
- All control output connections were indisposable and now one or more output connections is disposable.

A control output connection is indisposable when

- A secondary has made an initialization request, or
- A communication/configuration error has been detected in retrieving an initialization request and initialization value from a secondary.

The following are the reasons why a secondary data point sends an initialization request to its primary data point:

- The secondary isn't in Cas mode, or
- The secondary is inactive.
- The initializable input to the secondary (the destination of the primary's control output connection) is not selected for a secondary that uses the Switch algorithm (configured for PV tracking) or the input is being bypassed by the Override Selector algorithm, or
- The secondary is in the initialization state.

Initialization of a Point in the Same PM—For a primary and a secondary that are both in the same PM, an enhancement is provided. This enhancement presents the operator with an immediate indication of initialization when a cascade strategy is opened or closed.

Initialization Forced by a Program or Logic Slot—A user-written program or a logic slot can cause a data point to initialize by setting the data point's control initialization-request flag (CTRLINIT). The next time the point is processed, it initializes. CTRLINIT is cleared when the processing pass is complete. An initialization request is sent to its primary, thus propagating initialization up through the control strategy.

Limit Checking During Control Initialization—Limit checks apply during initialization except for output rate-of-change limits.

How Initialization is Indicated at Universal Stations—When a data point that is initializing is displayed, the display indicates that it is initializing. For example, on a group display or a detail display, INIT appears in the point-status field that is just below the mode indicator.
8.11 WINDUP PROTECTION

PID algorithms are protected from windup caused by reset action. Windup status parameters are maintained that pass the status "upstream" to the primary points along the initialization path. Each PID algorithm checks its output windup status and takes appropriate action to prevent reset windup. These functions are standard and require no configuration by the user.

8.11.1 Windup Status

The following parameters contain windup-status information:

- **ARWOP**—Output (OP) windup status
- **ARWNET**—Windup status for SP or another initializable input.

When this point's ARWOP contains something other than Normal, integral control in the windup direction stops. Integral action in the other direction and P and D action continue.

For the remainder of the control subsystem, the windup status serves only as a warning, and not as a constraint. For example if the status in ARWNET is Lo, lowering SP won't have an immediate effect on the output of the final secondary; however, SP can be lowered if the SP low-limit has not yet been reached.

The values in the windup-status parameters indicate whether raising or lowering the associated parameter value will affect the output of the final secondary, as it should. The values for parameters ARWNET and ARWOP are as follows:

- **Normal**—Free to move in either direction
- **Hi**—Free to move only in the lower direction
- **Lo**—Free to move only in the upper direction
- **HiLo**—Not free to move in any direction

8.11.2 Status Propagation

Windup status is propagated to ARWOP and ARWNET of the same point, and then from ARWNET of the secondary point to the primary point, and so on.

Propagation from secondary to primary is instantaneous if both are in the same process unit and the same PM. Otherwise, it takes place on the next processing pass for each point.
8.12 OVERRIDE CONTROL

Override control strategies are primarily used for multivariable constraint control. In such a strategy, control of a single process variable is based on one of two or more PVs. These multiple PVs are referred to as "constraints." A selector algorithm selects the PV to be used for control. When a different PV is selected, the former PV has been overridden—the new PV has constrained the others.

Consider the following examples:

- In typical boiler-control strategy, the constraint on the fuel flow (SP of the fuel-flow PID controller) can be that it cannot exceed the actual air flow, multiplied by a ratio (which may be computed by the O2 controller). In this case, the fuel flow is the primary PV to be controlled and the actual air-flow PV is the "constraint."

- In some heating applications it may be desirable to control the temperature of the feed (the primary PV) as well as possible, without ever letting the temperature of the hottest part of the pot (or the heat exchanger) exceed a safe limit. In this case, the safe limit on the pot temperature is the "constraint."

- In an oven temperature-control application, the temperatures can be measured at several places in the oven, and it may be desirable to control all these PVs by controlling one valve. One PID controller can be used for each PV, and the PID controller representing the PV that is farthest from its SP can be allowed to control the valve. In this case, there is no primary PV, because all the PVs have the same importance. Each PID controller represents a constraint on the other PID controllers.

Most often the objective is to achieve the best possible control of a PV without violating any of the constraints. The manipulated variable is driven by the output of an Override Selector algorithm that selects the highest or the lowest of up to four inputs. A PID that is in a cascade strategy (but is not selected) is prevented from winding up with the help of override initialization. In the rest of this section, the term "O/R selector" is used to mean an Override Selector control algorithm that is configured for external initialization. Refer to the detailed description of the Override Selector algorithm in this section.

8.12.1 O/R Status and Feedback

Regulatory data points contain the following parameters to support O/R strategies:

**PTORST**—This parameter contains the O/R status of the point as follows:

- **NotCon**  The point is not connected to an O/R selector. Strictly, it means that this point is not on an initializable path to an O/R Selector or it is now being initialized. PTORST defaults to this value.

- **Sel**  The point is a part of an O/R control strategy and is now selected

- **NotSel**  The point is part of an O/R control strategy and is not selected by the O/R selector.
When the point is returned from inactive to active status, when it undergoes a cold start, or when it is initialized, the status in PTORST becomes NotCon.

The following two parameters apply only to the Override Selector Control algorithm:

**OROPT**— When on, the feedback value is propagated to non-selected primaries of the override selector algorithm. When Off, the feedback value is not propagated.

**OROFFSET**— When On, PID output is initialized to: Feedback Value + Gain * Error. When Off, PID output is initialized to only the Feedback value.

### 8.12.2 Processing in an Override Control Strategy

Figure 8-3 is an example of an O/R strategy. The override portion of the strategy includes the Override Selector point and all points "upstream" from it. Here is how O/R processing works:

- There must be at least one PID controller in the O/R strategy. In Figure 8-3 the points named TAG-A, TAG-B, TAG-C, TAG-D, and TAG-E constitute the O/R strategy.

- All points upstream of the O/R selector are processed on normal cycles (highest slot index to lowest). In the example, the points can be processed in TAG-D, TAG-A, TAG-B, TAG-C order. Their PV and control algorithms are executed normally.

- The next point to be processed is the O/R selector (TAG-E in the example). It selects one input. Assume input X2 is selected.

- The O/R selector then propagates appropriate O/R status to each one of its own initializing primaries. It also propagates the O/R-feedback value to the nonselected, initializing primaries. In the example, TAG-E propagates O/R status of Sel to TAG-C because input X2 is selected, and O/R-status Notsel to TAG-B. Further, TAG-E propagates the O/R-feedback value to the nonselected, initializing primary, TAG-B. TAG-D does not receive the O/R status nor the feedback value because it is not an initializing primary.

- Each primary (provided it is in Cas mode), in turn, propagates O/R status to its own primaries (if any). It also propagates O/R feedback upstream, if it is not selected. In the example, TAG-B would propagate Notsel and an O/R feedback value to TAG-A.

- The propagation upstream continues until there are no more primaries. The output of any PID in a cascade chain, connected to a nonselected input of the O/R selector is initialized to override-feedback value, plus gain times deviation (PV-SP) if OROFFSET is On. If OROFFSET is Off, it is initialized to the override-feedback value. Because TAG–A contains a PID algorithm and is not selected, it undergoes O/R initialization.
• The whole cycle is repeated.

• All points downstream of the O/R selector are processed at their specified interval. In the example, TAG-F is processed after TAG-E.

**NOTE**

The override status (Feedback Value) can be propagated to a maximum of five primaries.

If there are multiple O/R selectors in a strategy

O/R-feedback propagation is initiated by only the most downstream O/R selector. In the example, if TAG-F were also an O/R selector, the O/R strategy would consist of points TAG-A, TAG-B, TAG-C, TAG-D, TAG-E, and TAG-F. O/R propagation would be initiated by TAG-F and not TAG-E, as before.

Initialization in an Override Strategy

When a cascade is broken in an O/R strategy, initialization propagation supersedes O/R propagation. In the example, if point TAG-B is placed in Man mode, it doesn't propagate O/R status or an O/R-feedback value to TAG-A. TAG-A's O/R status then is Notcon.

![Diagram](image-url)
8.12.3 Guidelines for Using Override Control

You should follow these guidelines to configure properly functioning O/R strategies:

- **Proportional and Derivative Action on PIDs**—While PIDs in an O/R scheme can be configured with proportional and derivative action on SP, use of these actions should be carefully considered because undesired results may occur, such as momentary oscillation caused by "kicks" in the error.

- **Boundaries**—The entire O/R strategy must be within the same PM. The number of primaries for initiating the O/R strategy must be $\leq 5$.

- **Fanout**—No fanout control output connections are allowed in an O/R strategy. All primaries upstream from the O/R-selector point can have only one control output connection.

8.13 CONTROL ALGORITHMS

8.13.1 Proportional, Integral, Derivative (PID)

8.13.1.1 Function

This algorithm operates as a 3-mode (proportional, integral, and derivative) controller. You can choose one of two forms of this algorithm: the interactive (or real) form and the noninteractive (or ideal) form.

The output of this algorithm is normally "floating," because of the dynamics of the integral and derivative terms. Internally, the output is calculated as increments of output change, but the increments are accumulated to provide a full-value output, thus simplifying the techniques used to achieve "bumpless" outputs when modes or tuning constants are changed.

The algorithm operates to reduce error in the control loop to zero. Error is represented by the difference between the process variable in percent (PVP) and the setpoint in percent (SPP). The control-algorithm output value (CV) is also calculated as a percentage of the configured engineering-units range for the data point that uses this algorithm.
8.13.1.2 Use

The PID algorithm is used as a controller that either directly moves a control device (valve) in the process, or provides an input to another data point.

This algorithm requires only one input connection. The default for number of input connections is 1; however, it can be increased to 2, allowing the SP to be fetched with an input connection. When the SP is fetched, the normal operating mode of the point is usually affected.

When the PM's PID point is a primary for another data point in the same PM or another PM on the same UCN, its output is connected to the SP of the other data point (via Tagname.Parameter). If the PM's PID point is directly controlling a valve, its output is connected to the output of a Analog or Digital IOP (through "Tagname.Parameter" or the hardware reference address !AOmmSss.OP or !DOmmSss.OP where mm is the IOP card number in the PM, and ss is the slot number of the output on the IOP card).

If the PM point is a secondary for another data point, it can be configured to receive an input from another source. Sources include another data point on the same UCN, an AM data point, or a point properly configured in another CM with proper access level. If the remote cascade connection is coming from a regulatory data point in the AM, it handles everything automatically.

Figure 8-4 — Functional Diagram, PID Control Algorithm

PID Forms: Interactive (Real)  
Noninteractive (Ideal)

Equations:
A: Full PID
B: PI on error, D on PV change only
C: I on error, PD on PV change only
D: Integral control only

Feedforward Action: Additive, Scale and Add  
Multiplicative; Scale and Multiply
In all other cases (including the continuous CL programs in the AM directly writing to the PM), the user must explicitly take care to assure

- The remote device must use "continuous_control" access level for stores to SP, OP, and MODE parameters.
- It must also handle mode changes for closing the cascade. See 8.4.4, Remote Cascade Requests, for additional information.
- Initialization for bumpless mode transfers.
- Windup protection.

This algorithm supports all remote cascade options. PV source selection is supported if the point is configured "full." See 7.5, PV Source Selection, for details.

For additional information on restrictions on types and numbers of control output connections, see 8.9.6, Control Output Connections.

8.13.1.3 Options and Special Features

8.13.1.3.1 Interactive and Noninteractive PID Forms

During configuration, select one of these two forms. They differ as follows:

- Interactive (Real) Form—This form emulates traditional pneumatic-PID controllers. The P, I, and D terms are calculated as the sum of P and I, multiplied by D. D interacts in the time domain with the P and I terms. An advantage of this form is that the poles (lags) and zeros (leads) can be easily placed (see the equations under 8.13.1.4). The poles and zeros must be real.

- Noninteractive (Ideal) Form—in this form, P, I, and D are added in the time domain. D is added as a damped derivative to limit peak amplitude. This form is often called the digital-computer version of the PID controller.

8.13.1.3.2 Engineering Unit Ranges

The PV engineering unit range (PVEULO and PVEUHI) must be specified. The setpoint engineering unit range (SPEULO and SPEUHI) always follows the PV range. The output engineering unit range (CVEULO and CVEUHI) is derived from the secondary if the number of output connections is greater than 0, otherwise it must be specified.
8.13.1.3.3 Four Combinations of Control Terms

You select the combinations of proportion, integral, and derivative control terms by choosing Equation A, B, C, or D. The equations function as follows (also see 8.13.1.4):

- **Equation A**—all three terms (P, I, and D) act on the error (PV - SP).

- **Equation B**—The proportional and integral terms act on error (PV - SP) and the derivative acts on PV changes. This equation is used to eliminate derivative spikes in control action that occur with quick changes in the setpoint.

- **Equation C**—The integral term acts on error (PV - SP) and the proportion and derivative terms act on PV changes. This equation provides the smoothest and slowest response to setpoint changes.

- **Equation D**—This equation provides only integral control.

8.13.1.3.4 Control By a Single Term

When you use equation A, B, or C, the integral or derivative terms can be eliminated by setting their time constants to 0 (see 8.13.1.4). Setting both T1 and T2 to 0 results in only proportional control.

Use Equation D to achieve only integral control.

8.13.1.3.5 Direct and Reverse Control Action

When configuring a data point that uses the PID algorithm, you can select direct-control action or reverse-control action. You can also change the control action through the detail display if you have an engineer's key, or a user-written program can change the control action. The control action can be changed at the Universal Station or by a program, only while the data point is in Man mode. The attribute must be appropriate (Oper or Prog) for the change to be accepted.

Changing the control action effectively changes the sign of the gain. With direct action, an increase in PV increases output; with reverse action, an increase in PV decreases output.

As an example, with direct-control action, assume

\[
\text{SPP} = 50\% \\
\text{PVP} = 51\% \\
\text{Deviation} = \text{PVP} - \text{SPP} = 1\%
\]

If PVP increases, the deviation (error) increases, so the output, CV, increases (see Equation A under 8.13.1.4).

The opposite occurs with reverse-control action: If the deviation increases, CV decreases.
8.13.1.3.6 **PV Tracking**

PV tracking is configured by setting PVTRACK to Track. If configured, SP is set equal to PV when the cascade is broken by an operator, a program action, or when this data point is a secondary in a local cascade strategy and the cascade is momentarily interrupted by one-shot initialization; that is, when the following conditions exist

- The data point that uses this algorithm is in Man mode.
- The mode of this data point is Cas and RCASOPT = Ddc
- INITMAN = On, and either the mode is not Auto, or RCASOPT is not Rsp
- The first time the data point is processed after becoming active.
- This slot is a secondary within a local (inside the same PM) and is going through 1-shot control initialization.

**NOTE**

The 1-shot control initialization occurs when

- the control initialization request flag (CTRLINIT) is On
- this slot is being processed for the first time after the PM state has changed to RUN (OK)
- this slot has just recovered from a bad PV
- this slot has only one disposable secondary that just underwent 1-shot initialization

PV tracking is typically chosen when the data point is a secondary in a cascade control strategy, because it allows the PID to resume control with no error, after the point has been in Man mode or is initialized.

PV tracking can also be used when the data point is the ultimate primary point. In such a case, a startup procedure could be used where the point is started in Man mode and the valve manually adjusted to bring the PV close to the desired value, and the data point would then be switched to Auto.

PV tracking (even if configured) is not done on return from a Bad PV.
8.13.1.3.7 Gain Options

When configuring a data point that uses the PID algorithm, and equations A, B, or C, you can choose any of the following four gain options:

- **Linear Gain**—This is the most commonly used gain option. The gain, \( K \), used in the chosen equation (see 8.13.1.4) is set by the user. The default value for \( K \) is 1.

- **Gap Gain Modification**—This option is used to reduce the sensitivity of the control action when the PV is in a narrow band (gap) around the setpoint. The size of this band is specified by the user. \( K \), as used in the chosen equation is derived as follows:

\[
K = KLIN \times KGAP, \text{ if } (SP - GAPLO) \leq PV \leq (SP + GAPHI)
\]

or,

\[
K = KLIN, \text{ if } PV \text{ is outside the gap.}
\]

Where:

- **KLIN** = A linear-gain parameter, in percent-per-percent. The range of KLIN is 0.0 to 240.0, and the value is tuned at a Universal Station. Default = 1.0
- **KGAP** = Gain-modification factor, specified by the user. The range of KGAP is 0.0 to 1.0. Default = 1.0.
- **GAPLO** = The bottom limit of the gap in the same engineering units as the PV. GAPLO can be any value \( \geq 0.0 \). Default = 0.
- **GAPHI** = The upper limit of the gap in the same engineering units as the PV. GAPHI can be any value \( \geq 0.0 \). Default = 0.

- **Nonlinear Gain Modification**—This option provides control action proportional to the square of the error, rather than the error itself. The gain, \( K \), used by the chosen equation, is derived as follows:

\[
K = KLIN \times KNL
\]

\[
KNL = NLFM + NLGAIN \times \left( \frac{|PVP - SPP|}{100} \right)
\]

If the resulting value in \( K \) exceeds 240.0, it is clamped at 240.0.

Where:

- **KLIN** = Same as for gap gain
- **KNL** = Nonlinear-gain modifier
- **NLFM** = Nonlinear-gain form. 0 or 1, as specified by the user. Default = 1.
- **NLGAIN** = Gain modification factor. The range of NLGAIN is 0.0 to 10.0. Default = 1.0.
For the ideal form of the PID, nonlinear gain does not act on the derivative component.

\[ \text{NLGAIN} = \text{Nonlinear gain, specified by the user. Value ranges from 0.0 to 240.0. Default = 0.} \]
\[ \text{PVP} = \text{PV in percent} \]
\[ \text{SPP} = \text{SP in percent} \]

• External Gain Modification—The gain, \( K \), used by the chosen equation, is modified by an input value that can be from the process, from a PV calculated from a process input by a PV algorithm, or from a user-written program.

The main use of this option is to compensate for nonlinear-process gain. The user can tune the PID gain independently of the operating point of the process. For example, in controlling the level in a tank whose cross section is not constant, the gain could be modified to compensate for the nonlinear rate of level change that is caused by the changing shape of the tank. The General Linearization PV algorithm (subsection 7.9.8) could be used to compute the inverse of the level-change characteristic, and the resulting PV could be used to modify the level-control gain.

\[ K = \text{KLIN} \times \text{KEXT} \]

If the resulting value in \( K \) exceeds 240.0, it is clamped at 240.0.

Where:

\[ \text{KLIN} = \text{Same as for linear gain} \]
\[ \text{KEXT} = \text{The external gain-modification factor. It can be entered by a user-written program, or it can be a general input from another data point. KEXT must be a positive number. Default = 1.0.} \]

It is possible to use this option for multiplicative-feedforward control, but the PID with Feedforward-control algorithm (subsection 8.13.2) is a better choice because it provides a better operator interface and better recovery from a "bad" feedforward input.

8.13.1.3.8 Windup Handling

When the output of this algorithm reaches the user-specified output limits, or reaches the setpoint limits of the data point's secondary, or when a woundup-status indication is received from the secondary, the PID algorithm stops calculating the integral term but the calculation of the proportional and derivative terms continues.

This is the same way that windup conditions are handled in Basic Controllers, Multifunction Controllers, and Extended Controllers.
8.13.1.3.9 Suppression of Output "Kicks" When Switching to Cas Mode

Without this suppression feature, the first setpoint change after switching from Man or Auto to Cas mode could cause a sudden move (kick) in the output because of the proportional or derivative terms. This "kick" occurs when, for some reason, the primary data point's output is not initialized, and an abrupt change in the setpoint occurs when Cas mode resumes.

To suppress this "kick," the proportional and derivative terms are not calculated the first time the PID data point is processed after changing to Cas mode.

This feature is especially useful when the PID point is one of two or more secondaries of its primary data point. When this data point is changed to Cas mode, even if the primary is not initialized, the output of this data point does not bump the first time it is processed.

8.13.1.3.10 Initializing PID Output Without Affecting Dynamics

A logic slot or a user-written program in the PM, AM, or a CM (FORTRAN or Pascal) can store a value in the CV parameter of the PID data point, even while the algorithm is doing its normal, incremental PID calculation. This may change the full-value output of the data point, but it has no effect on the continuing incrementation or decrementation of the output. It is possible, therefore, for a user-written program to initialize a PID output without affecting the dynamics of the PID calculations, and without initializing the output of the primary data point.

As an example of the usefulness of this feature, consider a single PID that is controlling temperature by controlling the flow of either gas or oil. This PID's output is connected to both flow controllers, but only one secondary is in cascade at any time. When a change from one fuel to the other is made, the user-written program initializes the output of the temperature-controller PID by storing a new, full-value output in CV. The cascade connection is switched from one to the other, and the dynamic compensation of the flow of the new fuel proceeds. The value stored in CV is the setpoint of the new secondary in percent (SPP). Through this technique, the full-value output of the primary has been initialized without affecting its dynamic calculations, so the fuel switchover is quick and smooth.
8.13.1.3.11 Restrictions on Some Values

The following are restrictions on some of the values used with this algorithm:

- The engineering units range that you specify for the PV also applies to the SP.

- For best performance, we recommend that the integral (T1) and derivative (T2) time constants be within the following ranges:

\[
T1 > 20.0 \times TS \\
T2 > 100.0 \times TS \text{ for the interactive form of the PID, and} \\
T2 > 10.0 \times TS \text{ for the noninteractive (ideal) form of the PID}
\]

Where TS = the interval at which the data point is processed, in minutes.

For the interactive form of the PID,

\[
\text{If } T1 > 0 \text{ but } < 2.0 \times TS, \text{ it is clamped to } 2.0 \times TS \\
\text{If } T2 > 0 \text{ but } < 10.0 \times TS, \text{ it is clamped at } 0.0
\]

8.13.1.3.12 Bias Options

Ratio control can be achieved by modifying the setpoint input to the PID algorithm by a RATIO of some other process point that is stored to through a control output connection, for example, a fuel-to-air ratio in furnace control (it can also be accomplished with the Ratio Control algorithm. See 8.13.5). When configuring a PID data point, you can select one of the following options for modifying the setpoint through the RBOPT parameter:

- No ratio or bias
- Fixed ratio and bias
- Auto ratio (fixed bias)
- Auto bias (fixed ratio)

If you select one of the ratio and bias options, configured or operator-entered ratio and bias values are used to modify the setpoint (by multiplying it by the ratio and adding the bias value) only while the data point is in Cas mode. In Auto mode, the ratio calculation does not occur because this option is intended to receive the process value to be modified by the ratio, only from another data point (which can happen only in the Cas mode).
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The "Auto ratio and Auto bias" options adjust the ratio or bias while the data point is in Auto or Man modes, or is undergoing initialization, so that when it returns to Cas mode, the new SP won't "bump" the process. The adjustment is as follows:

- For Auto ratio, the operator can change only bias, and ratio is calculated to maintain the same setpoint when the mode is changed to Cas. The operator can change the ratio in Cas mode.

- For Auto bias, the operator can change only ratio, and bias is calculated to maintain the same setpoint when the mode is changed to Cas. The operator can change the bias in Cas mode.

Modification of the setpoint by a ratio and a bias is actually handled by setpoint processing rather than by the PID algorithm. It is applied to only PID setpoints.

These options allow this one algorithm to perform PID Ratio, PID Auto Ratio, and PID Auto Bias functions.

The parameters used for these options are RBOPT, RATIO, BIAS, RTHILM, RTLOLM, BSHILM, and BSLOLM.

8.13.1.3.13 Operating Modes

The PID algorithm operates in the following modes:

- Man
- Auto
- Cas
- Bcas — If RCASOPT = Spc or Ddc or DdcRsp

8.13.1.3.14 Remote Cascade Options

All Remote Cascade Options are supported: Spc, Ddc, DdcRsp and Rsp.

8.13.1.3.15 Restart or Point Activation

On a warm restart, or when the data point is activated, initialization takes place as described under 8.13.1.5.

8.13.1.3.16 Error Handling

If the status of the PV value goes bad, the CV value is changed to bad (NaN) and the data point remains in the current mode. When the PV-value status returns to normal, the CV value is initialized and the PID dynamics are returned to a steady state. An initialization request and initialization value are sent to the primary data point.
8.13.1.4 Equations

You can select one of four equations when you configure a data point that uses the PID control algorithm. Equations A through D differ in the interactive and noninteractive forms of the algorithm.

For the Interactive form:

**Equation A** — P, I, and D act on the error

\[
CV_s = K \times \left[ \frac{1 + T_1 \times s}{T_1 \times s} \times \frac{1 + T_2 \times s}{1 + a \times T_2 \times s} \times (PVP_s - SPP_s) \right]
\]

**Equation B** — P and I act on error, D acts on PV

\[
CV_s = K \times \left[ \frac{1 + T_1 \times s}{T_1 \times s} \times \frac{1 + T_2 \times s}{1 + a \times T_2 \times s} \times PVP_s - \frac{1 + T_1 \times s}{T_1 \times s} \times SPP_s \right]
\]

**Equation C** — I acts on error, P and D act on PV

\[
CV_s = K \times \left[ \frac{1 + T_1 \times s}{T_1 \times s} \times \frac{1 + T_2 \times s}{1 + a \times T_2 \times s} \times PVP_s - \frac{1}{T_1 \times s} \times SPP_s \right]
\]

**Equation D** — Integral control, only

\[
CV_s = \left[ \frac{1}{T_1 \times s} \times PVP_s - SPP_s \right]
\]

For the Noninteractive form:

**Equation A** — P, I, and D act on the error

\[
CV_s = K \times \left[ \left( \frac{1 + T_1 \times s}{T_1 \times s} + T_2 \times s \right) \times (PVP_s - SPP_s) \right]
\]

**Equation B** — P and I act on error, D acts on PV

\[
CV_s = K \times \left[ \left( \frac{1 + T_1 \times s}{T_1 \times s} + T_2 \times s \right) \times PVP_s - \frac{1 + T_1 \times s}{T_1 \times s} \times SPP_s \right]
\]

**Equation C** — I acts on error, P and D act on PV

\[
CV_s = K \times \left[ \left( \frac{1 + T_1 \times s}{T_1 \times s} + T_2 \times s \right) \times PVP_s - \frac{1}{T_1 \times s} \times SPP_s \right]
\]
Equation D — Integral control, only

\[ CV_s = \frac{1}{T_1} * s * (PVP_s - SPP_s) \]

Where:

- \( CV \) = Output of the PID algorithm, full value in percent
- \( a \) = A constant equal to 0.1. \( 1/a \) is the high-frequency gain or rate amplitude.
- \( K \) = Gain. See 8.13.1.3.7.
- \( PVP \) = The process variable in percent
- \( s \) = The Laplace operator
- \( SPP \) = The setpoint in percent
- \( T_1 \) = The integral time constant in minutes per repeat for interactive form. See 8.13.1.3.11, Restrictions on and Recommendations for Some Values.
- \( T_2 \) = The derivative time constant in minutes. See 8.13.1.3.11, Restrictions on and Recommendations for Some Values.

8.13.1.5 Initialization

When the output destination of the primary is to the secondary, initialization occurs as follows:

- When the control initialization request flag (CTRLINIT) is on
- When this slot is being processed for the first time after the PM state (PMSTS) has changed to Run or OK
- When this slot is just recovering from a Bad PV
- When this slot has only one disposable secondary that just underwent 1-shot initialization
- When the output is indisposable (when the mode of the secondary slot is not in Cas)
8.13.1.6 Override Feedback Processing

When a PID point's secondary uses an Override Selector algorithm (see Figure 8.5), the following functions take place:

• When override feedback is propagated, override status is returned in PTORST to the PID point. The status is one of these.
  
  Not Connected
  Selected
  Not Selected

• When the PID point is processed, it does the following.

  If the status returned is Not Connected, there is no action.

  If the status returned is Not Selected and if the PID point's mode is Auto or Cas and CV is not equal to NaN, the PID point's CV is initialized as follows:

  IF OROFFSET = On, CV = ORFBSEC* + GAIN * ERROR

  \[ CV = ORFBSEC + K \times (PVP - SPP) \]

  where \( K \times (PVP - SPP) \) = offset value if the direct-control option is chosen, or

  \[ CV = ORFBSEC - K \times (PVP - SPP) \]

  if the reverse-control option is chosen.

  IF OROFFSET = Off

  \[ CV = ORFBSEC \]

  where ORFBSEC is the override-feedback value (in %) sent to the PID from the secondary.

  When the PID point is not selected, if it is in Cas mode an override-feedback value is calculated as follows and sent to the primary:

  If RBOPT is not equal to NoRatBi

  \[ ORFB = \frac{PV - BIAS}{RATIO} \]

  otherwise, \( ORFB = PV \)

  Note that if equation D is selected, \( K=1 \) in these equations.

\*ORFBSEC is not an external parameter
The not connected/not selected/selected status received from the PID's secondary, is also sent on to the primary.

**NOTE**

If the offset value is in such a direction that it causes the nonselected PID to become selected, the offset values will be set to 0.0.

See 8.12, Override Control, for more information on override control.

**8.13.1.7 PID Parameters**

In addition to the parameters already mentioned, the following parameters are associated with the PID algorithm (refer to the *Process Manager Parameter Reference Dictionary*):

- CTLEQN
- PVTRACK
- DEV
- DELCV

Deviation (DEV) and incremental output (DELCV) are accessible parameters.

**8.13.1.8 Control Output Connections**

Control outputs can be to the following destinations:

- **SP, RATIO, X1, X2, X3, and X4 parameters of another control slot in the same PM box.**

  When output connections are made to RATIO, the secondary mode should be Cas and MODATTR should be PROGRAM and RBOPT should be AutoRat.

- **SP of a control slot in another PM (or APM) box on the same Universal Control Network.**

  Note that such a connection counts as one output and one input for the purpose of limiting the number of UCN connections.

When output connections are not to any of the above, they can be to

- **OP parameter of an analog output slot inside an AO IOP in the same PM box.** AO point must be configured as a component point.

- **OP parameter of a digital output slot (configured for DOTYPE = PWM ) in the same PM box.**

- **Any addressable parameter of any accessible slot if the control algorithm is PID with external reset feedback.**

Output does not go to a device on the Data Hiway (MC, EC, CB).

* See 8.9.6, Control Output Connections, for restrictions and additional information.
8.13.2 PID with Feedforward (PIDFF)

8.13.2.1 Function

This algorithm operates as a 3-mode (proportional, integral, and derivative) controller. It is identical to the PID algorithm (8.13.1), except that it accepts a feedforward signal to be added to, or multiplied by, the algorithm's incremental output, before the full-value output is accumulated. This algorithm lets you combine a feedforward signal with the PID output without using another data point or algorithm to do it.

8.13.2.2 Use

The use of the PID Feedforward Control algorithm is the same as the PID algorithm, except that this algorithm can accept a dynamic feedforward signal from the process, or a value that is representative of some condition in the process, to be combined with the PID's incremental output before the full-value output is accumulated.

This algorithm requires two input connections (from PV processing and FF inputs). The inputs can be increased to three, allowing the SP to be fetched with an input connection.

The feedforward signal can be obtained from an analog-input point, and it is often subjected to dead-time compensation or lead-lag compensation before being connected to the FF input of this algorithm. That compensation can be provided by algorithms such as the Variable Dead-Time with Lead-Lag Compensation PV algorithm (7.7.6). Figure 8-7 shows an example of such a strategy.

If additive-feedforward action is chosen, the feedforward signal is multiplied by a user-specified scale factor (KF) and added to the incremental output of the PID computation. This scale factor might be used to convert an engineering-units input to a percentage.
If multiplicative feedforward action is chosen, the feedforward signal is multiplied by the scale factor (KF) and then multiplied by the full-value output of the PID computation. This action is typically used to compensate for variations in process gain that are caused by changes in throughput. For example, if the feed rate is doubled in a heating application, twice the amount of fuel might be required, which is the equivalent to doubling the process gain.

This algorithm supports all remote cascade options and PV source selection (if the point is configured as a full point).

8.13.2.3 Options and Special Features

All of the following PID Control-algorithm options and special features apply to the PID Feedforward Algorithm:

- 8.13.1.3.1 Interactive and Noninteractive PID Forms
- 8.13.1.3.2 Engineering Unit Ranges
- 8.13.1.3.3 Four Combinations of Control Terms
- 8.13.1.3.4 Control By a Single Term
- 8.13.1.3.5 Direct and Reverse Control Action
- 8.13.1.3.6 PV Tracking
- 8.13.1.3.7 Gain Options
- 8.13.1.3.8 Windup Handling
- 8.13.1.3.9 Suppression of Output "Kicks" when Switching to Cas Mode
- 8.13.1.3.10 Initializing PID Output Without Affecting Dynamics, except where multiplication of the feedforward signal is configured
- 8.13.1.3.11 Restrictions on Some Values
- 8.13.1.3.12 Ratio Control
- 8.13.1.3.13 Operating Modes; Man, Auto, and Cas
- 8.13.1.3.14 Remote Cascade Options
- 8.13.1.3.15 Restart or Point Activation
- 8.13.1.3.16 Error Handling
8.13.2

PID Forms: Interactive (Real)
Noninteractive (Ideal)

Equations:
A: Full PID
B: PI on error, D on PV change only
C: I on error, PD on PV change only
D: Integral control only

Feedforward Action: Additive, Scale and Add
Multiplicative; Scale and Multiply

Figure 8-6 — Functional Diagram, PID Feedforward Control Algorithm

Figure 8-7 — Example, PIDFF Control Algorithm in Feed Heater Control
8.13.2.3.1 Add or Multiply Action

Parameter FFOPT is configured to specify whether the feedforward signal is to be added to the incremental PID output or multiplied by it.

8.13.2.3.2 Bypassing Feedforward Control Action

An operator at a Universal Station or a user-written program can bypass the feedforward action by one of the following:

- If the feedforward signal comes from a PV algorithm, switch the PV source for the data point that is using the PV algorithm to Man (if you do this and the PV is changed while the PVSOURCE is Man, the feedforward signal is affected). To resume feedforward action, switch the PVSOURCE back to Auto.

- If the feedforward signal comes from a control algorithm, switch the mode of the data point that is using the control algorithm to Man (if you do this and the output (OP) is changed while the source point is in manual, the feedforward signal is affected). To resume feedforward action, switch back to Normal mode (Auto or Cas).

8.13.2.3.3 Feedforward Signal Value Status

If the value status for the feedforward signal goes bad, the feedforward component of the output value is frozen at the last good value and normal PID processing continues.

When the value status of the feedforward signal returns to normal, normal feedforward action resumes. This does not cause a bump in the output because any change from the last good value is internally absorbed and the PID dynamics are not affected. The floating, full-value output continues as if there were no feedforward change, but the contribution of the feedforward action continues from that time.

8.13.2.3.4 Operating Modes

The PIDFF algorithm operates in the following modes:

- Man
- Auto
- Cas
- Bcas — If RCASOPT = Spc or Ddc or DdcRsp

8.13.2.3.5 Remote Cascade Options

All Remote Cascade Options are supported: Spc, Ddc, DdcRsp and Rsp.
8.13.2.4 Equations

You can select PID equations, just as described for the interactive form and the noninteractive form under 8.13.1.4.

In addition, the feedforward signal is applied to the incremental output of the PID computation, as follows:

- If additive action is configured
  \[ CV_n = CV_{n-1} + DELCV + KFF \times (FF_n - FF_{n-1}) \]
  \[ DELCV = \text{Incremental output} \]
  If the status of FF\(_n\) or FF\(_{n-1}\) is Bad,
  \[ CV_n = CV_{n-1} + DELCV. \]

- If multiplicative action is configured
  \[ CVPI = CVPI + DELCV \]
  \[ CV = CVPI \times (KFF \times FF_n + BFF) \]

When multiplicative action is configured, CV is a read-only parameter for CL programs.

If the status of FF\(_n\) is Bad,
\[ CV = CVPI \times (KFF \times FF_{l_{g_{v}}} + BFF), \]
where FF\(_{l_{g_{v}}} = \text{last good value of FF.} \)

If FF\(_n\) is OK but the status of FF\(_{n-1}\) is bad,
\[ CVPI = \frac{CV}{KFF \times FF_n + BFF} \]

Note that the back calculation of CVPI keeps CV unchanged, and thus, prevents a bump.

If the result of (KFF \* FF\(_n\) + BFF) is less than 0.01, it is clamped at 0.01.

Where:

- \( CV = \) Full-value output in percent, PID combined with feedforward action
- \( CVPI = \) The full value output before the multiplicative term. This is an internal parameter and is not available to displays nor to user-written programs.
- \( DELCV = \) The incremental output of PID computation. Default = N/A.
- \( BFF = \) Bias value for multiplicative action. Default = 0.
$\text{FF} = \text{The feedforward input signal, from a control-input connection. Normally from a parameter with a percentage value. Default = N/A}$

$\text{FF lgv} = \text{Last good value for the FF input (notation only, not a user-visible parameter).}$

$\text{KFF} = \text{Scale factor applied to FF. Normally the source parameter is in units of percent. However, if it isn't, KFF can be used as an EU to percent conversion factor. In this case, KFF is set to:}$

$$\frac{100}{\text{EUHI} - \text{EULO}}$$

$\text{Where EUHI and EULO correspond to the EU range of the source parameter.}$

$n \text{ and } n-1 = \text{Notation to indicate the value this pass (n) and the preceding pass (n-1).}$

**8.13.2.5 Initialization**

Initialization is as described under 8.13.1.5.

**8.13.2.6 Override Feedback Processing**

Override-feedback processing is the same as described under 8.13.1.6, except that, if multiplicative action is configured, a feedforward term is added to the output calculation, as follows:

If the status returned is not selected and if the PID point's mode is Auto or Cas and CV is not equal to NaN, the PID point's CV is initialized as follows:

If OROFFSET = On

$$\text{CV} = \text{ORFBSEC} + K \times (KFF \times \text{FF} + \text{BFF}) \times (\text{PVP} - \text{SPP})$$

if the direct-control option is chosen, or

$$\text{CV} = \text{ORFBSEC} - K \times (KFF \times \text{FF} + \text{BFF}) \times (\text{PVP} - \text{SPP})$$

if the reverse-control option is chosen.

$\text{ORFBSEC}^{*}$ is the override-feedback value from the secondary in percent

If OROFFSET = Off

$$\text{CV} = \text{ORFBSEC} + (KFF \times \text{FF} + \text{BFF})$$

If direct-control option is chosen, or

$$\text{CV} = \text{ORFBSEC} - (KFF \times \text{FF} + \text{BFF})$$

if reverse-control option is configured.

$^{*}\text{ORFBSEC is not an external parameter}$
8.13.3 PID with External Reset-Feedback (PIDERFB)

8.13.3.1 Function

This algorithm operates as a 3-mode (proportional, integral, and derivative) controller. It is identical to the PID algorithm (8.13.1), except that it accepts a reset feedback signal to be combined with this algorithm's incremental output, before the full-value output is accumulated. It also accepts a tracking-value signal.

The intent of this algorithm is to prevent windup when it has a secondary data point, typically a PID point, that may or may not be responding to the output of this data point.
8.13.3.2 Uses

The use of the PID with External Reset-Feedback algorithm is the same as the PID algorithm, except that this algorithm can accept a reset-feedback signal (RFB) from another data point, typically the PV of the secondary PID data point that is receiving its setpoint from this data point.

This algorithm requires three input connections:

- From PV Processing (PVAUTO)
- RFB (Reset Feedback Value) — typically from the PV of another data point which is receiving its setpoint from this data point
- TRFB (Tracking Value) — typically the PV or SP of another data point that is receiving its setpoint from this data point.

Output destination can be to a secondary data point in the PM or to any desired destination using control output connection (that is, any addressable parameter of any accessible slot).

The number of inputs can be increased to four, allowing the SP to be fetched with an input connection.

The tracking switch-control signal (S1) is usually stored with an output connection from a Logic slot (or a program). If the switch control is On, the CV value from this data point is replaced by the tracking value. If, for some reason, the secondary is not using the output of this data point, S1 can be set to On by logic external to the PIDERFB, which causes this point's CV to track the secondary's PV. When the secondary begins to accept OP from this point for control, S1 is set to Off (by the external logic), and CV is then at the same value as the controlled variable (PV), so there is no bump and normal control can resume.

In a simple application, both the reset-feedback signal and the tracking value may come from the PV of the secondary data-point. See Figure 8-9.
8.13.3.2.1 Use of Hand/Auto Stations

The following functions will be supported by the PM to integrate a third-party hand/auto station:

- **OUTPUT** Ability to manipulate the output of the hand/auto station (when in Auto position) from the PID, and to initialize the PID output to allow the hand/auto station to switch bumplessly to auto position.

- **MODE** Indication that the hand/auto station is in "hand" (or Local Manual) position at the group display of the PID driving the output.

- **PV and SP** Indication of PV and SP at the hand/auto station, and optionally the ability to raise or lower the PID SP from the hand/auto station. PV and SP may be from the PID driving the output, or from a different PID. For example, in a single loop case, the PV, SP and output all come from the same PID, but in case of a temperature flow cascade, the PV and SP come from the temperature controller, and the output is driven by the flow controller.

In order for the interface to be generic (to allow support for hand/auto stations from many different vendors), all signals are wired into the PM through analog and digital IOPs. This requires a total of two AI slots, one AO slot, and two DI slots in addition to the requirements if no hand/auto station support is desired.
**Interface Requirements for Hand/Auto Station**

The following I/O signals must be supported by the third-party hand/auto station:

- **PV_IN**: Analog input used to display the PV value on the hand/auto station. The signal from the analog transmitter is wired into this input as well as to the PM through an AI IOP.

- **CV_IN**: Analog input from the controller. It represents the control value position requested by the PM's PID.

- **CV_OUT**: Analog output. This output drives the control valve. When the hand/auto station is in auto position, CV_OUT should track the CV_IN input; when in local manual position, it can be manipulated by the raise/lower keys. This output is also fed back to the PM through an AI IOP for initialization of the PID output. The corresponding AI FTA must not be grounded (the zero-ohm resistor to ground at the FTA should be removed). Also the output current drive capability of the hand/auto station must be sufficient to handle an additional 250 ohm resistor used to convert 4-20 milliamps to 1-5 volts.

- **MAN_STS**: Digital output indicating that the hand/auto station is in local manual position.

- **SP_IN**: Analog input used to display the SP value on the hand/auto station. The setpoint of the PM's PID controller is connected to this input through an AO IOP.

  NOTE: This is not required if SP raise/lower capability is not to be supported.

- **SP_OUT**: Analog output generated by the hand/auto station to change the SP value of the PM's SP.

- **SP_CHNG**: Digital output requesting the PM to accept a new SP (equal to SP_OUT) from the hand/auto station.

  NOTE: This is not required if SP raise/lower capability is not supported.
8.13.3 Options and Special Features

All of the following PID Control-algorithm options and special features apply to the PID with External Reset Feedback algorithm:

- 8.13.1.3.1 Interactive and Noninteractive PID Forms
- 8.13.1.3.3 Four Combinations of Control Terms
- 8.13.1.3.4 Control By a Single Term
- 8.13.1.3.5 Direct and Reverse Control Action
- 8.13.1.3.6 PV Tracking
- 8.13.1.3.7 Gain Options
- 8.13.1.3.9 Suppression of Output "Kicks" when Switching to Cas Mode
- 8.13.1.3.11 Restrictions on Some Values
- 8.13.1.3.12 Ratio Control
- 8.13.1.3.13 Operating Modes; Man, Auto, Cas and Bcas
- 8.13.1.3.14 Remote Cascade Options
- 8.13.1.3.15 Restart or Point Activation
- 8.13.1.3.16 Error Handling

8.13.3.3.1 Error Handling, RFB and TRFB Inputs

If S1 is Off, and the reset-feedback input has a bad value, the data-point mode doesn't change and the CV value goes bad (NaN). When the RFB input is again good, the CV value is initialized (see 8.13.1.5) and the dynamic terms are returned to a steady state. If configured for external initialization, an initialization request is sent to the primary data point.

If S1 is On, and the tracking-value input has a bad value, the data-point mode doesn't change and the CV value goes bad (NaN). When the TRFB input is again good, the CV value is initialized (see 8.13.1.5) and the dynamic terms are returned to a steady state. If so configured, an initialization request is sent to the primary data point.
NOTE: #1 SP, AND PV MAY BE CONNECTED TO THE PID_SEC IN A SINGLE LOOP CONTROL SITUATION.

#2 SEE THE NEXT PAGE FOR DETAILS OF THE LOGIC SLOT CONFIGURATION.

Figure 8-10 — Configuration and Wiring Diagram Hand/Auto Station
8.13.3.2 Output Connections

The output of this algorithm can be to any desired destination using control output connections.

NOTE

Initialization and windup protection normally associated with control output connections are not performed with this algorithm. That is, initialization occurs only when S1, the tracking switch-control signal, is true.

Output connections store the value of the OP after converting to engineering units.

See 8.9.6, Control Output Connections, for restrictions on the number of output connections and destinations for this algorithm.

8.13.3.3 Engineering Unit Ranges

PV Engineering unit range (PVEULO and PVEUHI) and the output engineering unit range (CVEULO and CVEUHI) must be specified. The SP engineering unit range (SPEULO and SPEUHI) always follows the PV range.

8.13.3.4 Operating Modes

The PIDERFB algorithm operates in the following modes:

- Man
- Auto
- Cas
- Bcas — If RCASOPT = Spc or Ddc or DdcRsp
8.13.3.5 Remote Cascade Options

All Remote Cascade Options are supported: Spc, Ddc, DdcRsp and Rsp.

8.13.3.4 Equations

If the value in the S1 parameter is On,

\[ CV = \frac{TRFB - CVEULO}{CVEUHI - CVEULO} \times 100 \]

For equations A, B, and C, if the S1 value is Off,

\[ CVRFB(s) = K \times \frac{K1}{T1} \times \frac{1}{s} \times (rfb(s) - CV(s)) \]

For equation D, if the S1 value is Off,

\[ CVRFB(s) = K \times \frac{1}{T1} \times \frac{1}{s} \times (rfb(s) - CV(s)) \]

\[ CV = CVPID + CVRFB \]

Where:

- **CV** = Full-value output in percent, PID combined with CVRFB.
- **CVPID** = The incremental output of the PID computation. This is an internal parameter and is not available to displays nor to user-written programs.
- **CVRFB** = The scaled, integrated deviation of RFB from CV. This is an internal parameter and is not available to displays nor to user-written programs.
- **K** = Gain
- **K1** = External, reset-feedback gain
- **RFB** = The external, reset-feedback signal in engineering units. Default = NaN.
- **rfb** = \( \frac{RFB - CVEULO}{CVEUHI - CVEULO} \times 100 \)
- **s** = The Laplace operator.
- **S1** = The switch-control flag. Default = Off.
- **TRFB** = The tracking value in engineering units. Default = NaN.
- **T1** = The integral term in minutes per repeat.
8.13.3.5 Initialization

Initialization normally associated with output connections is not performed with this algorithm. Output connections store the value of the OP (after converting to engineering units based on CVEULO and CVEUHI) to the secondary.

8.13.3.6 Override Feedback Processing

Override-feedback processing is as described under 8.13.1.6; however, use of PIDERFB in override strategies is not recommended.

8.13.4 Position Proportional Controller (POSPROP)

8.13.4.1 Function

This algorithm manipulates two digital outputs, raise and lower, to drive the PV toward the SP. The setpoint is typically the desired position of a valve and the PV is the actual feedback from the process.

Digital outputs are pulsed at a time interval specified by the CYCLETIME parameter and the pulse width is proportional to the error signal.

This algorithm requires only one input. The number of inputs is defaulted to one; however, the SP can be fetched with an input connection. PV Source selection is supported if the point is configured as a full point. The Advisory (ASP) and Target Value (TV) options of SPOPT (Setpoint Option) are supported.

The Raise/Lower digital outputs are stored to the destinations specified by the parameters RAISDSTN and LOWRDSTN respectively. The only valid output destinations are to pulsed (but not PWM type) digital outputs. The pulse can be ONPULSE or OFFPULSE.

See Figure 8-12.

![Figure 8-12 — Position Proportional Algorithm Functional Diagram](image-url)
8.13.4.2 Use

This algorithm is used to pulse two digital outputs to drive the process variable toward the setpoint. This algorithm would typically be used to step a valve open or closed, to raise or lower a rotary device, or to move plates of a pulp mill refiner together or apart.

8.13.4.3 Options and Special Features

8.13.4.3.1 Modes

All four modes (Man, Auto, Cas, and Bcas) apply. When in Auto, Cas or Bcas modes, the normal computation is performed. When in Man mode, the output pulses are issued on operator demand.
8.13.4.3.2 *Remote Cascade Options*

Only the SPC option is supported.

8.13.4.3.3 *Output Manipulation in Manual Mode*

In Manual mode, the output can be manipulated from the group and detail displays using the Raise/Lower keys. At the time of configuration, the engineer must define "manual output pulse time (MANOPTIM)." When the operator presses the Raise key (single up-arrow), raise output pulse of width equal to MANOPTIM is issued. When the operator presses the fast raise key (double up-arrow), raise output pulse to width equal to 10 times MANOPTIM is issued. Lower output pulses can be similarly generated.

8.13.4.3.4 *Windup Feedback Limit Switches*

Output high and low flags can be set to indicate the status of the limit switches representing the valve position. When OPHIFL is set, the Raise output pulses are not generated. When OPLOFL is set, Lower output pulses are inhibited.

OPHIFL and OPLOFL are usually set by output connections on Logic slot based on limit switch feedback (brought into the system through digital inputs) from the process.

**NOTE**

In manual mode, the operator can manipulate the output Raise/Lower pulses regardless of the status of the OPHIFL and the OPLOFL.

8.13.4.3.5 *Raise/Lower Output Destinations*

The Raise/Lower digital outputs are stored to the destinations specified by RAISDSTN and LOWRDSTN, respectively. The only valid outputs are to ONPULSE or OFFPULSE of digital outputs configured as Status type.

8.13.4.3.6 *Setpoint Options*

Both options, advisory setpoint (ASP) and target value (TV), are supported.

8.13.4.3.7 *PV Source Selection*

PV source selection and PV alarm reporting are supported.
8.13.4.3.8  Engineering Unit Ranges

The PV Engineering unit ranges (PVEULO and PVEUHI) must be specified. The setpoint engineering unit range (SPEULO and SPEUHI) always follows the PV range. The output engineering unit range (CVEULO and CVEUHI) does not apply.

8.13.4.3.9  Analog Output Related Parameters

The standard control slot parameters that are normally related to the analog output value do not apply because analog outputs are not valid destinations for outputs from this algorithm. The OPHIFL and OPLOFL are explained under 8.13.4.3.4. Other parameters associated with analog outputs cannot be fetched or stored by any system function. Internally, they are defaulted such that they do not have any effect on the system functions.

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<th>PARAMETER NAME</th>
<th>INTERNALLY DEFAULTED TO</th>
</tr>
</thead>
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<tr>
<td>CVEUHI</td>
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</tr>
<tr>
<td>CVEULO</td>
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<td>-6.9% of Full Scale</td>
</tr>
<tr>
<td>OPEU</td>
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<td>OPROCLM</td>
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<tr>
<td>OPMCHLM</td>
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</tr>
<tr>
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<tr>
<td>NOCOPTS</td>
<td>1</td>
</tr>
<tr>
<td>INITMAN</td>
<td>Off</td>
</tr>
</tbody>
</table>
8.13.4 Equations

Only one equation is available. The equation is calculated as follows:

The raise and lower pulses are generated at a rate specified by the cycle time. At the beginning of each cycle time, the pulse width is calculated and the digital outputs are pulsed as follows:

If CYCLE_TIMER expired:

IF (PVP < (SPP - DEADBAND)) AND (OPHIFL = Off) THEN

Issue a raise pulse of width equal to:

\[ \text{RAISETIM} = K \times \frac{(SPP - PVP)}{\text{RAISRATE}} + \text{DEADTIME} \]

ELSE IF (PVP > (SPP + DEADBAND)) AND (OPLOFL = Off) THEN

Issue a lower pulse of width equal to:

\[ \text{LOWERTIM} = K \times \frac{(PVP - SPP)}{\text{LOWRRATE}} + (RT \times \text{DEADTIME}) \]

ELSE Reset the cycle timer to the beginning.

Where:
- **PVP** = PV in percent
- **SPP** = SP in percent
- **DEADBAND** = the error deadband in percent (Range = 0.0 to 100.0; Default = 5.0)
- **OPHIFL** = High output windup flag
- **OPLOFL** = Low output windup flag
- **CYCLETIM** = the cycle time in seconds. Range: 0.25 to 1000.0; Default = 10.0
- **RAISRATE** = the raise stroke rate in percent per second. Default = 100.0% per sec
  Range: greater than 0.0
- **LOWRRATE** = the lower stroke rate in percent per second.
  Range: greater than 0.0. Default = 100.0% per second
- **RAISETIM** = the raise pulse time in seconds. Default = N/A.
  It is clamped to the lower of MAXPULSE or CYCLETIM. If smaller than MINPULSE, no pulse is issued.
- **LOWERTIM** = the lower pulse time in seconds. Default = N/A
  It is clamped to the lower of MAXPULSE or CYCLETIM. If smaller than RP*MINPULSE, no pulse is issued.
- **K** = Gain constant (Range = 0.0 to 10.0; Default = 1.0)
- **RP** = Pulse ratio (Default = 1)
- **RT** = Deadtime ratio (Default = 1)
- **DEADTIME** = Additional pulse time required to overcome friction in the motor when it begins to move or change direction. It is added to the computed pulse time except when the pulse issued last cycle time was in the same direction (as the pulse this time) and the pulse width was equal to CYCLETIM. Default = 0.0
- **MAXPULSE** = Maximum pulse time limit. If computed pulse time is greater than this, it is clamped to the lower of MAXPULSE or CYCLETIM. Default = 60 seconds
- **MINPULSE** = Minimum pulse time limit for raise pulse. If computed pulse is smaller than this, no pulse is issued. Default = 0.0 seconds.
8.13.4 Initialization

The Raise and Lower outputs are both set to OFF (or their normal states) and the cycle is restarted when forward calculation is resumed after initialization.

The SP is set equal to the PV (subject to the setpoint limits) when any of the following conditions exist:

- The mode is Man.
- The slot is being processed for the first time after becoming active.
- This slot is a secondary within a local (inside the same PM box) cascade control strategy, and it is going through one-shot control initialization.

NOTE

The one-shot control initialization occurs:

- when the control initialization request flag (CTRLINIT) is On,
- when this slot is being processed for the first time after the PM state has been changed to RUN (Ok),
- when just recovering from a bad PV.

The position proportional control algorithm is forced to initialize when outputting to a digital output point that has its INITREQ parameter = ON.

8.13.5 Ratio Control (RATIOCTL)

8.13.5.1 Function

This algorithm calculates a setpoint for a PID algorithm that is the desired ratio of a controlled variable to an uncontrolled variable. The value of the controlled variable is maintained at a specified ratio of the value of the uncontrolled variable. The data point that uses this algorithm usually uses Calculator PV algorithm to calculate the measured value of the ratio for displays and reports.

Ratio control can also be accomplished with the ratio-bias options of the PID or PID Feedforward control algorithms (see 8.13.1, 8.13.2). This Ratio-control algorithm has several advantages, including the display of the actual ratio attained as calculated by the Calculator PV algorithm and direct control of the ratio through the SP of the Ratio algorithm.
8.13.5.2 Use

This algorithm is typically used in the control of the flow of a gas or fluid, as a ratio of an another flow. For example, in a furnace, the air supply might be controlled as a ratio of the fuel supply. If more heat is required to maintain combustion efficiency, the fuel flow is increased and the air flow can be increased as a ratio of the fuel-flow increase.

Figure 8-15 shows an example of such an application. In this example, the data point that uses the Ratio-control algorithm also uses the Calculator PV algorithm to calculate the actual ratio achieved, for display or printing. The Calculator PV should use the filtered value (X2FILT) of the uncontrolled variable.

To evaluate this example, see the equations under 8.13.5.4 and you will note that the same scale factor, 0.7, is used in for both P1 in the PV algorithm and K1 in the Ratio-control algorithm. The resulting scaled ratio between the "other" flow and the controlled flow is 2.00/0.7 = 2.857, so if the "other" flow is 6.00 gallons per minute, the controlled flow must be 6.00*2.857 = 17.143 gallons per minute.

The 0.7 scale factor is used for C1 and K1 in the example to illustrate that the same scale factors and bias values must be used with the PV algorithm and the Ratio-control algorithm (K1 = C1, K2 = C2, B1 = C3, and B2 = C4), so that the actual ratio calculated by the PV algorithm will be the same as the desired ratio (2.00) when the loop is stable. If the scale factor in C1 and K1 were 1.0, the controlled flow would stabilize at the "other" flow, multiplied by the ratio. In the example of Figure 8.15, the controlled flow would be 6.00*2.00 = 12.00 gallons each minute. In any case, the controlled flow stabilizes at a value equal to the "other" flow, multiplied by the desired ratio, as modified by any scale factors other than 1.0 or any bias values other than 0.
8.13.5.3 Options and Special Features

8.13.5.3.1 Control Input Connections

This algorithm requires two input connections, for PV processing and X2. The number of input connections is defaulted to 2; however, it can be increased to 3, allowing the SP to be fetched with an input connection.

8.13.5.3.2 Engineering Unit Ranges

The PV engineering unit range (PVEULO and PVEUHI) must be specified. The setpoint engineering unit range (SPEULO and SPEUHIU) always follows the PV range. The output engineering unit range (CVEULO and CVEUHI) is derived from the secondary if the number of output connections is greater than 0; otherwise, it must be specified.
8.13.5.3.3 **Role of the Calculator PV Algorithm**

Any data point that uses RATIOCTL should use the Calculator PV algorithm (7.7.9). X2FILT, the filtered value of the uncontrolled variable X2 is connected to P2 and the variable controlled by the PID algorithm (see Figure 8-15) is connected to P1. The scale factors and bias values in the Calculator PV algorithm must have the same values as their counterparts in the Ratio Control algorithm:

\[
\begin{align*}
\text{RATIOCTL} & \quad \text{CALCULATOR} \\
K1 &= C1 \\
K2 &= C2 \\
B1 &= C3 \\
B2 &= C4
\end{align*}
\]

Thus, Calculator can calculate the actual (measured) ratio attained, and when the PVSOURCE is Auto, that value is available in the PV parameter of the data point for use on displays and reports.

8.13.5.3.4 **Operating Modes**

The RATIOCTL algorithm operates in the following modes:

- Man
- Auto
- Cas
- Bcas—if RCASOPT = Spc

8.13.5.3.5 **Remote Cascade Options**

Only the Spc option is supported.

8.13.5.3.6 **Restart or Point Activation**

On a cold or warm restart or when the RATIOCTL data point is activated, initialization takes place as described under 8.13.5.5.

8.13.5.3.7 **Error Handling**

If the value status of the X2 input is bad, the CV value is changed to bad (NaN). The data point remains in the same mode. When the X2 input again has normal status, initialization takes place as described under 8.13.5.5.
8.13.5.3.8 Ramping Bias

An optional initialization method using an internal ramping bias is available. Parameter RATE1 specifies the decay rate for the Internal Bias, BI.

Compatibility—If RATE1 is set to NaN, the initialization value for the primary is determined by back calculation for compatibility with the algorithm prior to Release 500.

When RATE1 = NaN

\[
\text{INITVAL} = \frac{K1 \cdot CV + B1}{K2 \cdot X2FILT + B2}
\]

Cascade mode—If RATE1 is set to a non-zero value, and the Ratio Control block is in Cascade mode, the SP value is back calculated. During initialization, an internal bias that is equal to the difference between the old CV value and the new CV value is added to the output calculation to produce a bumpless output. Internal Bias (BI) is calculated as follows:

\[
BI = CV_{\text{old}} - \frac{SP \cdot (K2 \cdot X2FILT + B2) - B1}{K1}
\]

where CV_{\text{old}} is the last calculated CV value before initialization.

If the primary accepts the initialization value (INITVAL), then BI turns out to be zero. If the primary does not accept the initialization value, then BI turns out to be non-zero. If not zero, the internal bias (BI) decays at the rate specified by RATE1. RATE1 is specified in engineering units per minute. If RATE1 = 0, then BI doesn't decay but remains fixed.

Auto mode—If the Ratio Control block operates in Auto mode during initialization when the mode changes from manual to auto, the internal bias (BI) is added to the output. BI decays at the rate specified by RATE1 as described for Cascade mode.

8.13.5.3.9 X2 Filter

At the X2 input to the Ratio Control block, the value of the uncontrolled variable is filtered by a single lag filter. Parameter X2TF determines the X2 filter time (0 - 60 minutes) and X2FILT is the filtered value of X2. The X2FILT value appears on the point detail display.

Compatibility—When X2TF is set for 0.0 minutes lag time, X2 is not filtered as was the case for the algorithm prior to Release 500.
8.13.5 Equations

The equations are as follows:

- Calculator PV Algorithm

\[
PVCALC = \frac{(C_1 \times P_1 + C_3)}{(C_2 \times P_2 + C_4)}
\]

Where (see Figure 8.15)

- \(PVCALC\) = The calculated, actual ratio achieved.
- \(C_1\) = P1 scale factor. Must equal \(K_1\) of the RATIOCTL algorithm. Default value = 1.0.
- \(C_2\) = P2 scale factor. Must equal \(K_2\) of the RATIOCTL algorithm. Default value = 1.0.
- \(C_3\) = Bias constant P1 input. Should be the same value as \(B_1\) in the RATIOCTL algorithm. Default value = 0.
- \(C_4\) = Bias constant P2 input. Should be the same value as \(B_2\) in the RATIOCTL algorithm. Default value = 0.
- \(P_1\) = The controlled process variable. Source should be the same as the PV of the PID controller that is RATIOCTL's secondary.
- \(P_2\) = The filtered value (\(X_2\text{FILT}\)) of the uncontrolled process variable. If there is a PID-controller controlling this other flow, the PV of that PID could be the source for \(P_2\) and \(X_2\).

- Ratio Control Algorithm

\[
CV = \frac{SP \times (K_2 \times X_2\text{FILT} + B_2) - B_1}{K_1} + B_I
\]

Where (see Figure 8-15)

- \(CV\) = The calculated output in engineering units.
- \(SP\) = The desired ratio input.
- \(X_2\text{FILT}\) = The filtered value of the uncontrolled process variable \(X_2\).
- \(B_I\) = Internal Bias.
- \(B_1\) = Bias constant. Should be the same value as \(C_3\) in the CALCULTR PV algorithm. Default = 0.
- \(B_2\) = Bias constant for the \(X_2\) input. Should be the same value as \(C_4\) in the CALCULTR PV algorithm. Default = 0.
- \(K_1\) = The ratio scale factor. Must equal \(C_1\) of the CALCULTR PV algorithm.
- \(K_2\) = The scale factor for \(X_2\). Must equal \(C_2\) of the CALCULTR algorithm.
8.13.5.5 Initialization

When the data point is initialized, an initialization request is sent to the primary, and the initialization value to be applied by the primary to the SP input is calculated and sent to the primary as follows:

\[
\text{INITVAL} = \frac{K_1 \times CV + B_1}{K_2 \times X_2\text{FILT} + B_2}
\]

Refer to 8.13.5.3.8 Ramping Bias for a more complete discussion.

![Figure 8-16 — Override Feedback Processing](image)

8.13.5.6 Override Feedback Processing

When the data point's secondary uses an Override Selector algorithm (see Figure 8-16), the following functions take place if the RATIOCTL algorithm is in Cas mode:

- The override status is sent to the primary data point in PTORST (Point Override Status).

- If the status in PTORST is not selected, a feedback value, calculated as follows, is sent to RATIOCTL's primary data point.

\[
\text{ORFB} = \frac{K_1 \times (\text{ORFBSEC} - B_1) + B_1}{K_2 \times X_2\text{FILT} + B_2}
\]

Where ORFBSEC is the override-feedback value received from the secondary data point.

For more detail on override control, see 8.12 of this publication.
8.13.6 Ramp and Soak (RAMPSOAPK)

Figure 8-17 — Functional Diagram of Ramp and Soak Control Algorithm

8.13.6.1 Function

This algorithm is typically used as a setpoint programmer. It produces an output that consists of up to twelve alternate ramps and soak periods—a total of 24 segments. Twelve pairs should be enough to cover most applications commonly encountered; however, if longer ramp and soak sequences are required, four such algorithms can be configured to push to a control switch algorithm. Then, using logic, the switch could select one of the ramp and soak algorithms. See 8.13.6.3.8.

When not used in connection with the switch algorithm, output from this algorithm is usually used as the setpoint for a secondary data point that uses a PID algorithm to control a process variable, according to the ramps and soak periods. The PV of a data point that uses RAMPSOAPK is normally the PV of the PID point.
8.13.6.2 Use

RAMP SOAK is principally used for automatic temperature cycling in furnaces and ovens. It can also be used for automatic startup of units, and for simple batch-sequence control where the batch sequence is part of a process that is otherwise a continuous process.

8.13.6.3 Options and Special Features

8.13.6.3.1 Single or Cyclic Sequencing

Once started, the configured sequence of ramps and soak periods repeats itself, if it is not stopped by an operator or by a user-written program. A Universal Station operator can put the point in Man mode to freeze the sequence, and then return it to Auto to continue the sequence.

A configuration parameter called cycle option (CYCLEOPT = Single or Cyclic) is provided that optionally permits the cycle to stop after completing a single cycle. This works as follows:

• CYCLEOPT = Single

When the mode is changed from Man to Auto, the algorithm cycles through the configured rampsoak sequence until the last soak segment is completed. At this point, the mode is switched back to Man and the current segment ID is set to RAMP1 (the first segment). Another sequence can now be executed by simply switching the mode back to Auto.

• CYCLEOPT = Cyclic

When the mode is changed from Man to Auto, the algorithm cycles through the configured rampsoak sequence until the last soak segment is completed. At this point, the current segment ID is set to RAMP1 (the first segment) and the whole cycle is repeated.
8.13.6.3.2 Operational Modes

The operating modes establish the operating state of the RAMPSOAK algorithm as follows:

- **Man**—The sequence is stopped and the ramp/soak timers are not running.
- **Auto**—The sequence is running.

Further functions in each mode are the following:

- **Man mode**
  - The Ramp and Soak actions are suspended.
    This allows the user to enter starting output value for the Ramp/Soak profile and to change the value during profile.
  - The timers are stopped and hold the last value.
  - The value in CV is replaced by the OP value (after converting to EUs).
  - \( SP = CV \) (SP doesn't affect the output but can be seen at Universal Stations and user-written programs).

- **Auto Mode**
  - If the current segment is a ramp, and if the guaranteed ramp conditions are OK (see 8.13.6.3.6),
    \( CV \) changes at the ramp rate.
    If \( CV \) should overshoot the next soak value it is clamped at that value, the remaining soak-time (REMSOAKT), the current-segment (CURSEGID), and the mark timers and flags (see 8.13.6.3.7) are updated.
  - If the guaranteed ramp conditions are not OK, the mark timers (see 8.13.6.3.7) are stopped.
  - If the current segment is a soak, and if the point just changed from Man to Auto, or just started the soak segment, and the guaranteed soak time conditions are not OK (see 8.13.6.3.5),
    The soak timer doesn't start.
    \( CV \) remains at its last value.
    The mark timers (see 8.13.6.3.7) are stopped.
If the guaranteed soak-time conditions are OK,

The soak timer begins to run or continues to run.

CV holds at its last value and the mark timers and flags (see 8.13.6.3.7) are updated.

The remaining soak time (REMSOAKT) is adjusted.

If the soak timer times out, the current segment (CURSEGID) becomes the next ramp segment.

– In any case, in Auto mode, SP is equal to CV. SP doesn't affect the output but can be seen at Universal Stations and by user-written programs.

NOTE

If the polarity of the ramp rate is opposite to the soak target value, the output jumps to the soak target value. That is, the ramp segment for this ramp/soak cycle is omitted and the next segment is invoked.

8.13.6.3.3 Remote Cascade Options

Remote cascade options are not supported.

8.13.6.3.4 Changing Remaining Soak Time and Current Segment

When the RAMPSOAK point is in Man mode, an operator at a Universal Station can change the remaining soak time (REMSOAKT) if the current segment is a soak.

Also, when the point is in Man mode, an operator can change the current segment (CURSEGID).

When the mode is returned to Auto the sequence continues, as modified by these changes. If the segment was changed, the sequence resumes with the new segment, which can be a ramp or a soak.

Because changes to these parameters don't change the mark functions (see 8.13.6.3.7), except if CURSEGID is a lower segment than the mark segment (SnSEGID), operators should not be allowed to change REMSOAKT or CURSEGID when the mark functions are configured.
8.13.6.3.5 Guaranteed Soak-Time

This feature guarantees that the PV is at the proper soak value before the soak-time measurement begins.

If, when a soak segment begins or is resumed by switching from Man to Auto, the PV is not within a user-specified deviation (MXSOKDEV) from the SP value (SP always equals CV), the soak timer doesn't start. When the deviation is within the MXSOKDEV value, the timer is started and continues, even if the deviation again exceeds MXSOKDEV.

Because the PV could be above or below SP, it is the absolute value of the deviation that is checked against MXSOKDEV.

To bypass this check you can change MXSOKDEV to NaN.

The soak timer can also be kept from starting when HOLDCMD is On. This allows you to use a Logic Slot to set HOLDCMD to hold the soak timer until some other condition is met.

HOLDCMD also affects the guaranteed ramp function. See 8.13.6.3.6.

8.13.6.3.6 Guaranteed Ramp Rate

This feature guarantees that the PV keeps up with the desired value indicated by SP (SP always tracks CV).

You can specify a maximum ramp-deviation value in MXRMPDEV. There are two conditions that cause the ramp to stop to wait for the PV to catch up with SP. They are

- RATEn > 0
  
  and
  
  PV < (SP - MXRMPDEV)

- RATEn < 0
  
  and
  
  PV > (SP + MXRMPDEV)

These checks are bypassed if MXRMPDEV contains NaN.

Another condition that stops the ramp is HOLDCMD containing On. You can use a logic slot to set HOLDCMD to stop or hold the ramp until some condition that you specify is met.

The content of HOLDCMD also affects the guaranteed soak-time feature. See 8.13.6.3.5.
By assuring that PV = proper soak value, the user is assured of, for example, the proper wait time between phases of a warm up or that temperature is held for the proper length of time during heat treating.

Figure 8-18 — Wait Time Between Phases (Ramp/Soak Algorithm)

By ensuring that the ramping "waits" for the process to catch up, we never have a large error caused by setpoint change.

Figure 8-19 — Ramping Waits for Process

8.13.6.3.7 **Mark Timer Functions**

Two flags are provided with the RAMPSOAK algorithm to indicate to other data points that a specified time has elapsed from the beginning of a specified ramp segment or soak segment. These mark-timer flags are S1 and S2.

Each of these flags has three associated parameters that specify the segment in which the flag is set On, the time counted from the beginning of the segment, and the time from the beginning of the segment until the end time (when the flag is set Off). These parameters are as follows:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Segment</th>
<th>Beginning Time</th>
<th>End Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>S1SEGID</td>
<td>S1BGNTIM</td>
<td>S1ENDTIM</td>
</tr>
<tr>
<td>S2</td>
<td>S2SEGID</td>
<td>S2BGNTIM</td>
<td>S2ENDTIM</td>
</tr>
</tbody>
</table>
The S1 or S2 flag is turned on at the number of minutes after the specified segment begins, as is specified in S\textsubscript{n}BGNTIM. The corresponding flag is turned Off at the number of minutes after the specified segment begins, as specified in S\textsubscript{n}ENDTIM.

The following functions also take place:

- At the end of the last segment in the sequence, the S1 and S2 flags are turned Off and the timers are reset.

- When a ramp or a soak segment is held up by the guaranteed-ramp or the guaranteed-soak functions, the mark timers are suspended.

- The mark timers suspend when the data point is in Man mode and the S1 and S2 flags are unchanged.

- If the remaining soak time (REMSOAKT) is changed (in Man mode), the mark timers are not affected.

- If the current segment (CURSEGID) is changed (in Man mode) to a segment that is earlier than or equal to a segment specified by S\textsubscript{n}SEGID, the corresponding mark flag goes to Off and its timers are reset. If a later segment is specified in CURSEGID, the flags and timers are not affected.
A sequence of more than 12 ramp and soak segments can be attained by interconnecting RAMPSOAK points. A Logic Slot can be used with a Switch Algorithm (see 8.13.9) to select any of the four RampSoak Algorithm data points.

Longer sequences can be accomplished by setting the S1 Mark Flag at the end of the last soak segment (S1 must be on for at least one sample time).

A Logic point reads the S1 Mark Flag and, using a pulse Logic Block (Pulse width can be one sample time), sets the corresponding S input on the Switch Algorithm. This causes the next RampSoak to become selected and all nonselected RampSoaks are INIT. The Switch Algorithm should be configured for tracking and Equation B.
8.13.6.3.9  Engineering Unit Ranges; Setpoint, Output and Deviation Limits

The PV engineering unit range (PVEULO and PVEUHI) and the output engineering unit range (CVEULO and CVEUHI) must be specified. The setpoint engineering unit range (SPEULO and SPEUHI) always follows the PV range.

If the RAMPSOAK data point uses a PV algorithm, the setpoint EU range is the same as the PV EU range, and can't be differently configured. You should configure this point's PV EU range to be the same as the SP EU range of the secondary point that is receiving this point's output.

The setpoint and output limits do not apply. Setpoint limits are not available at all, and the output limits are defaulted to -6.9% to 106.9% and cannot be changed.

The deviation limits (MXRMPDEV and MXSOKDEV) apply to all segments in the sequence.

8.13.6.3.10  Restart or Point Activation

On a cold restart, a warm restart, or when the data point is activated, the mode goes to Man and the CV value is NaN. All timers are reset, and the current segment ID is made equal to the first ramp segment.

No special action occurs on a hot restart and the operation continues from where it was.

8.13.6.3.11  Control Input Connections

The ramp soak control algorithm requires only one control input connection (for PV). The number of control input connections is fixed at one.

In a typical application, the output of this algorithm provides the SP of a secondary controller (which is usually a PID control algorithm). The PV of the secondary controller is then fetched with a control input connection into the PV of the RAMPSOAK. If used in some different way such that the PV is not available from the secondary, the PV of the RAMPSOAK should be fetched from its own SP parameter.

8.13.6.4  Equations

There are no configurable equations for the RAMPSOAK algorithm. The ramp and soak segments are specified in the following parameters (also see Figure 8.17):

- Number of ramp/soak segment-pairs in the sequence—NORSSEQ
  Default = 2

- Ramp Rates, EUs per minute—RATE1 through RATE12
  Default = NaN

- Soak values—SOAKV1 through SOAKV12
  Default = NaN

- Soak times, in minutes—SOAKT1 through SOAKT12
  Default = 0
8.13.6.5 Override Feedback Processing

This algorithm does not participate in override-feedback processing.

8.13.6.6 RAMPSOAK Parameters

All of the significant parameters associated with the RAMPSOAK algorithm have been described. Refer to the Process Manager Parameter Reference Dictionary for additional parameter information.

8.13.7 Auto Manual (AUTOMAN)

8.13.7.1 Function

In cascade mode, this algorithm calculates a control output that is equal to the input value plus a bias value. The bias value is normally provided by a Universal Station operator. In manual mode, the output is controlled by a Universal Station operator or a user-written program. See Figure 8-22.

Equation A is designed to provide "bumpless" returns to cascade operation, even though its primary data point may not accept the initialization value from the AUTOMAN data point. Equation B provides automatic balancing of the biases between several auto manual stations and "bumpless" closing of cascades, with ramping of the initialization component.

8.13.7.2 Use

The AUTOMAN control algorithm typically serves as the ultimate secondary data point in a cascade-control strategy. As such it directly drives the control element (valve) through an analog output slot (a slot using a PID algorithm). See Figure 8-23.

This algorithm is very useful for a secondary data point that is one of two or more secondaries of the same primary data point (a "fan-out" configuration). In such a configuration, AUTOMAN can provide a "bumpless" output even if its primary doesn't accept AUTOMAN's initialization request, but accepts one from one of its other secondaries. This might happen because the AUTOMAN point is temporarily out of the cascade because it is inactive or because it is in Man mode.

For a example of output from a PID controller to two auto manual stations, see the example under Equation B (8.13.7.4).
CV = X1 + B

Where:

X1 = Input (usually from a Primary PID controller)

B = BO + BI

B = Overall Bias, consisting of:

**Equation A:**

BO = Operator-entered bias = K * X2 for Equation B

BI = Initialization Bias Component

**Figure 8-22 — Functional Diagram, Auto Manual Control Algorithm**
8.13.7.3 Options and Special Features

8.13.7.3.1 "Bumpless" Returns to Cascade Operation

To support the use of this algorithm as one of the secondaries in a fan-out configuration, special handling of the bias value is provided. When the data point is configured for external initialization, the bias value, B, consists of two components.

\[ B = B_0 + B_I \]

- Internal adjustment-value storage. Usually \( B_I = 0 \).
- Internal storage for operator-entered or program-entered bias value

When the user or a program enters a bias value in B while in cascade operation, that value goes to \( B_0 \) and \( B_I \) is forced to zero. \( B_I \) is an internal parameter that cannot be accessed by a user. B cannot be entered in Equation B.

When the cascade connection is broken (in Man mode, initialization-manual input, etc.) a value is calculated for the primary to initialize to, as follows:

\[ \text{INITVAL} = CV - B_0 \]

When cascade operation resumes, the value in \( B_I \) is calculated as follows:

\[ B_I = \text{INITVAL} - \text{OPprim} \]

The actual output value from the primary data point (X1 input)

If the primary data point did accept AUTOMAN’s initialization value, \( B_I \) turns out to contain zero. If the primary did not accept INITVAL, \( B_I \) contains a value that causes CV to contain the value it had just before the cascade closed. In either case, CV does not "bump."
If BI has a value other than zero, that value ramps to zero at a rate specified by the user in the RATE1 parameter. RATE1 is specified in engineering units-per-minute or NaN. If RATE1 is set to NaN, then the internal bias instantaneously changes to 0 and may cause a bump in the output. If a positive value is entered in RATE1, the value of BI ramps to zero at a rate specified in the RATE1 parameter. Thus, while the output doesn’t “bump” it does ramp to the new value called for by the input from the primary.

For example, assume that the AUTOMAN data point is operating in Cas mode

\[
\begin{align*}
X_1 &= 6 \\
B &= 5; \ BI = 0, \ BO = 5 \\
CV &= X_1 + B = 11 \\
RATE1 &= 2 \text{ units per minute}
\end{align*}
\]

The mode is changed to Man

\[
\begin{align*}
\text{INITVAL} &= CV - BO = 12 - 5 = 7 \\
\text{The operator changed the output value}
\end{align*}
\]

\[
\begin{align*}
B &= 5; \ BO = 5, \ BI = 0
\end{align*}
\]

The primary does initialize

\[
\text{OPprim} = 7
\]

Go back to Cas mode

\[
\begin{align*}
X_1 &= 7 \\
BI &= CV - BO - X_1 = 12 - 5 - 7 = 0 \\
B &= BO + BI = 5 + 0 = 5 \\
CV &= 7 + 5 = 12 \\
\text{Same value as when in MAN mode}
\end{align*}
\]

Go to Man mode again

\[
\begin{align*}
CV &= 12 \ (\text{the operator didn’t change it}) \\
\text{INITVAL} &= CV - B = 12 - 5 = 7 \\
B &= 5; \ BI = 0, \ BO = 5
\end{align*}
\]

This time, the primary doesn’t accept INITVAL, and the output of the primary went to nine units

\[
\text{OPprim} = 9
\]
Go back to Cas

\[ X_1 = 9 \]
\[ B_I = \text{INITVAL} - \text{OPprim} = 7 - 9 = -2 \]
\[ B = 5 - 2 = 3 \]
\[ C_V = 9 + 3 = 12 \]

Now, because BI ramps from -2 units to zero, CV changes as follows:

\[ \begin{align*}
\text{12 Units} & \quad \text{14 Units} \\
\text{1 minute (2 units per minute)} & \quad \text{1 minute (2 units per minute)}
\end{align*} \]

8.13.7.3.2 Operating Modes
- Man
- Cas
- Bcas if RCASOPT = Ddc

8.13.7.3.3 Remote Cascade Options
Only the Ddc option is supported.

8.13.7.3.4 Engineering Unit Ranges
You must configure the X1 input range in XEULO and XEUHI. The output engineering unit ranges (CVEULO and CVEUHI) always follow the X input ranges.

8.13.7.3.5 Restart or Point Activation
On a cold or warm restart or when the data point is activated, initialization takes place as described under 8.13.7.3.1. On a hot restart, initialization does not occur.

8.13.7.3.6 Error Handling
If the X1 input has a bad-value status (or Equation B and X2 is bad), the CV value is bad but the data point remains in the same mode. When the bad input returns to normal, CV is recalculated and an initialization request is sent to the primary.
8.13.7.4 Equations

This algorithm has two forms:

**Equation A**

\[ CV = X_1 + B \]

Where \( B = B_0 + BI \)

\( X_1 \) is the input that is typically pushed from the primary PID controller and \( B \) is the overall bias, which consists of the operator set bias component (\( B_0 \)) and the initialization bias component (\( BI \)).

This form of the equation requires NO input connection. The number of input connections is defaulted to 0; however, it can be increased to 1, allowing the \( X_1 \) input to be fetched with an input connection (\( X_1 \) fetched by connection number 1).

**Equation B**

\[ CV = X_1 + B \]

Where:

- \( CV \) = Control algorithm output in Engineering Units
- \( X_1 \) = Initializable input pushed from primary
- \( B \) = Bias Value, and
- \( B = (K \times X_2) + BI \)
- \( X_2 \) = input connection fetched with input connection #1
- \( BI \) = Initialization Bias Component

\( X_1 \) is the input that is typically pushed from the primary PID controller and \( B \) is the overall bias, which consists of the automatic bias adjustment (\( K \times X_2 \)) and the initialization bias component (\( BI \)). \( X_2 \) is fetched with an input connection (#1) from a calculated input. Bumpless closing of cascades is provided the same as in Equation A (with ramping of the initialization component). The overall Bias \( B \) is a read-only parameter and cannot be stored to.

Equation B requires only one input connection — \( X_2 \). The number of input connections is defaulted to one; however, it can be increased to two, allowing the \( X_1 \) input to be fetched with input connection #2.

Consider the following example:

If a PID controller outputs to two auto manual stations, the operator may want the total required offset between the outputs of the two auto manual stations to be distributed equally above and below the PID's output. The operator can store the bias (= half the required offset) to the first auto manual station (configured for Equation A). The second auto manual must be configured with Equation B, have \( K \) of -1.0, and get its \( X_2 \) input from the \( B_0 \) parameter of the first one. Thus, whenever the operator changes \( B_0 \) of the first auto manual point, the bias of the second point tracks automatically.
Alternately, the strategy could be configured so that the bias value is held in a numeric. Each auto manual point would then fetch the numeric value into its X2 input. In this configuration, bias balancing is achieved by setting K on the two auto manual stations to +0.5 and -0.5 respectively.

8.13.7.5 Initialization

Refer to 8.13.7.3.1 for information on when initialization can occur. Initialization value = CV - B.

8.13.7.6 Override Feedback Processing

When the data point's secondary uses an Override Selector algorithm (see Figure 8-24), the following functions take place:

- If this point is in Cas mode, Override Status PTORST is returned to this point through special processing. If that status is "not selected," an override-feedback value is calculated as follows, and it is passed on to the AUTOMAN data point's primary:

\[
\text{ORFB} = \text{ORFBSEC} - B
\]

For more details on override control see subsection 8.12 of this publication.
8.13.8 Incremental Summer (INCRSUM)

8.13.8.1 Function

This algorithm calculates the sum of the incremental changes in up to four input values. The output is obtained by adding the sum of the changes in all inputs, after each input is multiplied by a scale factor. See Figure 8-25.

\[
CV = \text{(last value)} + \text{sum of changes in all inputs}
\]

Figure 8-25 — Functional Diagram, Incremental Summer Control Algorithm

8.13.8.2 Use

This algorithm is typically used where more than one primary data point is used to manipulate the setpoint of the same secondary data point. The primaries usually use PID algorithms, and are connected to an INCRSUM data point. The output from the INCRSUM data point is connected to the secondary, as shown here. This is sometimes referred to as a "fan-in connection."

Example — Fan-in Connection
8.13.8.3 Options and Special Features

8.13.8.3.1 Control Input Connections

This algorithm requires NO input connections. The number of input connections is defaulted to 2, but it can be increased to up to four. For each input connection, the user must also specify the destination parameter, X1, X2, X3 or X4.

8.13.8.3.2 Handling of Full Value, Floating PID Outputs

Special handling of the outputs of PID data points is necessary in the Incremental Summer, because it is the dynamic operation of the PID that is significant—the full-value output is not significant. As the process variables change, PID outputs have no direct relation to the input, therefore they are said to be "floating." The incremental summer responds only to changes in the PID outputs, and calculates a full-value output to be applied to the control device (valve) in the process or to the secondary data point.

While the PID algorithms handle SPs, PVs, and outputs as percentages of the configured range, the Incremental Summer performs its calculations in engineering units.

To prevent a primary PID point in Auto or Cas mode from winding-up beyond its own output limits, every time the Incremental Summer point is processed it changes the PID's output value to its own CV value after converting to percent. This does not affect the dynamic changes in the PID outputs.

If a primary PID is in Man mode, the PID's CV is not changed by the Incremental Summer.

The following restrictions apply to the PID points that are the Incremental Summer point's primaries.

- Each must have only one control-output connection.
- Each must reside in the same PM box.
- Each must be a normal PID (8.13.1) or a PID Feedforward.

8.13.8.3.3 Engineering Unit Ranges

You must configure the X-input ranges in XEU LO and XEU HI. The output engineering unit ranges (CVEULO and CVEUHI) always follow the X input ranges.

8.13.8.3.4 Changes to Incremental Summer Output by User-Written Programs

User-written CL programs in the AM or user-written programs in a Computing Module can directly store new values in the CV parameter of the Incremental Summer's data point while the Incremental Summer point is in BCas mode, or if in CAS mode and RCASOPT is not = DDC, and normally operating. This causes a shift in the CV value but the dynamic changes continue, because the Incremental Summer dynamically increments or decrements CV each time the point is processed.
8.13.8.3.5 Override Control Strategy

If the Incremental Summer's secondary is an Override Selector data point, and its Override Status (PTORST) is not selected, the CV of the INCRSUM data point is set equal to the override feedback value. During the next pass of forward calculation, the incremental summer computes its CV in the normal fashion.

This is very useful for cases where several feedforward signals are added to the output of a PID controller (the addition done by the incremental summer algorithm) and the overall result is fed to an override selector. Because the output of the PID controller tracks the output of the incremental summer, which in turn tracks the output of the override selector when not selected, the output of the PID controller is prevented from winding up when not selected by the override.

8.13.8.3.6 Operating Modes

This algorithm operates only in Man and Cas modes, and in Bcas if RCASOPT = Ddc. Because the output of each PID primary tracks the OP output value of the INCRSUM data point, switching this point from Man to Cas does not "bump" the process.

Note: The dynamic correction calculated by a PID primary appears as a change in that data point's output after it is processed again and the Incremental Summer actually uses this change as its input. The full-value outputs of PIDs connected to the Incremental Summer have no meaning.

8.13.8.3.7 Remote Cascade Options

Only the Ddc option is supported.

8.13.8.3.8 Restart or Point Activation

On a warm restart, or point activation, initialization takes place as described under 8.13.8.5.

8.13.8.3.9 Bad Control Handling

When an input becomes bad (= NaN), it is not used in the calculation. No bad control alarm is generated. When the bad input returns to a normal value, its use in the output computation is resumed in the CV calculation without "bumping" the value. This feature allows adding multiple feedforward signals to the output of a PID controller.

NOTE

If a single feedforward input is needed, the PID feedforward control algorithm should be used.
8.13.8.4 Equations

CV is calculated as follows:

\[ CV(n) = CV(n-1) + K_1 \times [X_1(n) - X_1(n-1)] + K_2 \times [X_2(n) - X_2(n-1)] + \cdots + K_m \times [X_m(n) - X_m(n-1)] \]

Where:

- \( CV(n) \) = Current full value of the output of this algorithm in engineering units.
- \( CV(n-1) \) = Past full value from the data point (value from the last time the data point was processed).
- \( m \) = The number of inputs actually used (\( m = 1 \) through 4).
- \( K_1 \) through \( K_m \) = User-specified scale factors (gains). \( K_1 \) through \( K_4 \) default to 1.0.
- \( X_1(n) \) through \( X_m(n) \) = Current values of each X input in use.
- \( X_1(n-1) \) through \( X_m(n-1) \) = Past value of each X input (value from the last time the data point was processed).

8.13.8.5 Initialization

Initialization occurs in Man mode when the output is indisposable, or when recovering from a bad CV value (NaN), as follows:

- An initialization request is sent to all primary data points (up-to-four).
- The Incremental Summer's CV value and past values are initialized:

\[ CV(n-1) = CV \]
\[ X_1(n-1) = X_1 \]
\[ \cdots \]
\[ X_m(n-1) = X_m \]
8.13.9 Switch (SWITCH)

8.13.9.1 Function

This algorithm operates as a single-pole, 4-position rotary switch. An operator at a Universal Station, a user-written program, or user-configured logic can change the position of the switch, thereby selecting any one of the four inputs to be the control-algorithm output value, CV.

Position Controller by Operator, User-Written Program, or User-Configured Logic

From up to 4 Other Data Points

\[ X1 \quad X2 \quad X3 \quad X4 \]

- MAN
- CAS
- CV
- OP

Output Processing

Equation A: Operator Controls Switch Position

Equation B: Program or Logic Controls Switch Position, Operator can store to SELXINP if all S1-S4 flags are OFF

Figure 8-26 — Functional Diagram, Switch Control Algorithm
8.13.9.2 Use

The SWITCH control algorithm is used to allow the operator at a Universal Station to alter control strategies by selecting any of four inputs to be passed on to the output, if Equation A is chosen. If Equation B is chosen, a Logic Slot can change the switch position, or the operator can store to SELXINP if all four input selection flags (S1, S2, S3, and S4) are Off.

You can use SWITCH to select inputs from differing sources and to pass them on to a single destination or you can use more than one SWITCH data point to switch a single source to differing destinations. Figure 8-27 shows an example of each of these situations.

8.13.9.3 Options and Special Features

8.13.9.3.1 Control Input Connections

This algorithm requires NO input connections. The number of input connections is defaulted to 0; however, it can be increased to up to 4. For each input connection, the user must also specify the destination parameter as X1, X2, X3 or X4.
**8.13.9.3.2 Engineering Unit Ranges**

The X-input engineering unit ranges (XEULO and XEUHI) must be specified for X-inputs. The output engineering unit ranges (CVEULO and CVEUHI) always follow the X-input ranges.

**8.13.9.3.3 Operator Control of Switch Position--Equation A**

If Equation A is chosen, an operator at a Universal Station can change the switch position in one of two ways:

- By altering the value in SWITCH data-point parameter SELXINP—The value in SELXINP specifies the Xn input selected. The corresponding S1, S2, S3, or S4 switch indicator goes On and the other three switch indicators go Off.

- By changing the desired switch indicator from Off to On—When one of the S1, S2, S3, or S4 indicators is changed to On, all others go Off. SELXINP then indicates the position selected.

The second method is very useful when operating with custom displays. The displays can be built to allow the operator to see the positions and strategies selected unless S1 through S4 are all OFF.

**8.13.9.3.4 Control of Switch Positions--Equation B**

Equation B is primarily intended for automatic switching between inputs with the help of logic (or user programs). In the PM, an operator is allowed to change the switch position, by storing to the SELXINP parameter when configured for Equation B, if all input selection flags (S1, S2, S3 or S4) are Off.

With Equation B, turning an S1, S2, S3, or S4 indicator On does not turn the others Off, as it does with Equation A; therefore, the switch position is changed by storing On and Off in the S1-S4 parameters as follows:

<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>Xn</th>
<th>SELXINP</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X1</td>
<td>SELECTX1</td>
</tr>
<tr>
<td>Off</td>
<td>On</td>
<td>-</td>
<td>-</td>
<td>X2</td>
<td>SELECTX2</td>
</tr>
<tr>
<td>Off</td>
<td>Off</td>
<td>On</td>
<td>-</td>
<td>X3</td>
<td>SELECTX3</td>
</tr>
<tr>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
<td>X4</td>
<td>SELECTX4</td>
</tr>
</tbody>
</table>

Where "-" means On or Off does not affect the switch position.

S1 has the highest priority, S4 has the lowest priority.
8.13.9.3.5 Tracking Option

You can configure the SWITCH algorithm for the tracking option, which causes nonselected inputs to track the selected input value. This allows the switch position to be changed without "bumping" the output.

When the tracking option is configured, the primaries connected to nonselected inputs can be initialized. Should one of the primaries not accept the initialization value from the SWITCH data point, the output may bump when that input is selected. (A primary might not accept an initialization value because it has more than one secondary and accepts initialization from one of its other secondaries.)

NOTE

For the tracking option to work, the Switch input must come from a PM primary Regulatory Control point. The output destination from the RegCtl point must specify the Switch point (that is, the Switch input must be pushed from the RegCtl point).

When SWITCH is included in an override control strategy, the tracking option must be configured.

8.13.9.3.6 Operational Modes

The Switch-control algorithm operates in the following modes:

• Man
• Cas
• Bcas if RCASOPT = Ddc

8.13.9.3.7 Remote Cascade Options

Only the Ddc option is supported.

8.13.9.3.8 Restart or Point Activation

On a cold or warm restart, or when the SWITCH data point is activated, initialization takes place, as configured. See 8.13.9.5.

On a hot restart, normal operation resumes with no initialization.

8.13.9.3.9 Error Handling

If a selected input has a bad-value status, the CV value goes bad (NaN), but the operating mode does not change. When the status of the selected input is again good, CV is recalculated, an initialization request is sent to the primary data point.
8.13.9.4 Equations

Equations A and B:

\[ CV = x_n \]

\[ n = 1, 2, 3, \text{ or } 4 \]

SELXINP = The selected input, which can range from SelectX1 through SelectX4.

S1 through S4 indicate the switch selection, as described under 8.13.9.3.3 or 8.13.9.3.4.

Where:

CV = The control output value in engineering units.
SELXINP = The selected-input. Default = SelectX1.
S1 through S4 = Switch indicators
M = The number of inputs configured. Default = 2.

NOTE
See 8.13.9.3.4 for special information regarding Equation B.

8.13.9.5 Initialization

When an initializing condition occurs, an initialization request is sent to the selected primary and the initialization value is the present CV value.

If the tracking option is configured (see 8.13.9.3.5), the nonselected primaries are continually initialized.

8.13.9.6 Override Feedback Processing

If this data point's secondary is an Override Selector point and if this point is in Cas mode, when override-feedback processing takes place, override status and an override value are passed to this point's primary. The status is in parameter PTORST.

If PTORST indicates not selected, the value passed to the selected primary in ORFB is equal to the value received from the secondary in ORFBSEC.
8.13.9.7 Switch Parameters

In addition to the parameters already mentioned, parameter TRACKING is associated with the SWITCH algorithm. Refer to the Process Manager Parameter Reference Dictionary.

8.13.10 Override Selector (ORSEL)

8.13.10.1 Function

The Override Selector Algorithm is used with up-to-four PID inputs, all of which are initializable. The input with the highest value or the input with the lowest value is selected and passed on to the output of this data point. The algorithm can operate as a simple selector or an override option can be configured that prevents PID points in an override-control strategy from winding up. Refer to Figure 8-28.

If the override option is configured (OROPT = On), an operator can put the ORSEL point in a bypass state and any of the inputs can be bypassed; that is, not used in the algorithm calculation. Four logical parameters are provided to select the input to be bypassed. These parameters are BYPASSX1, BYPASSX2, etc. There is an additional parameter, BYPASS. When BYPASS = On, the input Xn for which BYPASSXn is On is initialized (equal to the selected input) and not used in the calculation of the output. When all four inputs are bypassed, the output is maintained at the last values.

All bypass parameters can be stored by the operator, or any system function, but only the BYPASS parameter is available for changing at the group display level.

8.13.10.2 Use

This algorithm can be used, without the override option, as a simple selector that selects either the highest or the lowest of the connected and active inputs. With the override option, it is used for override-control strategies where a process variable is measured and normally controlled, but where another variable is selected to constrain the controlled variable, under a specified condition. This is often referred to as 'multivariable-constraint control.'

Figure 8-29 illustrates an override strategy. The X1 input to the ORSEL point is normally selected and applied as the setpoint to the fuel-flow controller. If the value of the air flow multiplied by some ratio exceeds the fuel-flow setpoint, the air flow constrains the fuel flow.
In a strategy like that of Figure 8-29, Equation A, the override option is configured. PID data points connected to nonselected inputs are prevented from "winding up" by forcing their outputs to track the override feedback signal (ORFBSEC). For more detail on such strategies, refer to 8.12.

The simple selector (override option not configured) can be set up to initialize one input, but not all inputs, by using control-input connections for the inputs that are not to be initialized, and by using a control-output connection from the point that is connected to the input to be initialized.

NOTE

There are some important guidelines that must be observed when configuring an override-control strategy. See 8.12 and the configuration information below.
8.13.10.3 Options and Special Features

8.13.10.3.1 Control Input Connections

This algorithm requires NO input connections. The number of input connections is defaulted to 0; however, it can be increased to up to 4. For each input connection, a destination parameter X1, X2, X3 or X4 must be configured.

8.13.10.3.2 Override and Bypass Options

If the override option is configured, PID points connected to nonselected inputs are prevented from "winding up" by forcing their outputs to track the override-feedback signal (ORFBSEC).

Override Offset

A configuration parameter called Override Offset (OROFFSET = On) is provided to control the behavior of any PIDs connected to the nonselected inputs. If Override Offset is configured, the output of the PID whose override status is not selected is set equal to the override feedback value, plus gain times error (after converting to percent). If the override offset is not configured, the output of the PID whose override status is not selected is set equal to the override feedback value (after converting to percent).
Bypass Options and Parameters

When configured as an override selector, any of the inputs X1, X2, X3, and X4 can be individually bypassed (not used in the algorithm calculation). Four logical parameters are provided to select the input to be bypassed. These parameters are BYPASSX1, BYPASSX2, BYPASSX3, and BYPASSX4. An additional parameter, BYPASS is provided. When BYPASS is On, the input Xn for which BYPASSXn is On is initialized (set equal to the selected input) and not used in the calculation of the output. When all four inputs are bypassed, the output is maintained at the last value.

These parameters are available only when the override option is configured (OROPT = On).

All bypass parameters can be stored by the operator, or any system function, but only BYPASS is available for changing at the group display level.

NOTE: When a selected input is bypassed, all parameters go through 1-shot initialization.

8.13.10.3.3 Engineering UnitRanges

The engineering-units ranges for the X1 through X4 inputs must be configured in parameters XEUHI and XEULO. These parameters contain the high and low values for the range, which is the same for all four inputs. The output engineering unit ranges (CVEULO and CVEUHI) always follow the X-input range.

8.13.10.3.4 Operating Modes

Because a data point that uses ORSEL is always a secondary to at least one other data point, this algorithm operates only in the following modes:

• Cas
• Man
• Bcas if RCASOPT = Ddc

8.13.10.3.5 Remote Cascade Options

Only the Ddc option is supported.

8.13.10.3.6 Restart or Point Activation

On a warm restart, or on activating the data point, the CV is initialized to the value returned from the secondary and an initialization request is sent to all of the primaries.
8.13.10.3.7 Error Handling

In Cascade mode with BYPASS Off, if any input has a Bad-Value status, CV’s value is bad (NaN) and the mode doesn’t change when the CV value goes bad. Also, in Cascade mode with BYPASS On, any non-bypassed input (BYPASSXn=Off) that has a Bad-Value status causes CV to go bad (NaN).

If a bad input, that was causing CV to be Bad, returns to Normal, CV returns to normal, CV is made equal to OP, and all bypassed primaries are initialized (see subsection 8.13.10.5).

8.13.10.4 Equations

There are two equation choices:

**Equation A**—Select the higher of the connected, active inputs.

\[ CV = \text{highest of } X_1 \text{ through } X_m \]

**Equation B**—Select the lower of the connected, active inputs.

\[ CV = \text{lowest of } X_1 \text{ through } X_m \]

Where

- \( CV \) = The control-algorithm output in engineering units
- \( X_1 \) through \( X_4 \) = The four available inputs
- \( M \) = The number of inputs configured. Default = 2.

For either equation

\[ \text{SELXINP} = \text{The selected input: Select}X_1 \text{ through Select}X_4. \text{ If more than one input has the highest (EqA) or the lowest (EqB) value, the lower-numbered input is selected, e.g., if } X_2 \text{ and } X_3 \text{ have exactly the same highest value (EqA) SELXINP contains Select}X_2. \]

8.13.10.5 Initialization

Initialization requests from secondary points are ignored as long as the ORSEL output is disposable.

If the ORSEL is initialized because it is in Manual mode, the output is indisposable, or it has just returned from bad control status, CV is made equal to INITVAL from the secondary, and SELXINP is set to None. When the ORSEL is in Manual mode, an initialization request is passed on to all primaries with an initialization value equal to CV. When the ORSEL is initializing because the output is indisposable or it is returning from bad control, an initialization request is passed on to all primaries whose input are bypassed (BYPASS = On and BYPASSXn = On) with an initialization value equal to CV.
8.13.10.6 Override Feedback Processing

8.13.10.6.1 Override-Feedback Initiation

If the override option is configured for the ORSEL point and the ORSEL point is in Cas mode and not initializing, it propagates override-feedback information to its primary points and on "upstream."

When BYPASS is Off, the appropriate NotCon, Sel, NotSel status is given to ORSEL's primaries in PTORST, and the override-feedback value that is passed to the primaries is calculated as follows:

\[
\text{ORFBSEC} = CV
\]

Where ORFBSEC is the feedback value from the secondary. (ORFBSEC is an internal parameter)

If, under the above conditions, BYPASS is On, the status sent to the primary connected to the nonbypassed selected input is Sel, NotCon is sent to the bypassed primaries and they are all initialized. NotSel is set to the nonbypassed nonselected primaries.

If there is more than one Override-Feedback data point in a strategy, only the one nearest the final control element (the "most downstream" point) initiates override feedback.

8.13.10.6.2 Override-Feedback Propagation

Override-feedback propagation is the passing of status and feedback values, from the initiating Override Feedback Selector, "upstream" through one or more other data points.

If a "downstream" Override Feedback Selector requests status and value propagation, an "upstream" Override Feedback Selector propagates the value and status "upstream," only if

• it is configured as an Override Selector (override configured), and
• it is in Cas mode, and
• its output is disposable.

If so,

\[
\text{If } \text{PTORST (Point Override Status)} = \text{SEL (selected)}, \text{ORFB} = CV \\
\text{else} \\
\text{ORFB} = \text{ORFBSEC}
\]

Where ORFBSEC is the feedback value from the secondary.

And, PTORST status sent to the selected primary is the same as that received from the secondary. If BYPASS is false, the status to all other primaries is NotSel. If BYPASS is true, nonselected inputs are initialized, so the status sent to them is NotCon.
8.13.10.7 ORSEL Parameters

In addition to the parameters already mentioned, the following parameters are associated with the ORSEL algorithm. Refer to the Process Manager Parameter Reference Dictionary.

BYPASS
BYPASSX1
BYPASSX2
BYPASSX3
BYPASSX4
CTLEQN
OROFFSET
OROPT

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Processing order is always important, but especially for the ORSEL strategy. ORSEL functions will not work properly if point processing order is incorrect.
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