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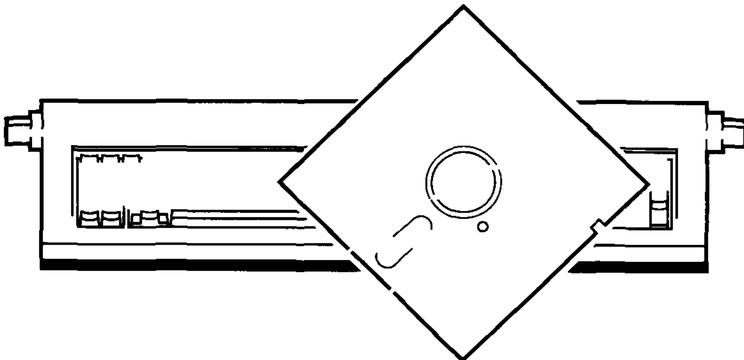
Bailey®
network 90®

C Language Implementation Guide For The Multi-Function Controller (NMFC03)



Product Instruction

E93-9

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PREFACE

WHO SHOULD READ THIS MANUAL

Users of Multi Function Controller Modules (NMFC03) who want to augment NETWORK 90 control strategies with the addition of C language programs will find this manual helpful and informative A background in process control, C and BASIC programming languages is helpful.

This manual is intended to provide the user with the necessary information to utilize C programming with the NMFC03 module. It is not intended as a tutorial in C programming techniques

MANUAL ORGANIZATION

This manual is divided into five sections **Introduction**, **Installation**, **Getting Started**, **The MFC**, and **Functions** An **Appendix** explaining NVM structure and a **Glossary** of unique terms is included in the rear of this manual

Section 1, Introduction provides an overview of the C language requirements for the MFC

Section 2, Installation provides step by step instructions for software (native and cross compilers), and hardware installation.

Section 3, Getting Started explains the procedures for compiling, linking, and executing C programs as well as the purpose of the C Utility Program (CUP)

Section 4, The MFC explains features such as the File System, Dynamic Memory Management and function codes. A table of errors and corrective actions is also provided.

Section 5, Functions explains the unique MFC ROM resident functions

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PREFACE

REFERENCE DOCUMENTS

The user should refer to the listed documents as needed

E93 900 20 Function Code Application Manual
E93 905 1 Serial Port Module
E93 905 2 CIU Hardware Manual
E93 905 9 CIU Programmer's Manual
E93 906 6 Multi Function Controller BASIC Programming Language Reference Manual
E93 906 7 Multi Function Controller Module (NMFC03) Product Instruction

The C Programming Language
by Brian W Kernighan and Dennis M Ritchie
Prentice Hall Software Series

LATTICE C Compiler Documents (supplied with software)

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SECTION 1

INTRODUCTION

GENERAL

The Multi Function Controller Module is the most versatile of the NETWORK 90 Controller family. A key module feature is the ability to execute both BASIC and C language programs. This document addresses C language applications. The addition of C to a control strategy provides the user with increased versatility, greater execution speed than with BASIC, and multi tasking capability (only one task at a time can run BASIC).

PROGRAMMING COMPONENTS

To use C, the following hardware is required.

1 Bailey Workstation

- RS 232 serial port
- 640 Kbytes of RAM
- Hard Disk Drive

2. Multi Function Controller Module (NMFC03)

- 68020 microprocessor
- 256 Kbytes EROM
- 512 Kbytes RAM
- 80 Kbytes Non volatile RAM (NVM)

3. Computer Interface Unit (NCIU02 or NCIU03) or Serial Port Module (NSPM01)

The following software for implementing C is supplied by Bailey:

1. Lattice® Software

- iAPX86 native C Compiler (4 f oppy disks)
- MS DOS>68000 C Cross Compiler (2 floppy disks)
- LMB68K Linker (included on Cross Compiler disks)

2 Workstation Resident Software
C Utility Program (CUP) (1 floppy disk) with the following files.

- CUP.EXE
- MFCLIB
- PCLIB
- Support Files

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BASIC Versus C

The NMFC03 is able to simultaneously execute BASIC and C programs. Table 1 1 provides the similarities and differences between the two languages

TABLE 1 1 MFC BASIC vs. MFC C

BASIC	C
Develop program on MFC	Develop program on EWS
Use dumb terminal connected to MFC terminal port	Download to MFC via CIU/SPM
BASIC editor	User's choice of source editor
Program executed by interpreter	Program executed as machine code (approximately 5 times faster than BASIC)
Memory requirements specified in Function Code	Memory requirements specified in CUP
Multiple invocations from 1 function block segment	Multiple invocations from all function block segments
Access to function block output values via BIN/BOUT	Same
Access to both serial ports	Same
	Dynamic memory allocation
	Dynamic data files

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INSTALLING THE C ENVIRONMENT

Native C Compiler

The Native **C** compiler (iAPX86) generates Workstation executable code. This compiler is installed first The compiler files are on four floppy disks To install, follow the steps below:

1. Insert disk 1 of 4 in drive A of the Workstation.

   NOTE: Disk 1 has a README file explaining the installation procedure and other notes of interest to the user. Refer to this file for clarification

2 Type **INSTALL**

3. Answer the system prompts. You will be asked which version(s) of the compiler you would like installed For maximum flexibility you should select A (for all memory models). If disk space is limited on your Workstation, the S option (small program and data) should be appropriate for most applications. Re installation of additional models can be done later Refer to the Lattice Programmer's Reference Volume I for a discussion of the various memory models

As the files are copied from floppy to hard disk, file names scroll on the display (this is true for all installation procedures).

The system generates an audible signal when the files are copied and prompts you to insert disk 2

4 Remove disk 1; insert disk 2.

5. Press any key.

After disk 2 files have been copied

6. Remove disk 2; insert disk 3.

7. Press any key.

After disk 3 files have been copied

8. Remove disk 3; insert disk 4

9 Press any key.

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INSTALLATION

After disk 4 files have been copied, the Native **C** compiler installation is complete Proceed to the next installation steps

Cross Compiler
The second step in the installation procedure is to install the Cross Compiler The Cross Compiler generates MFC executable code

To install the Cross Compiler:

1. Insert the SCCU IPC C Utility Disk into drive A

2. Type INSTALL

3. Press ENTER.

You will be prompted to insert the Lattice Cross Compiler diskettes into the drive

As in the previous installation procedure, file names scroll on the display as they are copied onto the hard disk. The system prompts you when the instal ation is complete.

The INSTALL.BAT program nstalls the utilities and library functions necessary for MFC interpretation This program creates two directories· C:\LCC and C:\CMFC Cross compiler executable files are copied into LCC; Bailey utilities into CMFC

Setting Environment Variables
The AUTOEXEC BAT file in the root directory needs to be edited so that the include' environment variable can be added:

    SET INCLUDE C \LC

Include instructs LATTICE compliers to look in the C \LC directory for files specified for inclusion by the '#include' directive Note that include files (e g., stdio h, math h) are different for MFC compilation than for Workstation compilation. The include files for the Workstation reside in \LC, while the include files for the MFC reside in \CMFC (this occurs during the installation procedure)

Additionally, set the path environment variable to look for commands in the \LC, \LCC, and \CMFC directories

    SET PATH C·\LC;C \LCC,C \CMFC

HARDWARE INSTALLATION

Either a Computer Interface Unit (CIU) or Serial P
(SPM) can be used as the interface between the W
and the MFC. Refer to related product instructions for c
CIU or SPM information.

When a **CIU** is used, connect the HCBL04 serial cable from t
Workstation COM1 or COM2 port to port 0 (terminal port) of the
NIMF01 termination module (or NTMF01 termination unit)

When an **SPM** is used, connect the HCBL04 cable from the
Workstation COM1 or COM2 port to the RS 232 female connector
on the faceplate of the Serial Port Module

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SECTION 3

GETTING STARTED

GENERAL

This section provides the progression of user actions required to create a C program for ultimate execution by the MFC. The first part of this section explains the compilation and linking procedures on the Workstation. The second part explains the procedures for the MFC

WRITE THE C PROGRAM

Using standard C Language types, operators, expressions; write the program

Any text editor that operates on the Bailey Workstation can be used to write the program The program source file should have .C as a file extension and be stored in one or more text files

COMPILE THE PROGRAM FOR THE WORKSTATION

After the program has been written and stored, a test execution is run for debugging purposes. To do so, the program must be compiled with the Native (Lattice) compiler This compiler requires two passes to complete the process The first pass (LC1.EXE) checks the syntax, etc. and generates an intermediate file. The second pass (LC2.EXE) generates the object file. The compilation procedure follows:

> Type LC**x** Program name. Press ENTER
>
> **x** is S, P, D, or L memory models Each memory model contains space for program and data addresses, library, and object files. When compilation starts, the compiler searches the directory in **x** above and pulls the appropriate library and object files

When the compilation is complete, the system prompts.

> TOTAL FILES: , SUCCESSFUL COMPILATIONS. ___

LINK THE PROGRAM

After the source files have been compiled, they must be 'linked to produce an executable program file.

> Type LINK**x** Program name Press ENTER.
>
> **NOTE:** x is the same memory model used in compilation

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GETTING STARTED

An executable program file with the .EXE extension is created *after a successful link When the program is invoked, three* buffered files are opened and assigned to the workstation: stdin, stdout, and stderr The buffers stdin and stdout can be redirected from the command line

Resolution at link time of MFC specific functions such as 'bin' and 'bout' can be achieved by linking the PCLIB library to your program PCLIB is included on the Workstation software disk

RUN THE PROGRAM

After successful compilation and linking, run the program for testing and debugging on the Workstation

COMPILE FOR THE MFC

The Workstation compiled version of the program must now be compiled for the MFC module This task is accomplished with the Lattice C Cross Compiler This compiler, like the Native compiler, requires two passes to complete the process The first pass (LC1M EXE) checks the syntax, etc and generates an intermediate file. The second pass generates the Object file The compilation procedure follows:

1 Change to directory in which the C source file resides.

2 Type CMFCC followed by program name

NOTE: CMFCC is a batch file which invokes the LCM compiler, using the appropriate options.

3 Press ENTER

When compilation is done, the display shows the hex values for idata, udata, and text Use these values when working with the Edit C Memory Specifications menu in CUP, which is invoked next

C UTILITY PROGRAM

The **C** Utility Program (CUP) is a Bailey designed program that enables the user to specify the memory and linking requirements for the MFC module to execute **C** programs This program is loaded into the \CMFC directory during the installation procedure CUP *is invoked only after the* C program has been compiled by the cross compiler

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CUP provides the following capabilities to the user.

- specify MFC module format
- specify C program memory requirements
- specify C program linking requirements (creates linker specification file (* lnk)
- communicate with the MFC

  format module
  change module mode
  monitor module status
  create, initialize, read data files on module
  download C programs to module

Using CUP
Before cross compiling the C program for the MFC, it is strongly recommended that the program be executed and tested on the Workstation After successful completion of execution and testing, the program is ready for the first CUP session which accomplishes the following:

a. Specifies module format requirements

b. Specifies program memory requirements

c. Creates linker specification files

To access CUP·

1. Type CUP.

2. Press ENTER.

Refer to Figure 3 1 for the CUP opening menu.

00 08 00 04 11 07

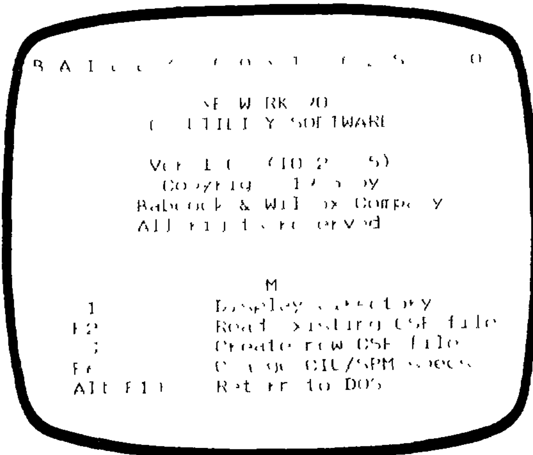

FIGURE 3 1 *CUP Opening Menu*

The C specification file (CSP) must be created first. The CSP file resides in the Workstation and contains information that describes the C environment for the MFC module. Included in this information is

- a format specifications
- b memory specifications
- c list of object files that comprise the C program

Note that one CSP file must exist for each target MFC.

From the CUP opening menu

1 Press the **F3** key to create a new CSP file The display of Figure 3 2 appears on the CRT.

2 Enter the name of the CSP file

00 08 01 04 11 07

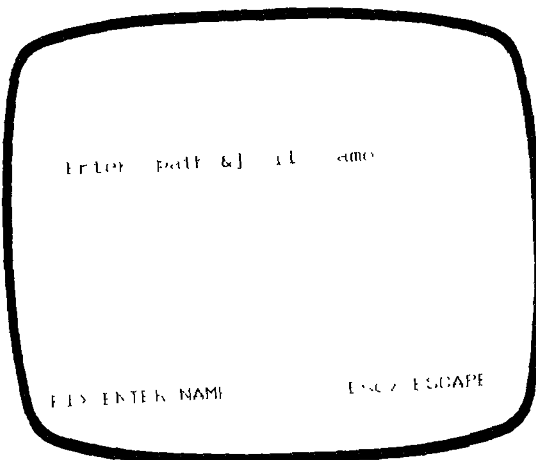

FIGURE 3-2 -- *CSP Enter Filename*

3 Press the F1 key The display of Figure 3 3 appears on the CRT

NOTE: PCU and module addresses specified here are subsequently used by CUP for communication with the MFC module

4 Key in applicable entries into the fields of this display

5 Press Escape.

00 02 01 04 11 07

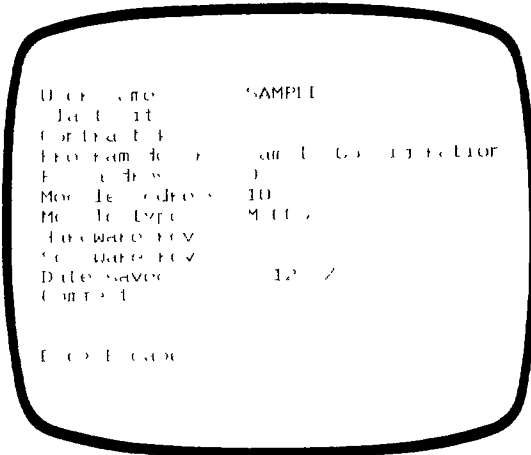

FIGURE 3 3 *CSP Title Page*

6 Press Escape again The entries you made in step 4 will be written to the disk. The display of Figure 3 4 is now on the terminal. The first task is to edit memory and link specs, select F1. The display shown in Figure 3 5 comes up

From this display, the user has several options Each option is explained in subsequent paragraphs

00 08 03 04 11 07

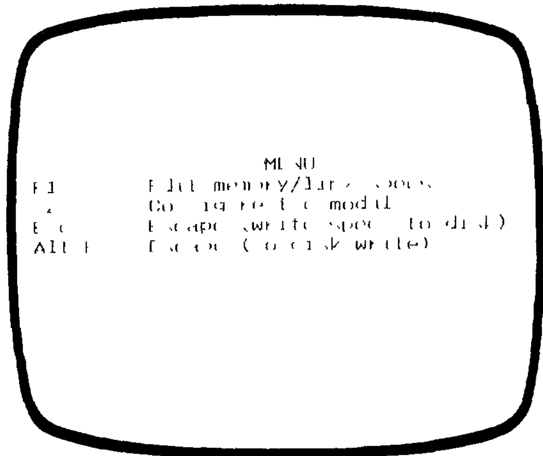

FIGURE 3 4 *Initial Edit Menu*

Edit Format Specifications
Format specifications are used to define the MFC's memory 'format." Through this editing function, the user defines the amount of RAM, NVM, and number of data files the C program uses To enter this function, press F1

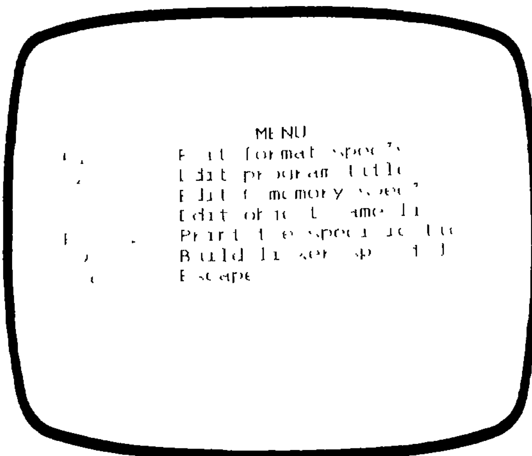

FIGURE 3 5 *Main Edit Menu*

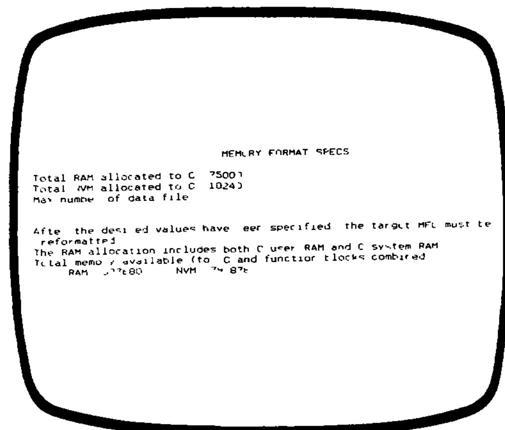

FIGURE 3 6 *Memory Format Specifications*

00 08 05 04 11 07

Finding appropriate values for the format specs depends very much on the programming application at hand If the user requires guidance in selecting these values, it is recommended that the 'Edit Memory Specs (F3)' chore be done first Then return to this menu afterwards.

When done with the menu, press F1 to save entries

Edit C Memory Specifications
Select F3 from the Main Edit Menu to access Edit C Memory Specifications. This menu is used to define the RAM requirements for the C program. There are three pages to this menu On page 1, the user defines User RAM area, including idata, udata, and dynamic memory pool sizes idata and udata values are displayed on the console after compilation These values are entered into their respective fields on page 1 (**NOTE:** The cross compiler outputs idata and udata in hexadecimal. Convert to decimal when using CUP)

Page 1 also requires assignment of dynamic memory pool and runtime stacks. (C program invocations receive an entry point and runtime stack based on the function block segment where the Invoke C function code is configured The user provides the name of the C function which serves as the entry point for each segment task which invokes C)

Dynamic memory pool and runtime stacks are part of the C User RAM area, which has 64K boundaries The user can configure excess memory into the dynamic memory pool or runtime stacks. Excess memory is assigned to the dynamic memory pool, by default. If the C program does not use dynamic memory functions, this default can be overridden by the user by specifying values in the stack fields to consume any excess memory (up to the next 64K boundary).

The user specifies the maximum RAM size as a result of compilation. The values should be based on those output by the cross compiler to the console (**NOTE:** The cross compiler outputs in hexadecimal; CUP in decimal) The user can specify larger than actual values to allow for program growth

On the first page of this display (Figure 3 7), the user identifies the idata, udata, and dynamic memory pool sizes.

00 08 05 04 11 07

FIGURE 3 7 *Edit C Memory Specifications Menu C User RAM page 1*

Press the PgDn key to access page two. Page two (Figure 3 8) is for entry of the System RAM area including the Code Section, Checkpoint Buffer and Module Bus File (MBF) I/O specifications These optional buffers are configured into System RAM Checkpoint buffers are used when file data is sent to the backup MFC in a redundant configuration.

MBF buffers are used for copying file data to respond to module bus requests for file operations This occurs when CLP performs file data reads at user's request, and for C callable Module Bus File transfers (see **rfilef** and **rfiler** in **Functions** section).

00 08 07 04 11 07

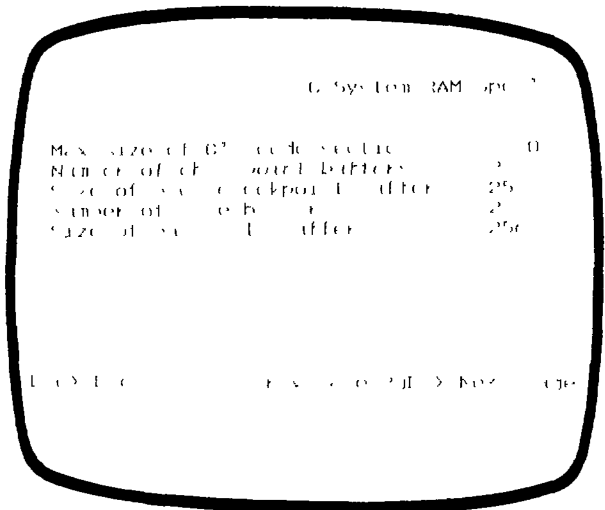

FIGURE 3-8 -- *Edit C Memory Specifications Menu C System RAM page 2*

Press the PgDn key to access page three. Page three (Figure 3 9) shows the totals resulting from the input of the previous pages. User RAM is rounded up to a 64K boundary The sum of User RAM and System RAM should not exceed the Total RAM specification entered in the Edit Format Specs menu It is important to note that the NVM requirement shown does not account for data file space. If you expect to use data files, estimate the limits of data file growth an add that amount to the given value

When done with page three, press the Escape key to save your entries

00 08 07 04 11 07

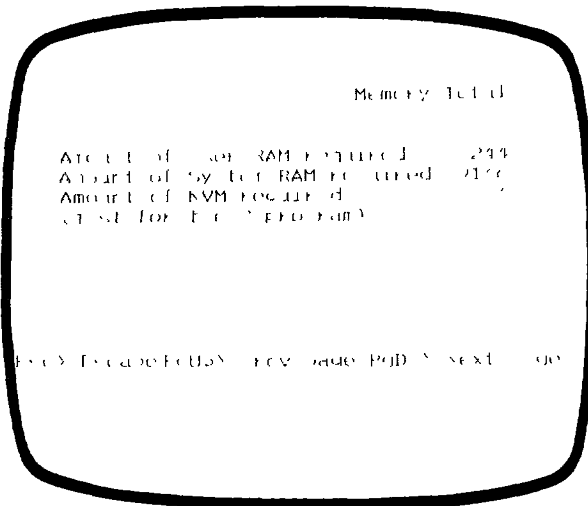

FIGURE 3-9 *Edit C Memory Specifications Menu Memory Totals page 3*

Edit Object Name List
From the Main Edit Menu, select F4 to access this menu Edit Object Name List (Figure 3 10) is used to tell the utility which object files (those created during the second pass of the LCM compiler) to include in the linking process Enter the name of all the O files you want included in the link The linker program is LMB68K EXE This linker searches the MFCLIB for MFC ROM resident functions, and LC L and LCM L for Lattice runtime support functions not found in MFC ROM Additionally, the user can request CUP to include user writer linker specification files To do so, put a tilde (~) in front of the filename Refer to section 4 2 2 of Lattice Cross Compiler document for instructions on how to create a linker specification file

00 08 09 04/11/07

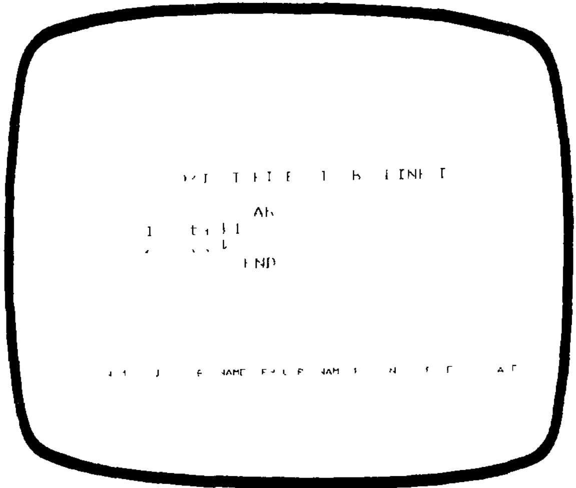

FIGURE 3 10 *Edit Object Name List Menu*

Build Linker Command File
From the Main Edit Menu, select F9 to access this menu This menu is used to create the linker command file (LNK) Values here are based on the previous entries Discrepancies between format specs and memory requirements are shown in the Memory Summary Display (Figure 3 11) Negative values in the row labeled unused flash on the display. This indicates an error condition When this happens either the format specs must be increased, or the C memory specs must be decreased to correct the problem

Upon completion of this display, the C program is linked using the CMFCL Batch file

00 08 09 04 11 07


```
                    MEMORY SUMMARY

                    RAM      NVM
Available           [illegible]  79 38  (total fo  C & FB )
Formatted fo (      75000    10[illegible]  (see format spe  )
Required by C       415[illegible]  [illegible]74  (rec memory specs )
Unused              [illegible]40[illegible]  185[illegible]  (1)

(1) This is the amount of NVM available for data files

Esc ) ABORT                            space) CONTINUE
```

FIGURE 3 11 *Build Linker File Menu*

Link for the MFC
To link the program, exit the C Utility by pressing Escape twice. At the system prompt, type CMFCL and the CSP filename you want to link; this creates the appropriate output files.

After completing this task, go back to CUP. The next section explains the procedures for configuring the module and downloading the program

Configure the Module
From the CUP opening menu, press F2 (read existing CSP file). Key in the CSP filename, press F1. The first menu of Figure 3 12 appears From this menu, select F1 Module Management The second menu of Figure 3 12 appears This menu is used to initiate the communication between CUP and the MFC The PCU and module addresses, and CIU/SPM specifications determine how CUP communicates with the MFC CUP continuously checks the status of the MFC and displays it through a window on the console. If addresses are incorrect, cable connections improper, the module is halted, etc , the message 'CAN'T COMMUNICATE WITH MODULE' appears

```
MENU
F1      - Module management
F2      - E, program management
F3        Data file management
Esc        cape
```

```
ME
F1      elect CONFIGURE mode
F2    - select EXECUTE mode
F3    - RESET the module
F4      FORMAT the module
F5      single/red start stat  display
F10     Switch target module
Esc     Escape
```

FIGURE 3-12 *Configure Module Displays*

00 08 11 04 11 07

From the second menu of Figure 3 12, press F1 (select CONFIGURE mode). Press the space bar to continue. Next, press F4 to format the module *It is important to note that doing so will ERASE everything in the module's memory.*

C Program Management Download
The linked program can now be downloaded to the MFC. Press Escape, the first menu of Figure 3 12 is back on the display Select F2 C program management This menu (Figure 3 13) is used to download the C program The C program at this point exists in three files C MAP, code section, and idata section When F1 is pressed, CUP verifies the file specifications (see the second display of Figure 3 13) Upon successful verification, the download begins When the download is complete, the system prompts the user.

NOTE: Any existing program files in the MFC are deleted when the download begins

	CSP Addr	CSP Size	MAP Addr	MAP Size
Code section	00FF05B8	00001F4C		
Idata section	00FE0000	00000100		
Udata section	00FE0100	00000800		
Dynamic memory	00FE30A0	00004E20		
Checkpoint buffers	00FE7EC0	00000100		
MB file IO buffers	00FE80E0			

	Stk addr	Stk Size	EP Name	EP Addr
Segment 0	00FE20D0	00001000	main1	
Segment 1	00FE30A0	00000E00	func1	
Segment 2				
Segment 3				
Segment 4				
Segment 5				
Segment 6				
Segment 7				

Reading [illegible] sample map

Esc ABORT

[illegible] RETRY

FIGURE 3 13 *C Program Download Menu*

00 08 12 04 11 07

Data File Management
After the program is downloaded to the MFC, the Data File Management (F3 of Figure 3 12) can be used to perform a variety of operations (see Figure 3 14). For example, press F1 to display the module's directory. This directory shows what files, their size, access, etc are currently in the module's NVM file system. Other operations such as copy files, create files, etc. are available. Figure 3 15 is an example of a module directory.

FIGURE 3-14 *Display Module's Directory*

00 08 12 04 11 07

00 08 14 04 11 07

THE MFC

GENERAL

This section explains how to set up the MFC for the C environment

MODULE FORMAT

The MFC has configurable memory of 320 Kbytes of RAM and 80 Kbytes of NVM This memory is divided between function blocks and C program structures The Module Format Table handles this system structure

The format operation involves initializing all function block space, writing values to the module format table, and creating a new file system and directory based on the entries in the format table

The format operation can be done one of two ways Hardware or Software. The Hardware (hard format) method is done with the Option dipswitch (U72 on the CPU Board refer to MFC Product Instruction for switch information). Set switches 1 and 3 to the "1' position. When this is done, the MFC writes a default format table and initializes NVM space The defaults are:

- 72 bytes of directory (free space and last entry)
- 512 bytes of file data space
- 0 bytes of C User RAM

The Software (soft format) method is done with the CUP program. From the CSP Edit Menu, press F2 Configure Module On the ensuing display, press F1 Module Management Select FORMAT MODULE from this display. The prompt 'SENDING FORMAT MESSAGE' appears. It is important to note that this deletes ALL existing configuration data in the NVM

MFC FILE SYSTEM

The dynamic data file system for C programs and the C Utility Program resides in the MFC's NVM. File space size and number of entries available in the directory is determined by the user during the Module Format task.

File names must be in the range 1 through 32759. When specified from a C program, filenames are character strings (refer to **open** or **creat** functions in LATTICE manuals) Files can be opened for reading simultaneously by multiple tasks, but write access is exclusive. If files need to be shared between readers and writers, the user must provide some synchronization. The system open file table has space for twenty entries

00 08 14 04 11 07

For error detection purposes, file data and directories have associated checksum fields. Data integrity checks are performed twice· when the MFC is powered up/reset, and when it goes from Configure mode to Execute mode.

The MFC's two serial ports are treated like files by the C program Therefore, they can be opened for reading/writing by supplying the correct reserved filename.

File Names/Device Names
Valid dynamic file names are in the range of 1 to 32759 in ASCII string representation (e.g., 1', '2', "12345').

Valid device names are Serial Port 0, Serial Port 1, and Null Device. The recognized strings for these devices are

Serial Port 0	'p0'	'PO	con"	'CON'
Serial Port 1	pl	'P1'	'prn'	'PRN'
Null Device	nul'	'NUL'	'null	'NULL'

NOTE: Functions to access files reside in the MFC's ROM

DYNAMIC MEMORY MANAGEMENT

The MFC03 supports a dynamic memory management scheme. This scheme allows C programs to acquire and free blocks of memory at runtime Memory is acquired by functions **malloc** or **calloc**, and returned to the heap through the **free** function. The heap (or dynamic memory pool) is sized by the CUP program (see **GETTING STARTED, Edit C Memory Specifications** for explanation)

C FUNCTION CODES

There are two function codes that must be assigned to function blocks in the module's configuration They are· Function Code 143 Invoke C and Function Code 144 C Allocation Function Code 143 must be in the configuration or the C program will not operate.

Function Code 143 Invoke C
The purpose of this function block is to invoke the C program This code calls a function designated as the segment entry point in the C program

00 08 16 04 11 07

The program can have up to eight segment entry points Each (e g., entry point 0 with function b ock segment 0). A function name (the name of one of the functions that compose the C program) is assigned to each entry point The same function name may be assigned to more than one entry point

When an Invoke C block is encountered during function block execution, control is transferred to the C program at the associated entry point. When that function returns, function block execution continues normally at the next logical block. The entry point function may call other functions of the C program before returning.

Invoke C function blocks can be configured in any of all function block segments. Since each function block segment is a separate task, the C program may also be executed by more than one task. When the program is subject to multi tasking. all shared functions among tasks must be coded so that they can be re entered.

Table 4 1 lists the specifications for this function code; Table 4 2 the outputs.

TABLE 4 1 *Function Code 143 Invoke C Specifications*

Spec No.	Tune	Default Value	Data Type	Range Min Max	Description
S1	Yes	0	I1	Full	Inhibit Execution Flag #1
S2	No	0	I2	0 9998	Block Address of Inhibit Execution Flag #2
S3	Yes	0	I1	Full	Program readable parameter
S4	Yes	0	I1	Full	Program readable parameter
S5	Yes	0	I2	Full	Program readable parameter
S6	Yes	0	I2	Full	Program readable parameter
S7	Yes	0.000	R(3)	Full	Program readable parameter
S8	Yes	0.000	R(3)	Full	Program readable parameter
S9	Yes	0	I1	Full	Spare
S10	Yes	0	I2	Full	Spare
S11	Yes	0 000	R(3)	Full	Spare

Module Utilization 28 bytes NVM, 106 bytes RAM

00 08 16 04 11 07

Function Code 143 has one output with a real data type Its value may be set by the C program using the putargs function

Function Code 144 Allocate C
The purpose of this function block is to define the amount of RAM and NVM allocated for C programs.

The amount of RAM is given in specification S1 It should be greater than or equal to the Total RAM allocated to C specification for Memory Format in CUP

The amount of NVM is given in specification S2 It should be greater than or equal to the Total NVM allocated to C specification for Memory Format in CUP

TABLE 4 2 *Function Code 144 Allocate C Specifications*

Spec No.	Tune	Default Value	Data Type	Range Min	Range Max	Description
S1	No	0	I2	0	320	RAM Allocation (in 1K increments)
S2	No	0	I2	0	80	NVM Allocation (in 1K increments)

Module Utilization 12 + (S2 * 1,024) bytes NVM, 36 + (S1 * 1,024) bytes RAM

Function Code 144 has one output with a Boolean data type. This output is unused at the present time.

CPU LEDS

There are eight front panel CPU LEDs that relay error code information If an error occurs, the LEDs will illuminate in a pattern indicating the specific error. See Table 4 3 for error codes and corrective actions

00 08 18 04 11 07

TABLE 4 3 – *LED Error Codes*

LED 8 7 6 5 4 3 2 1	Hex	Meaning	Action
0 0 1 0 0 0 0 0	20	Inconsistent Format Table data caused by a configuration restore operation	Put MFC in Configure mode and retry the Restore operation.
0 0 1 0 0 0 0 1	21	File system error	Put MFC in Configure mode, check module's file directory for the file in error.
0 0 1 0 0 0 1 0	22	Invoke C error. Invoke C function code is configured but program files are missing, or Invoke is configured in the wrong function block segment.	Check configuration. check module's file directory for program files.
0 0 1 0 0 0 1 1	23	User write violation. The C program attempted to write outside the allowable user address space	Check C program for writes to null pointers, etc.
0 0 1 0 0 1 0 0	24	Stack overflow detected The C program wrote past the end of the stack	Check C program for unbounded stack growth

00 08 18 04 11 07

00 08 20 04 11 07

GENERAL

This section provides a listing of unique MFC runtime support functions

bin input function block output

This function inputs fixed or configured block output values. On return, the caller's buffer will indicate the block's data type, whether quality is defined for the block (if defined, the quality and alarm fields are set), and the block's output value.

synopsis:

```
#include <n90 h>

status   bin(blockno,bufptr),

int blockno,             block number to input
struct fbbuf *bufptr,    pointer to buffer structure
int status               return status

                          0    ok
                          1 = block does not exist
```

bout output a value to a function block

This function outputs a value and optional quality/alarm status to a function block At entry to bout, the data type and an indication of whether quality is defined are provided by the caller in the user structure An error occurs if the block number is out of range or does not exist, if the block is not an OUTPUT BUFFER function code (function code 93, 94, 137, or 138), or if the data type specified does not match with the function block type.

Overflow can occur for type real block outputs because the floating point representation used internally by MFC firmware differs from C programs representation If the value is too large to be represented, then the largest value of the same sign is output and the return status is set to 1

synopsis·

```
#include <n90.h>

status   bout(blockno,bufptr),
```

00 08 20 04 11 07


```
int blockno;                  block number to output to
struct fbbuf *bufptr,         pointer to user structure
int status,                   return status:

                               0   ok
                               1   overflow occurred
                               1   Error
```

cpfil request a file checkpoint operation

This function allows the user to request that a given file be copied to the backup MFC in a redundant pair It is by this mechanism that changes in file data can be updated in the backup. The mode parameter specifies the action to take if a buffer error occurs, such as no buffers being currently available

Note that the file must currently be held open by the caller. If deferred checkpointing is requested, the MFC task responsible for sending the copy must gain access to the file This means that if the file is open for writing by the C program, then it must be closed by the C program after the request has been made so that the task can acquire the file

synopsis:

```
status    cpfil(mode, filedescr, fid);

short mode,     error action (no buffer or file too big
                 for buffer)

                 0   immediate return
                 1   request deferred checkpoint and
                     return
                 2   wait until checkpoint complete
long filedescr, file descriptor (file must be opened)
long fid,       file id number
long status,    return status

                 0   ok
                 1   no buffer available
                 2   file too big for buffer
                 3   file read error
                 4   problem with backup
```

00 08 21 04 11 07

fltr 3 convert a float variable to NETWORK 90 real 3 format

The floating point variable pointed to by pr4 will be converted to NETWORK 90 real 3 format The C program can use this function to convert its internal floating point variables to a format usable by a Computer Interface Unit.

Because a 4 byte representation is being converted to a 3 byte representation, overflow and underflow are possible. If either occurs, default maximum and minimum values are assigned and an indication is returned in the function.

synopsis

```
error    fltr3(pr4,pr3),

float *pr4;     pointer to value to convert
char *pr3;      pointer to buffer to fill
int error;      overflow/underflow indicator

                 0   ok
                 1   underflow, *pr3 LOWLIM
                 1   overflow, *pr3  HILIM
```

getargs get information from Invoke C function block

This function allows the C program to read the Invoke C function code's block number, program readable parameters (S3 through S8), and its tune flag (set to 1 if the block has been tuned). The C program can also read the block output and a private checkpointed save area which the C program can write by the **putargs** function

The parblock structure is defined in the file **n90.h** Note that the C program need not declare memory for the structure itself; a pointer variable is all that is required

synopsis:

```
#include <n90.h>

pp = getargs();
struct parblock *pp;          pointer to this Invoke's
                              parblock
```

00 08 22 04 11 07

inque/outque examine the state of the serial port buffers

The inque function returns the number of bytes (or characters) waiting to be read from an MFC serial port input The outque function returns the number of bytes waiting to be sent to an MFC serial port for transmission In both cases, a value of zero indicates the buffer i empty

These functions provide a means of sensing the state of the serial ports in order to avoid suspension of execution, if other operations can be performed.

Note that the interrupt driven port handlers in the MFC firmware queue up all characters as they are received (or sent) The default buffer size for C programs is 256 bytes, but can be overridden by user buffer allocation using the portopen function

synopsis

```
nbytes   inque (portno),
nbytes   outque (portno);

int nbytes,   number of bytes in buffer
int portno,   port number (0 or 1)
```

portopen open a serial port with user buffer.

This function allows the user to provide buffering for a serial port of a larger size than the default size achieved from the **open** function Note that the buffer provided is divided into three pieces: 38_{10} bytes of overhead and two circular queues (1 for input, 1 for outputs) The default buffer configured by **open** is 550 bytes (256 bytes for each input and output), and cannot be reclaimed.

synopsis

```
fd   portopen (pn,mode,bufptr,bufsiz)

int fd;          > 0   file descriptor
                   1   FAIL
int pn;          port # (0 or 1)
unsigned short
mode,             0   PMODE (default)
                 !0   specifies port control
```

00 08 23 04 11 07

chart *bufptr, user buffer address

int bufsiz: must be 50 or more (38 bytes of overhead)

The mode parameter is used to configure the 6850 UART as follows:

FLOW CONTROL

Hardware Only	0	
Xon/Xoff Enable	128	0 x 80

BREAK DETECT

Yes (Enabled)	64	0 x 40
No (Disabled)	0	

STOP BITS

1 Stop Bit	0	
2 Stop Bits	32	0 x 20

PARITY

None	0
Odd	4
Even	8

DATA LENGTH

7 bits	0 or 2
8 bits	1 or 3

A mode parameter of 0 gets the default value 0 x c3
A NULL bufptr designates that the system commbuffer be used.

Note that portopen fails if the specified port is already open. Since port 0 is opened automatically at startup for standard input and output, it is necessary to issue **fclose** calls for stdin, stdout, and stderr prior to a portopen call for port 0.

putargs write the block output and save area to Invoke C.

The C program can write to the Invoke C function block output and to the private save area associated with each Invoke C block. The block output has quality and alarm fields which can be written by this means The **getargs** function must be first called to obtain a pointer at the parblock structure which **putargs** uses

00 08 23 04 11 07

FUNCTIONS

putmsg write to serial ports with gapless transmission

This function works much like the write function for output to the serial ports If gapless tranmission of the message is required, then putmsg should be used Note that the port must first be associated with a file descriptor acquired from open or portopen.

synopsis

status putmsg(fd,buffer,length)

int fd;	file descriptor
char*buffer	pointer at message
int length,	length of message
int status	1 if bad fd nbytes written

rfilef copy remote file to local file

This function copies a remote file' (i e , a file residing in another module) into a local file

The specifications of the copy operation are passed to the function in a structure of type 'rffspec." The status of the operation is passed back to the caller in this structure The structure is defined in the header 'n90.h.' and is described below

rffspec

	Specified by Caller
short loop,	loop address of remote module
short pcu;	PCU address of remote module (must be 0 for Plant Loop)
short mod,	remote module address
short rfid,	remote file ID number
short lfid,	local file ID number
short lfdscr,	local file descriptor (if file is opened by caller) or 1 (if not opened by caller)
short wait,	wait mode 0 immediate return 1 wait until done
short maxtime,	maximum time (in seconds) allowed for operation

00 02 25 04 11 07

	Returned by Function
short sts;	Status:
	1 busy
	0 normal completion
	1 invalid spec
	2 can not open/read remote file
	3 local memory overflow
	4 can not write local file
	5 timeout

synopsis

```
#include 'n90 h'
void rfilef (&specs),
struct rffspec specs,
```

Miscellaneous Comments

1 This function copies whole file only; will not copy parts of a file

2. If the destination file is opened by the caller, it must be opened for read/write and the caller must not access the file while the status is "busy' When the function completes, the "file position' is indeterminate (the caller must seek to the desired position).

   If the caller does not open the file, it will be opened and closed inside the function, i.e., the function obeys the same file access rules as the C program

3 The function reads the entire file into local dynamic memory before writing to the local file. Therefore, if the read operation is not successful, the local file is not modified

4. Multiple copy requests may be active at one time (immediate returns and/or multip e tasks). There is no built in limit on the number of concurrent requests

5. Errors detected by the function are classified as fatal (e.g , the specified remote file does not exist) or non fatal (e.g., the remote module is busy) When a fatal error is detected, the function terminates immediately When a non-fatal error is detected, the operation which caused the error is retried periodically until it succeeds or the elapsed time (measured from the call to the function) exceeds 'maxtime."

00 08 25 04 11 07

6. Dynamic memory usage each active request uses about 180 bytes of local dynamic memory. As described above, a complete copy of a file is read into dynamic memory before being written to the destination file However, even if multiple requests are active, only one request at a time is allowed to make its copy. The memory usage for a copy depends on several factors but typically is about 1 2 times the file size

7 The module bus reads are performed by the same task which performs the module bus I/O for function blocks such as Analog Input/Block, Digital Input/Block A file read requires at least 2 cycles of this task (see function code 90, spec 2)

8 The number of module bus messages required to read a file is at least 4 + n/90 (where n is the file size).

9. The remote module uses one MBF buffer for each active copy operation. If the entire file fits in an MBF buffer, the remote module locks the file only long enough to read the file into its MBF buffer. Otherwise, the remote module locks the file during the entire module to module transfer It is usually desirable to avoid this situation by making the MBF buffers large enough to hold the largest file to be transferred

rfiler read remote file to RAM.

This function reads a remote file (i.e , a file which resides in another module) into a buffer provided by the caller

The specifications of the read operation are passed to the function in a structure of type "rfrspec." The status of the operation and a byte count are passed back to the caller in this structure The structure is defined in the header "n90.h and is described below:

<u>refspec</u>

	<u>Specified</u> <u>by</u> Caller
short loop;	loop address of remote module
short pcu:	PCU address of remote module (must be 0 for Plant Loop
short mod;	remote module address
short rfid,	remote file ID number
long ofs;	remote file offset (byte number) where read is to start
long cnt,	maximum number of bytes to read (must be less than or equal to size of destination buffer)

00 08 27 04/11/07

char *ptr,	pointer to destination buffer
short wait,	wait mode 0 immediate return 1 wait until done
short maxtime;	maximum time (in seconds) allowed for operation

Returned by Function

short sts,	status 1 busy 0 normal completion 1 invalid spec 2 cannot open/read remote file 3 local memory overflow 5 timeout
long nb,	number of bytes read

synopsis

```
#include n90.h'
void rfiler (&specs),
struct rfrspec specs,
```

Miscellaneous Comments

1. By setting 'ofs" and 'cnt' to the appropriate values, it is possible to read all of a file or any continuous block within a file. For example, to read an entire file set ofs' to zero and cnt" equal to or greater than the file size

2 The file data is read from the remote module in block (usually 90 bytes but sometimes less) and put directly in the destination buffer. Therefore, the buffer should not be accessed while the status is 'busy.' If the final status (0 or neg) indicates an error, the buffer contents are indeterminate and should not be used

3 Multiple read requests may be active at one time (immediate returns and/or multiple tasks). There is no built in limit on the number of concurrent requests.

4 Errors detected by the function are classified as fatal (e.g., the specified remote file does not exist) or non fatal (e g., the remote module is busy). When a fatal error is detected, the function terminates immediately. When a non fatal error is detected, the operation which caused the error is retried periodically until it succeeds or the elapsed time (measured from the call to the function) exceeds 'maxtime "

00 08 27 04 11 07

5 Dynamic memory usage each active request uses about 140 bytes of local dynamic memory.

6 The module bus reads are performed by the same task which performs the module bus I/O for function blocks (e g , Analog Input/Block, Digital Input/Block) A file read requires at least 2 cycles of this task (see function code 90, spec 2)

7 The number of module bus messages required to read a file is at least 4 +n/90 (where n is number of bytes read)

8 The remote module uses one MBF buffer for each active read operation If the requested number of bytes (or the entire file) fits in an MBF buffer, the remote module locks the file only long enough to read the file into its MBF buffer Otherwise, the remote module locks the file during the entire module to module transfer It is usually desirable to avoid this situation by making the MBF buffers large enough to hold the largest file to be transferred

r3flt convert NETWORK 90 real 3 format to floating point

The real 3 value supplied is converted to a real 4 format in IEEE format, and placed into the four bytes pointed to by pr4. A real 3 value received from a CIU can be converted to a format which can be manipulated using arithmetic and floating point operations by a C program by using this function. There is no return value.

synopsis

```
void r3flt (pr3,pr4);
char *pr3,      pointer to r3 to convert
float *pr4;     result
```

sysclk read MFC 1 millisecond resolution clock

The value returned from sysclk is a 31 bit positive integer This means that the clock rollovers occur approximately every 596 hours The value is reset to zero when the MFC is reset, and increases monotonically to maximum value. The next clock tick resets the value returned by sysclk to zero, and the cycle repeats All time interval applications must take clock rollover into account

00 08 29 04 11 07

synopsis:

```
value   sysclk();
(long) int value;              timer value
```

00 08 29 04/11/07

00 08 31 04/11/07

APPENDIX A

MFC MEMORY STRUCTURES

RAM STRUCTURE

C RAM

All of the configurable, RAM resident structures related to C are contained in this area.

The C user RAM contains the data structures that are directly accessible by the C program The C program can read from and write to any address in this space An attempt to write anywhere outside this space will put the module in Error mode.

The C system RAM contains the program's executable code and other data not directly accessible to the C program

The total size of this space is established during the Format operation and is specified by the format spec

total RAM allocated to C

The partitioning between user and system space is established during the program download operation and is determined from the memory specs and the constraint that the size of the user space must be a multiple of 64K

Function Block RAM

The entire RAM resident function block configuration is contained in this space

The size of this space is established during the Format operation and is inferred from the format specs:

size of C/FB RAM total RAM allocated to C

Idata Section

This area of RAM holds the C program's initialized data. The idata section file is read into this space during Execute mode start up.

The size of this space is established during the download program operation and is specified by the memory spec:

max size of C's idata section

Udata Section

This area of RAM holds the C program's uninitialized data This space is initialized to zeroes before the C program is started.

00 08 31 04 11 07

The size of this space is established during the download program operation and is specified by the memory spec:

max size of C's udata section

Segment Stacks and Library Data

This area of RAM holds the per task" data space (each function block segment (task) which invokes C must provide its own stack space and C library data space).

The size is established during the download program operation The total size allocated is determined by the memory specs as follows

the sum of (segment stack size + 2000) for each specified segment entry point

The amount of stack space required for each task depends on several factors including depth of function nesting and amount of automatic data defined by each function. Allocate at least 2 Kbytes for each stack

Dynamic Memory Pool

This area of RAM is available to the C program for data storage It is managed by the functions **malloc** and **free.**

The size of this space is established during the download program operation and is specified by the memory spec·

min size of dynamic memory pool

Checkpoint Buffers

This area of RAM is used for temporary storage of file data while it is transmitted from a primary MFC to its backup When a request is made to checkpoint a file, the file data is first copied into an available checkpoint buffer and then is transmitted to the backup from the buffer

The size is established during the download program operation. The total size allocated is determined by the memory specs

(number of checkpoint buffers *
(size of each checkpoint buffer +30))

MBF Buffers

This area of RAM is used for temporary storage of file data while it is being accessed via the module bus. When a request is made via the module bus to open a dynamic file, the file data is first copied into an available MBF buffer and subsequent reads and writes operate on the copy instead of the actual file

00 08 32 04 11 07

The size is established during the download program operation The total size allocated is determined by the memory specs as follows:

(number of MBF buffers * (size of each MBF buffer+40))

Code Section
This area of RAM holds the C program's executable code The code section file is read into this space during Execute mode startup.

The size of this space is established during the download program operation and is specified by the memory spec

max size of C's code section

C Function Block RAM

Address	Area	Details
F80000	C user RAM	idata section udata section segment data dynamic memory pool
XX0000	C system RAM	checkpoint buffers mb buffers unused code section
Function FD0000	Block RAM	function block space

NOTES:

1 One segment data area per FB segment (size is zero if no segment entry point is defined).
2 C library segment data (part of segment data area)·
accessed via A6 (A6 points to base)
no initialization
3 Stack·
accessed via A7 (stack pointer) and A5 (frame pointer)

00 08 33 04 11 07

APPENDIX A

NVM STRUCTURE

Module Format Table

This table contains information specifying the format of the module (e.g , amount of NVM allocated to C, max number of data files) It is initialized by the Format operation It's size is 34 bytes

File Directory

This directory contains the system information for the current files It is made up of fixed sized records with one record for each existing or potential file It is initialized by the Format operations

The size established by the Format operation is derived from the format specs.

36 * (5 + max number of data files) bytes

File Space

This area of NVM contains the C program files and the data files. Each file is composed of a linked list of fixed sized blocks (256 bytes) Unused file space is organized as a special file called the free list Initialized by the Format operation

The size of the file space is established by the Format operation and is specified by the format spec·

total NVM allocated to C (in bytes)

Function Block Space

This area of NVM contains the function block configuration The Format operation or EE initialization can be used to initialized this space

The size of this space is established by the Format operation The size is not explicitly specified; it is the remaining NVM space not assigned to the other structures.

00 08 34 04 11 07

NVM Structure

68000 to 68222	Reserved
	Module Format Table
	Directory
	File Space
7BFFF	Function Block space

File ID

1 32759	data files
32760 32764	reserved, unused
32765	C code file (section 0)
32766	C data file (section 1)
32767	C map file

00 08 34 04 11 07

00 08 36 04 11 07

GLOSSARY

C Compiler	There are two compilers Native and Cross. Native produces code for Workstation execution, Cross produces code for MFC execution
C file	<filename> C the Workstation resident text file that contains a file to be read by the C compiler (C program source file).
checkpoint buffers	MFC module buffers that provide temporary storage for file data while it is transmitted from primary MFC to backup MFC
C map file	MFC resident file containing memory map data of C program Written during the download function (File ID 32767)
C RAM	Two parts C user RAM and C system RAM. Continuous block of RAM in the MFC containing all configurable, RAM resident structures of the C environment
code section	The executable code of a C program (also known as text section).
code section file	MFC resident file (file ID 32765) that contains the C program's code section This file is wr tten to the MFC during the program download operation The file contents are derived from the LMS and MAP files.
CSP file	The Workstation resident file containing information about the C environment for the MFC. Information such as format specs, memory specs, object files, etc. is found in this file A CSP file exists for each target MFC.
CUP	Acronym for C Utility Program, the Bailey supplied software that is used to specify and manage the C environment of the MFC module.

00 08 36 04 11 07

GLOSSARY

C system RAM	The part of C RAM containing the code section, checkpoint buffers, and MBF buffers
C user RAM	The part of C RAM containing data structures that are directly accessible to the C program Included are idata, udata, segment stacks and C library data, and dynamic memory pool This is the only part of MFC address area that the C program can write to
dynamic file	An MFC file that can be modified while the module is in the Execute Mode.
file attributes	Certain file characteristics that are specified when the file is created, for example, write access type.
file ID	Unique MFC file identifier The following IDs are permanently assigned 0 free list 32765 code section file 32766 idata section file 32767 udata section file Data file IDs (1 32759) are assigned by the user when the files are created
format operation	Operation performed on the MFC to format and initialize its user configurable memory. This operation establishes the major partitions of the configurable RAM and NVM (i.e., the boundaries between C and function blocks), deletes all files and initializes the function block configuration. The format operation can be performed one of two ways: 1. via the module bus (through CUP) 2. by hardware reset with switch U72 set for the format special operation 0C0CCCCC
format specs	The set of specifications that define the MFC's memory format The format specs are stored in the module's CSP file.

00 08 38 04/11/07

function block	Address in MFC memory containing a function code
function block segment	A group of function blocks that are associated with the same Segment Control Block (function code 82); belonging to the same scan cycle Each function block segment is executed by its own, independent ROS task
idata section	Refers to the initialized data of a C program.
idata section file	MFC resident file (file ID 32766) that contains the C program's initialized data This file is written to the MFC during the program download operation The contents of the file are derived from the LMS file
lc1m/lc2m	LATTICE C compiler for the 68000 processor. This compiler runs on the Workstation. It is implemented in 2 phases lcm1 and lcm2 Phase 1 reads a C source module (C file) and produces an intermediate quad file (Q file). Phase 2 reads the Q file (then deletes it) and produces an object file (O file).
linker	A program that combines separately produced object modules into a single load module. There are two linkers: DOS link LATTICE load module builder Both linkers execute on the Workstation. The distinction between them is their target environments The target of the DOS linker is the Workstation; the load module builder is the MFC 68000 processor

00 08 38 04 11 07

GLOSSARY

LMS file

<filename> LMS A Workstation resident file that contains a C program 'load module' The load module contains the C program's code section (the executable code) and the initialized data (idata) section This file and related MAP file is produced by the load module builder During the program download operation, the C Utility Program reads the LMS and MAP files and transmits the appropriate information to the MFC.

LNK file

<filename>.LNK A Workstation resident text file that contains the commands for the Load Module Builder (LMB command file) The LNK file is produced by the C Utility Program from information in the **csp** file

load module builder

(LMB) Workstation resident linker program that combines a set of object modules (O files) into a single load module (LMS file) that can be downloaded to an MFC.

Example of lmb invoke command:
lmb68k <**.lnk>** map ** lms

where ** is a filename (same as csp)

MAP file

<filename>.MAP A Workstation resident text file which contains the memory map of a C program load module The map indicates addresses and sizes of the load moulde's control sections and the addresses of the global symbols. The MAP file is produced by the Load Module Builder During the program download operation, the C Utility Program reads the MAP file to verify the control section locations and to determine the addresses of the segment entry points.

00 08 40 04 14 07

MBF buffers	MFC resident buffers that provide temporary storage of file data while the file is being accessed via the module bus. When a request is made via the module bus to open a dynamic file, the file data is first copied into an available MBF buffer and subsequent reads and writes operate on the buffer instead of the actual file
memory specs	The set of specifications that determine the structure of an MFC's C RAM The memory specs for a particular MFC are stored in its csp file
NVM	The MFC module's configurable non volatile memory (battery backed RAM).
O file	<filename> O Workstation resident file containing a C object module (i e , a file produced by the C compiler)
segment entry point	The function in the C program that is called by an Invoke C function block. For each function block segment with one or more Invoke C blocks, there is one entry point into the C program All Invoke C blocks in a segment call the same entry point An entry point may be shared among 2 or more segments
segment stack	An area in RAM used by the C program to store temporary data There is one segment stack for each function block segment (task) which invokes C
udata section	The uninitialized data of a C program.
write access	MFC file attribute that controls write access to the file. There are 3 types UW unrestricted write The file can be written by the local C program and via the module bus. LW - local write. The file can be written by the local C program but not via the module bus.

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RO read only. The file cannot be written by the local C program or via the module bus (although the file can be written, it can be initialized via the module bus).

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