RMB-167 USER'S GUIDE

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1 Overview

The RMB-167 is an evaluation board for the Siemens SAB C167 microcontroller. The RMB-167 board accepts the following processors, the SAB C167-LM, the SAB C167SR-LM, and the SAB C167CR-LM. The evaluation board is designed as a low-cost demonstration board using the microcontroller in the 16-bit non-multiplexed addressing mode. The microcontroller is configured to run at 40Mhz with no wait states. The SAB C167SR-LM, and the SAB C167CR-LM use a 5Mhz oscillator with a phase-lock-loop to generate the ccorrect operating speed. A 16-bit nonmultiplexed data bus and an 18-bit nonmultiplexed address bus are implemented. Several memory options are supported. The default configuration is the 64K RAM and no EPROM mode. In this mode, the monitor program or user program is downloaded to RAM using the SAB C167 bootstrap feature. All system address, data, and control lines as well as microcontroller ports 2 through 8 are terminated at three 50-post headers. The SAB C167 serial port is available to the user at RS-232 level through a DB-9 socket and a 3-post connector. The serial port is used to communicate to a PC host. A set of option headers, decoded by GAL devices make the RMB-167 a flexible hardware platform.

1.1 Hardware

- SAB C167 high-performance microcontroller.
  - Internal 16 channel 10-bit analog-to-digital converter.
  - Bootstrap loading feature
  - Runs at 40Mhz with zero wait states
  - One serial port
  - One high speed synchronous serial channel
  - Five 16 bit timers
  - Watchdog timer
- One serial port with a MAX232 driver
- One high speed synchronous serial channel.
- 111 bits of general-purpose input/outputs ports.
- Accommodates 64K of EPROM (not installed)
- Accommodates 64K or 256K of SRAM (64K installed).
- Push buttons for RESET# and NMI# (non-maskable interrupt).
- GAL decoded memory map for maximum flexibility. (GAL's can be reprogrammed by user or by Rigel Corporation)
- Flexible and embeddable evaluation board.
- Board size 4"x6 1/2"

1.2 READS166 Evaluation Software Overview

READS166, version 3.00, is Rigel Corporation's Integrated Development Environment for the Siemens/SGS Thomson 16-bit processors. READS166 includes an editor, a host-to-board communications system, an assembler, and a C compiler. READS166 is completely rewritten in native 32-bit code to run on Windows95 and WindowsNT. READS166 includes a sophisticated project management system to simplify code reusability and version control. The C compiler is rewritten to support a full debugger. The debugger allows you to step through your code with breakpoints and variable watches as the compiled code runs on the target board, similar to the operation of an in-circuit emulator.

RMON166 - The READS166 monitor program

RMON 166 is downloaded after bootstrapping (or it may be placed into ROM) and supports basic memory and port functions. RMON166 allows downloading and running applications programs. The complete source code for user modifications or upgrades is included on disk.

Ra66 - The READS166 Assembler

Ra66 is an assembler for the C166 family of controllers. It is a multi-pass absolute assembler which generates HEX code directly from assembly source code. The assembler in the demo version of READS166 limits the size of code to about 2K.

Rc66 - The READS166 C Compiler

Rc66 is a C Compiler for the C166 family of processors. It compiles code for the tiny memory model which fully resides in the first segment of memory. Rc66 is a designed as a low-cost C compiler which provides a quick development cycle for simpler applications which do not need more than 64K of code, or the use of standard C libraries. Rc66 implements a subset of ANSI C. Rc66 works in conjunction with Ra66: first an assembly language program is generated from the C source, then a HEX file is generated.

Currently, structures, unions, enumerated types, and the typedef directive are not implemented. The C-compiler in the demo version of READS166 limits the size of code to about 8K.

1.3 Parts List

Your RMB-167 package includes the following:

Hardware

1. RMB-167 evaluation board with a 64K of static RAM.
2. Serial modem cable with adapter

Software

1. RMON167 monitor program with source code.
2. READS166 host driver for Microsoft Windows.
3. Bootstrap file source code.
4. Sample programs.

Documentation

1. User's Guide with circuit diagrams

A regulated (+/- 5%) 5 volt 500mA power source is to be supplied by the user.

2 SOFTWARE

The RMB-167 board comes with software from Rigel Corporation and third party vendors, whom we work very closely with. Rigel's own software for the 166 family may be found on the CD-ROM in the Rigel Products file, under 166 Software.

2.1 System Requirements

READS166 is designed to work with an IBM PC or compatible, 486 or better, running Windows 95 or Windows NT.

2.2 Software Installation, READS166

Place the CD-ROM in your drive. Go to the **Rigel Products | 166 Software | READS166 | .exe** program**.** Click on the exe file and the program will begin to load in your system.
Follow the standard install directions answering the questions with the appropriate answers.

2.3 Third Party Software

A variety of third party software is available on Rigel's CD-ROM. The software may be found in the Strategic Partners Folder under Keil, Tasking, and PLS.

Data sheets on the IC's used on our boards may also be found on Rigel's CD.

Please note that software updates occur frequently. Please check our web site (and the third party vendors web sites) occasionally to make sure you have the most recent versions of the software.

3 START-UP

3.1 Connections, Jumper Settings

1. Connect your RIGEL board to the PC host via a serial cable.
2. Connect the board to a power supply.
   The red LED will come on if power is connected correctly
3. Check to make sure jumpers are the correct position. There are two jumpers, one in position P0.4 the other in P0.6. This is the default configuration for the RMB-167 and the board will be populated this way from the manufacturer.

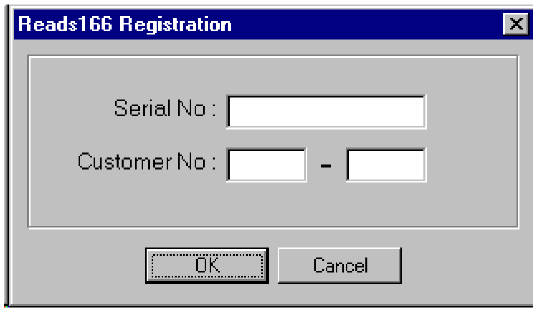
3.2 Software Initialization

Run the READS166 host driver by selecting **Start | Programs | READS166**. You may also start READS166 by double clicking on the READS166 short cut icon if installed.

3.3 Serial Number

3.3.1 Demo Version

When you run the READS166 software a pop-up registration box will open asking for your serial and customer numbers. If you are using the demo version of the software you may press **CANCEL** and the box will disappear and the About Box will appear. Press the **OK** button in the About Box and the software will run in the Demo mode. The demo mode limits the size of the files you can compile to about 8K.

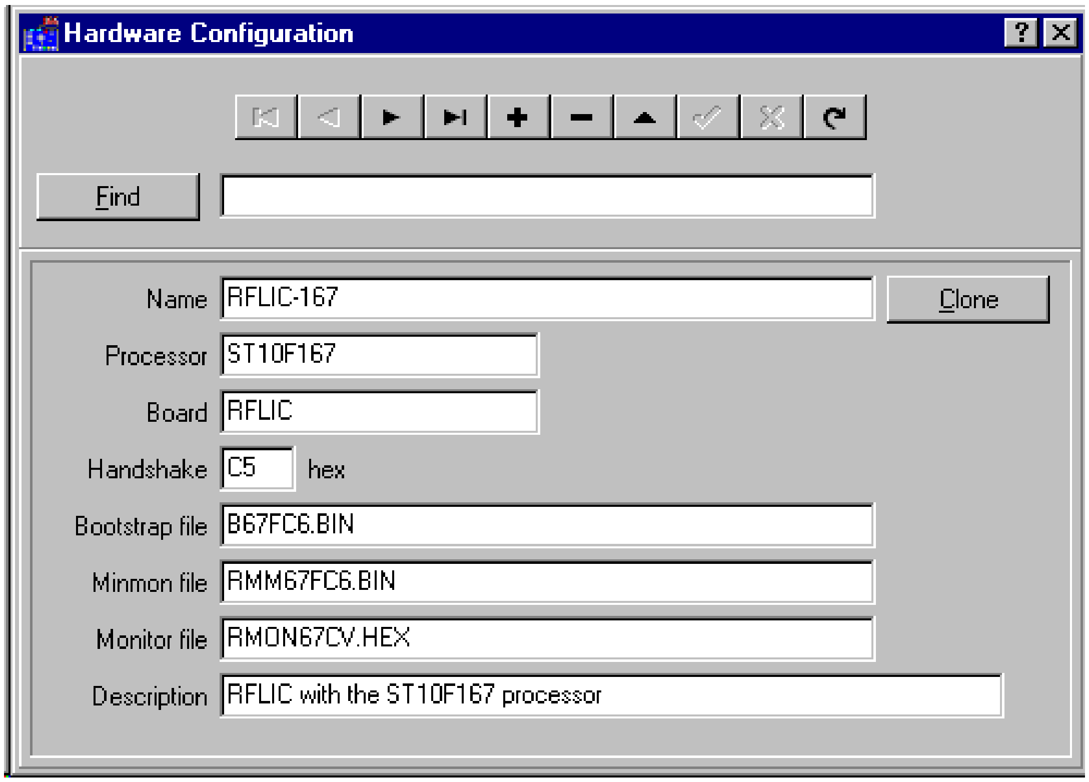


3.3.2 Full Version

If you've purchased the READS166 software a registration sheet with the serial number and customer number will be included with the READS166 User's Guide. When you run the READS software insert these numbers in the correct boxes, press **OK** and then press **OK** in the About Box. Your software is registered and ready to use.

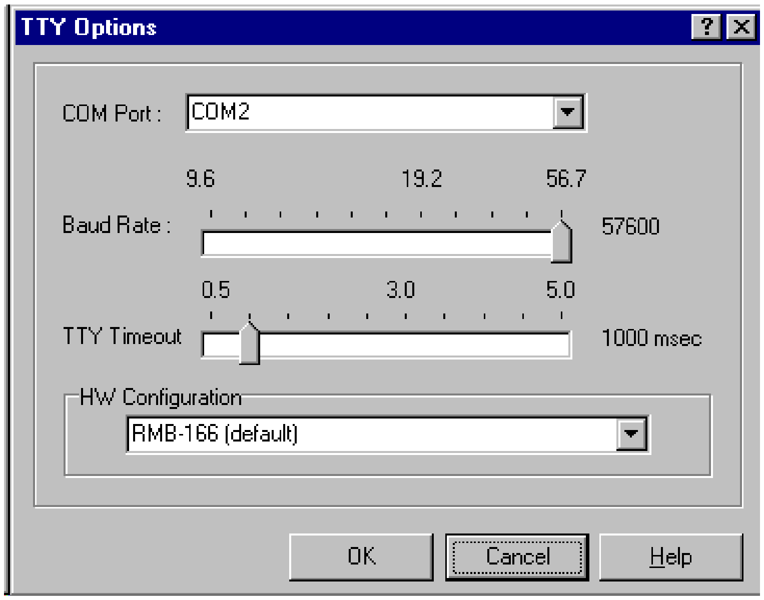
3.4 Configuring READS166 and Initiating Host-to-Board Communications

1. Press the **Projects | Options | Project Properties | HW Configuration** to select the board you are using from the list. Or using the **Tools | Hardware Configuration** menu command, choose the name of the board you are using from the board list which appears.



Name	RFLIC-167
Processor	ST10F167
Board	RFLIC
Handshake	C5 hex
Bootstrap file	B67FC6.BIN
Minmon file	RMM67FC6.BIN
Monitor file	RMON67CV.HEX
Description	RFLIC with the ST10F167 processor

2. Open the TTY window using the **Tools | TTY** menu command. Select the communication port parameters using the **Tools | TTY | TTY Options** menu command. You will need to select the COM port you are using, and the baud rate.



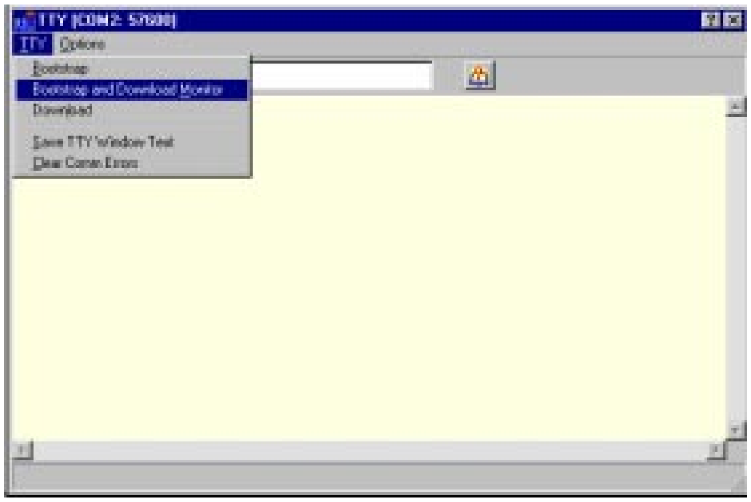
COM Port : COM2
Baud Rate : 57600
TTY Timeout 1000 msec
HW Configuration: RMB-166 (default)

3.5 Bootstrapping

In the default configuration, all monitor programs are downloaded to the boards after the boards are bootstrapped. That is, there is no ROM on the board that is executed upon reset. Bootstrapping loads a small monitor, called MinMon, which in turn loads a larger monitor

RMON16x. Once the monitor program is loaded, the monitor commands are available to the user.

1. Press the reset button on the board.
2. From the menu in the TTY window select **TTY | Bootstrap and Download Monitor**. The board will now bootstrap and download the monitor program.



You may observe the bootstrap progress in the status line of the TTY window. When bootstrapping is completed, the READS166 monitor prompt appears in the TTY window.

3.6 Verifying that the Monitor is Loaded

Make sure the TTY window is active, clicking the mouse inside the TTY window to activate it if necessary. Then type the letter '***H***' (case insensitive) to verify that the monitor program is responding. The 'H' command displays the available single-letter commands the monitor will recognize.

The READS monitors use single-letter commands to execute basic functions. Port configurations and data, as well as memory inspection and modifications may be accomplished by the monitor. Most of the single-letter commands are followed by 4 hexadecimal digit addresses or 2 hexadecimal digit data bytes. The following is a list of the commands.

R E A D S   C O M M A N D S

C nn	Read port nn Configuration (DPnn)
C nn=mmmm	Set port nn Configuration (DPnn=mmmm)
D	Download HEX file
G XXXX	Go, execute code at XXXX
H	Help, display this list
M XXXX	Memory, contents of XXXX
M XXXX=nn	Memory, change contents of XXXX to nn
M XXXX-YYYY=nn	Memory, change block XXXX-YYYY to nn
P nn	Read Port nn (Pnn)
P nn=mmmm	Write to Port nn (Pnn=mmmm)
W XXXX	Word memory, contents of XXXX
W XXXX=mmmm	Word memory, change contents of XXXX to mmmm
W XXXX-YYYY=mmmm	Word memory, change block XXXX-YYYY to mmmm

3.7 Troubleshooting

All the boards are functionally tested before shipment. If the system does not bootstrap as expected, review the hardware, software, and PC setup.

3.7.1 Hardware Set-up

1. Make sure that that you have the power connected correctly.
2. Verify that the power-on LED is lit.
3. Review the jumper settings.
4. Check the modem cable connections to the board and to the host PC.
5. Run the READS software and try to bootstrap and download the monitor again.

If the board still won't operate correctly, check the software setup.

3.7.2 Software Set-up

1. Select the TTY menu **TTY Option**.
2. Verify that the COM port correctly matches that of the host PC.
3. Select the Baud rate to be 19.2K
4. Select a large TTY Timeout parameter, one of at least 2 seconds.
5. Note the hardware configuration given in the drop list "**HW Configuration**."
6. From the Reads166 main window, select the menu option **Hardware Configuration** located under the **Tools** menu.
7. Find the record corresponding to the hardware configuration selected in the **TTY Options**.
8. The Name, Processor, Board, and Description fields are for information purposes only. If the fields are not as listed above, you may search for a record which matches the desired fields. Once located, go to the **TTY Options** dialog and select the correct hardware configuration. Alternatively, you may create a new hardware configuration record or modify an existing one from the Hardware Configurations dialog.

If the board still won't operate correctly, check the PC setup.

3.7.3 PC set-up

1. Go to the Windows **Control Panel** usually located under the Settings menu (**Start, Settings, Control Panel**).
2. Click on the **Ports icon**. (If one does not exist, you may need to install some Windows components again.)
3. Select the port you are using. If the port number does not appear in the list add the port by clicking on the "**Add**" button. You need to restart Windows for the new port selection to take effect.
4. Click on the "**Settings**" button.
5. Select 57600 Baud, 8 data bits, no parity and 1 stop bit. Set "**Flow Control**" to none.
6. Click on the "**Advanced**" button. Select the port you are using.
7. Specify the "**Base I/O Port Address**" and the "**Interrupt Request Line (IRQ)**" fields to be "**default.**"
8. You should try both enabling and disabling FIFO.

If these steps do not remedy the problem, please contact Rigel Corporation at (352) 373-4629 or http://www.rigelcorp.com.

4 OPERATING NOTES

The RMB-167 needs two connections: to a 5 volt well regulated power supply and to the serial port of a host via a modem cable.

4.1 Power

Power is brought to the RMB-167 board by a two-position screw-type terminal block. A well regulated 5 volt DC source is required. The (+) and (-) terminals are marked on the board. Note that a diode is placed across the input in reverse. Thus if the power is applied to the RMB-167 board in reverse polarity, the diode will short the power supply attempting to prevent damage to the board. Populated with 64K of CMOS RAM, the RMB-167 draws less than 175 mA.

4.2 Serial port 0

Serial port 0 is accessed through the RS-232 level converter U11. The microcontroller supports the transmit and receive signals. A minimal serial port may be constructed with just 3 lines: transmit, receive, and ground, disregarding all hardware handshake signals. Port P1 (HOST) of the RMB-167 is a DB-9 female connector used to connect the board to an IBM compatible PC. A straight-through modem cable may be used. That is a cable connecting pin 2 of the RMB-167 to pin 2 of the host, and similarly pin 3 to pin 3, and pin 5 to pin 5. This cable and a DB9-DB25 adapter is supplied when the board is purchased directly from Rigel Corporation. JP11 is a 3-pin header, which carries the same signals as P1. It is convenient if the board is to be used as an embedded controller. JP11 is also denoted by S0, and its 3 lines by G (Ground), T (Transmit), and R (Receive) on the RMB-167 silk-screen.

4.3 Serial Port 1

Serial port 1 is used as a synchronous serial channel by the SAB-C167. It has 3 TTL-level signals, MRST (Master Receive Slave Transmit). MTRS (Master Transmit Slave Receive), and SCLK (Serial Clock). Header JP12 carries these three signals as well as provides VCC and GND for reference. Header JP12 is also denoted by SSC (Serial Synchronous Channel) on the silk-screen. The individual pins of the header are denoted by VCC, R, T, C, and GND, which correspond to VCC, MRST, MTSR, SCLK, and GND, respectively.

4.4 Jumper Selection

Two jumpers are needed to use the RMB-167 in the default 64K/256K RAM and no EPROM mode. These should be placed at the Options jumper JP3 corresponding to P0.4 and P0.6. The jumper at P0.4 invokes the bootstrap mode upon a reset. P0.6 selects the bus configuration.

4.5 LEDs

The RMB-167 has three LEDs. The red LED, when lit, shows power is connected to the board. The yellow LED is an auxiliary LED, whose state is determined by the GAL equations. For example the user may program the yellow LED to indicate the presence of a program in EPROM. The default PAL equations set the yellow LED to be the complement of the green LED.

The green LED indicator marked RO (Reset Out) is connected to a GAL device. The LED is turned on after system initialization is completed. More specifically, the LED is turned on when the RSTIN# is high and RSTOUT# makes a 0-to-1 transition, which normally follows an EINIT instruction.

<u>The LED RO will be off and remain off until the bootstrap loader successfully completes loading the bootstrap file into RAM.</u>

5 MEMORY OPTIONS

The RMB-167 memory decoding is accomplished by two 16V8-type GAL devices, U1 and U2. Both devices are collectively responsible of selecting the options of determining the memory map. An output of U1, AUX0 is an input to U2. Similarly, AUX1 connects the two devices. The signal on AUX1 may flow in either direction, giving a wide range of possible ways to divide the functionality between the two devices. A slide switch is also provided to allow switching between alternate memory maps. The GAL inputs include RSTIN# and RSTOUT#, so that a memory map swap upon completion of the reset process is possible, as explained in the Siemens Application Notes. The RMB-167 decodes the address lines A13 to A17. Thus the memory map may be constructed in blocks of 16K. For example, EPROM may occupy only the lower 16K of memory, whereas RAM occupy the remaining addresses. The GAL equations for the default configuration are given in Section 5.1.

5.1 RAM Memory Options

Either 32K 62C256-type or 128K 681000-type static RAM chips may be used. Two chips are needed, one for EVEN and the other for ODD addresses.

5.2 EPROM Memory Options

The RMB-167 has sockets to accommodate two 27C256-type 32K EPROMS. Two chips are needed, one for EVEN and the other for ODD addresses. The EPROMS may be configured to occupy low memory, high memory, or start at low memory and then relocate to high memory upon initialization by appropriate jumper selections.

The SAB C167 may be programmed to insert wait cycles during external memory access. However, in order to run the SAB C167 at its full potential of 40MHz, the RAMs should be rated at 70 nano seconds or faster, and the EPROMs should be rated at 85 nano seconds or faster.

5.3 Alternate Memory Map with EPROM in Low Memory

The default RMB-167 memory map uses only the RAM chips. That is the range 0 to FFFFh is decoded as RAM. The addresses are decoded by a GAL device. Alternate memory maps are possible by changing the GAL programs. Moreover, several jumper inputs allow switching between memory maps by changing jumper configurations. One possible implementation is given below. Other memory maps are possible with different GAL equations.

The jumpers marked CFG0 and CFG1 are used to switch between the memory maps as shown below. In words, CFG0 determines the memory type for the lower 32K of memory, and CFG1, the higher. Inserting a jumper selects EPROM. The GAL equations to achieve the alternate memory maps are given in Section 5.2.

	Address Range	
Jumpers inserted	0-7FFFh	8000h-FFFFh
none	RAM	RAM
CFG0	EPROM	RAM
CFG1	RAM	EPROM
CFG0 and CFG1	EPROM	EPROM

The EPROM at low memory may contain start-up code which is executed upon reset. In this case the jumper at P0.4 must be removed so that the microcontroller does not enter the bootstrap loader mode. The microcontroller simply starts executing from address 0.

With the jumpers CFG0 or CFG1 (or both) installed, the RMB-167 may still be bootstrapped. Again, the jumper P0.4 must be installed. This forces the SAB-C167 to enter the bootstrap mode upon reset. The bootstrap sequence terminates with a software reset instruction which starts executing the program starting at address 0. With CFG0 installed, this is the beginning of EPROM. That is, upon bootstrap, the code in EPROM is executed. While possible, first bootstrapping and then executing the code in EPROM is somewhat superfluous since any initialization code of the bootstrap loader may be placed in EPROM.

5.4 Moving RMON167 to EPROM

As an example of placing a valid program in EPROM, consider modifying the monitor program RMON167 as given below. It is assumed that the lower 32K of memory is EPROM, and the higher 32K is RAM. The origin of the program is changed to 1000h. Note that the monitor needs buffers to store the commands and the parameters. These buffers are defined to occupy the beginning of RAM at 8000h. Also, the greeting message is changed to indicate that it is the EPROM version of the monitor.

Only the beginning few instructions and the greeting message are changed. Namely,

1. The buffers are moved to 8000h and 8020h, respectively,
2. Jump statements are placed at RESET and NMI vectors,
3. The origin of the monitor program is moved to 1000h
4. The initialization to CPS is now accomplished by an inter-segment jump to 1010h,
5. And finally, the greeting message is changed.

Also note that the address of register SYSCON is different in the SAB80C166 and SAB C167 microcontrollers. The monitor program must be assembled by specifying the C167 register definitions. The program listing follows.

```
CODE0 section code AT 0000h
;  r15 is used for flags:
;  bit 0 - error
;      1 - dash
;      2 - equal
;      3 -
;---------------------------------------------------
; --- monitor system variables ---
; --- !!! ASSUMES 8000h-FFFFh is RAM !!! ---
;      org     08000h
cmdbuf equ     08000h
pbuffr equ     08020h
;-----------------------------------------------
   org   0           ; RESET vector
RSTISR    proc   near
   jmp   cc_UC, mon  ; branch to monitor
RSTISR    endp   near

   org   00008h      ; NMI vector
NMISR     proc   near
   jmp   cc_UC, mon  ; branch to monitor
NMISR     endp   near
; ----------------------------------------------
org     01000h
; ----------------------------------------------
; --- monitor program ---

MON proc   near
   mov   SYSCON, #0F800h  ; #1111 1000
   ; 0000 0000 b
   nop
   mov   SYSCON, #0F800h  ; #1111 1000
   ; 0000 0000 b
   nop

; --- initialize CPS -----------------------------
       ;0xFA 0x00 0x10 0x80  ;  jmps   far 1000h ;
 (jump to next1) ; far intersegment jump to update CPS
                              ;next1:
       dw 000FAh
       dw 01010h
next1:
; --- initialize DPPx ----------------------------
    mov     DPP0, #0
  .
  .
( no changes to the code here )
  .
  .
; ----------------------------------------------;--- message
strings ---
; ----------------------------------------------
EVEN
msggreet:
 db  0ah, 0dh, 'SAB-C167 MONITOR IN EPROM > ', 0
  .
  .
  .
( no changes to the code here )
```

As mentioned, the address of register SYSCON is different (89h) in the C167. The instruction setting the SYSCON register is a move instruction. In machine code, the instruction takes four bytes: E6h, 89h, 00h, F8h, which may be hand-coded as,

```
;               mov     SYSCON, #0F800h
; SYSCON is 89h on the 167
        dw 089E6h
        dw 0F800h
        nop
;               mov     SYSCON, #0F800h
; SYSCON is 89h on the 167
        dw 089E6h
        dw 0F800h
```

6 GAL EQUATIONS

Two PALCE16V8 are used. The first (U1) is responsible for the reset logic and auxiliary options, and the second (U2), for the memory decode logic. Refer to the circuit diagrams for more information.

6.1 Default GAL Equations

6.1.1 U1 Equations

```
;U1 Bootstrap Loader Logic
;---------------- PIN Declarations --------------
; --- inputs ---
PIN  1         A18                     COMBINATORIAL ;
PIN  2         A19                     COMBINATORIAL ;
PIN  3         A20                     COMBINATORIAL ;
PIN  4         A21                     COMBINATORIAL ;
PIN  5         A22                     COMBINATORIAL ;
PIN  6         A23                     COMBINATORIAL ;
PIN  7         RSTIN_                  COMBINATORIAL ;
PIN  8         RSTOUT_                 COMBINATORIAL ;
PIN  9         CFG0                    COMBINATORIAL ;
PIN 11         CFG1                    COMBINATORIAL ;
; --- outputs ---
PIN  12        HISEG                   COMBINATORIAL ;
PIN  13        RSTCYC                  COMBINATORIAL ;
PIN  14        RSTCYC_                 COMBINATORIAL ;
PIN  15        AUX0                    COMBINATORIAL ;
PIN  16        AUX1                    COMBINATORIAL ;
PIN  17        DUMMY                   COMBINATORIAL ;
PIN  18        LEDRST_                 COMBINATORIAL ;
PIN  19        LEDAUX_                 COMBINATORIAL ;
;---------------- Boolean Equation Segment ------
EQUATIONS
RSTCYC   =  /(  RSTIN_  * RSTCYC_ )
RSTCYC_  =  /( /RSTOUT_ * RSTCYC  )

HISEG     =  A18 * A19 * A20 * A21 * A22 * A23
AUX0      =  1
AUX1      =  1
DUMMY     =  1
LEDRST_   =  RSTCYC
LEDAUX_   =  RSTCYC_
```

6.1.2 U2 Equations

```
; U2 Memory Decode Logic
;---------------- PIN Declarations --------------
; --- inputs ---
PIN  1          A0                 COMBINATORIAL ;
PIN  2          A14                COMBINATORIAL ;
PIN  3          A15                COMBINATORIAL ;
PIN  4          A16                COMBINATORIAL ;
PIN  5          A17                COMBINATORIAL ;
PIN  6          BHE_               COMBINATORIAL ;
PIN  7          MON                COMBINATORIAL ;
PIN  8          HISEG              COMBINATORIAL ;
PIN  9          RESET              COMBINATORIAL ;
PIN 11          AUX0               COMBINATORIAL ;
PIN 19          AUX1               COMBINATORIAL ;

; --- outputs ---
PIN  12         RAMSELL_           COMBINATORIAL ;
PIN  13         RAMSELH_           COMBINATORIAL ;
PIN  14         ROMSEL_            COMBINATORIAL ;
PIN  15         MA14               COMBINATORIAL ;
PIN  16         MA15               COMBINATORIAL ;
PIN  17         MA16               COMBINATORIAL ;
PIN  18         MA17               COMBINATORIAL ;
;---------------- Boolean Equation Segment ------

EQUATIONS
RAMSELL_ =  A0
RAMSELH_ =  BHE_
ROMSEL_  =  1
MA14     =  A14
MA15     =  A15
MA16     =  0
MA17     =  0
```

6.2 Alternate GAL Equations

6.2.1 U1 Equations For EPROM In Low Memory

```
;PALASM Design Description
; EPROM/RAM selected by CFG0 and CFG1
;
;

;  jumper at     low 32K   high 32K
; -----------    -------   --------
;    NONE          RAM       RAM
;    CFG0         EPROM      RAM
;    CFG1          RAM      EPROM
;CFG0 and CFG1    EPROM     EPROM

; --- Declaration Segment ----------------------------

TITLE    RMB-167 Memory Decode Logic -- RAM/EPROM
PATTERN
REVISION
AUTHOR
```

```
COMPANY  Rigel Corporation
DATE     07/20/94
CHIP  _r167u1  PALCE16V8

; --- PIN Declarations -------------------------------; --- inputs ---
PIN  1          A18                 COMBINATORIAL
PIN  2          A19                 COMBINATORIAL
PIN  3          A20                 COMBINATORIAL
PIN  4          A21                 COMBINATORIAL
PIN  5          A22                 COMBINATORIAL
PIN  6          A23                 COMBINATORIAL
PIN  7          RSTIN_              COMBINATORIAL
PIN  8          RSTOUT_             COMBINATORIAL
PIN  9          CFG0                COMBINATORIAL
PIN 11          CFG1                COMBINATORIAL
; --- outputs ---
PIN  12         HISEG               COMBINATORIAL
PIN  13         RSTCYC              COMBINATORIAL
PIN  14         RSTCYC_             COMBINATORIAL
PIN  15         AUX0                COMBINATORIAL
PIN  16         AUX1                COMBINATORIAL
PIN  17         DUMMY               COMBINATORIAL
PIN  18         LEDRST_             COMBINATORIAL
PIN  19         LEDAUX_             COMBINATORIAL
; --- Boolean Equation Segment ----------------------

-EQUATIONS
RSTCYC   =  /(  RSTIN_  * RSTCYC_ )
RSTCYC_  =  /( /RSTOUT_ * RSTCYC  )

HISEG     =  A18 * A19 * A20 * A21 * A22 * A23
AUX0      =  CFG0
AUX1      =  CFG1
DUMMY     =  1
LEDRST_   =  RSTCYC
LEDAUX_   =  RSTCYC_
;-----------------------------------------------------
```

6.2.2 U2 Equations For EPROM In Low Memory

```
;PALASM Design Description
; CFG0 and CFG1 select RAM and EPROM
;
;  jumper at     low 32K   high 32K
; -----------    -------   --------
;    NONE          RAM       RAM
;    CFG0         EPROM      RAM
;    CFG1          RAM      EPROM
;CFG0 and CFG1    EPROM     EPROM
; --- Declaration Segment ---------------------------
-TITLE    RMB-167 Memory Decode Logic
PATTERN
REVISION
AUTHOR
COMPANY  Rigel Corporation
DATE     09/14/94
CHIP  _r167u2  PALCE16V8
```

```
; --- PIN Declarations -------------------------------; --- inputs ---
PIN  1          A0                  COMBINATORIAL
PIN  2          A14                 COMBINATORIAL
PIN  3          A15                 COMBINATORIAL
PIN  4          A16                 COMBINATORIAL
PIN  5          A17                 COMBINATORIAL
PIN  6          BHE_                COMBINATORIAL
PIN  7          MON                 COMBINATORIAL
PIN  8          HISEG               COMBINATORIAL
PIN  9          RESET               COMBINATORIAL
PIN 11          AUX0                COMBINATORIAL
PIN 19          AUX1                COMBINATORIAL

; --- outputs ---
PIN  12         RAMSELL_            COMBINATORIAL
PIN  13         RAMSELH_            COMBINATORIAL
PIN  14         ROMSEL_             COMBINATORIAL
PIN  15         MA14                COMBINATORIAL
PIN  16         MA15                COMBINATORIAL
PIN  17         MA16                COMBINATORIAL
PIN  18         MA17                COMBINATORIAL

; --- Boolean Equation Segment -----------------------
EQUATIONS
RAMSELL_ =  A0   + (A15+/AUX0) * (/A15+/AUX1)
RAMSELH_ =  BHE_ + (A15+/AUX0) * (/A15+/AUX1)
ROMSEL_  =         (A15+AUX0)  * (/A15+AUX1)
MA14     =  A14
MA15     =  A15
MA16     =  A16
MA17     =  A17
; ---------------------------------------------------
```

7 HEADERS AND JUMPERS

7.1 System and I / O Headers

The RMB-167 board has three headers, two of which are compatible with those of the RMB-166. The two RMB-166 headers, the input output port header JP2 and the system header JP1, are similar to the headers JP6 and JP7 of the RMB-167. In addition, the RMB-167 has JP8, the Extra Input/Output header XIO. Ports 2, 3, and 5 are available on JP7. JP6 contains the address, data and control busses. JP8 contains the additional ports and signals of the SAB-C167 microcontroller. Individual signals of these jumpers are listed below. The tables reflect the physical orientation of the headers and the enumeration of their individual posts. Pin 1 is identified as the post with the square pad on the circuit board.

JP6 - System Header

Signal		Pins		Signal	
RMB-166 (JP1)	**RMB-167 (JP6)**			**RMB-166 (JP1)**	**RMB-167 (JP6)**
Ground		1	2	VCC (+5V)	
Ground		3	4	VCC (+5V)	
D0		5	6	A0	
D1		7	8	A1	
D2		9	10	A2	
D3		11	12	A3	
D4		13	14	A4	
D5		15	16	A5	
D6		17	18	A6	
D7		19	20	A7	
D8		21	22	A8	
D9		23	24	A9	
D10		25	26	A10	
D11		27	28	A11	
D12		29	30	A12	
D13		31	32	A13	
D14		33	34	A14	
D15		35	36	A15	
RD#		37	38	A16	
ALE		39	40	A17	
RSTIN#		41	42	WR#	WR# / WRL#
RSTOUT#		43	44	BHE#	
NMI#		45	46	not used	A18
A22	not used	47	48	not used	A19
A21	not used	49	50	not used	A20

Note that pins 46-50 on the RMB-167 are not connected to any signal.

JP7 - Input/Output Header

Signal		Pins		Signal	
RMB-166 (JP2)	**RMB-167 (JP7)**			**RMB-166 (JP2)**	**RMB-167 (JP7)**
Ground		1	2	VCC (+5V)	
Ground		3	4	VCC (+5V)	
P5.0		5	6	P5.1	
P5.2		7	8	P5.3	
P5.4		9	10	P5.5	
P5.6		11	12	P5.7	
P5.8		13	14	P5.9	
VAGND		15	16	S1I	not used
VAREF		17	18	S1O	not used
P2.0		19	20	P3.0	
P2.1		21	22	P3.1	
P2.2		23	24	P3.2	
P2.3		25	26	P3.3	
P2.4		27	28	P3.4	
P2.5		29	30	P3.5	
P2.6		31	32	P3.6	
P2.7		33	34	P3.7	
P2.8		35	36	P3.8	
P2.9		37	38	P3.9	
P2.10		39	40	P3.10	
P2.11		41	42	P3.11	
P2.12		43	44	P3.12	
P2.13		45	46	P3.13	
P2.14		47	48	P3.14	not used
P2.15		49	50	P3.15	

JP8 - Extra Input/Output Header of the RMB-167

Signal	**Pins**		**Signal**
RMB-167			**RMB-167**
Ground	1	2	VCC (+5V)
Ground	3	4	VCC (+5V)
P6.0	5	6	P6.1
P6.2	7	8	P6.3
P6.4	9	10	P6.5
P6.6	11	12	P6.7
A23	13	14	READY#
VAGND	15	16	not used
VAREF	17	18	not used
P5.0	19	20	P7.0
P5.1	21	22	P7.1
P5.2	23	24	P7.2
P5.3	25	26	P7.3
P5.4	27	28	P7.4
P5.5	29	30	P7.5
P5.6	31	32	P7.6
P5.7	33	34	P7.7
P5.8	35	36	P8.0
P5.9	37	38	P8.1
P5.10	39	40	P8.2
P5.11	41	42	P8.3
P5.12	43	44	P8.4
P5.13	45	46	P8.5
P5.14	47	48	P8.6
P5.15	49	50	P8.7

Note that Port 5 pins P5.0 to P5.9 are available on the Input/Output Header JP7 as well as on the Extra Input/Output Header JP8. Pins 16 and 18 on the header JP8 are not connected to any signal.

7.2 Analog-to-Digital Converter Reference Jumpers

The analog-to-digital converter requires a ground and reference voltage. These reference voltages may be provided either from JP2 lines marked VG (ground reference voltage) and VR (reference voltage), or connected to the +5 volt TTL supply. Jumpers JP4 and JP5 select the source of reference voltages. The center posts of JP4 and JP5 are connected to the SAB-C167 VAREF and VAGND inputs. Post 1 of JP4, marked VCC is connected to the +5 volt supply. Thus, connecting this post with the center post selects VAREF to be the same as the +5 volt supply. In the alternate position, VAREF is to be supplied from JP7 from the terminal marked VR.

Similarly, the post marked GND of JP5 is connected to the ground of the supply. Connecting the center post of JP5 with the post marked GND selects VAGND to be the same as the ground of the supply voltage. In the alternate position, the ground reference is to be supplied from the JP7 terminal marked VG.

8 BOOTSTRAPPING

The RMB-167 bootstrapping is triggered by grounding P0L.4 at reset. A 16 pin header is used to ground the bits of P0L via a resistor array with a nominal value in the range of 22K to 33K.

Note that the GAL which controls the bootstrap load operation is also responsible for turning on the LED. In its default implementation, the LED is lit once the RSTOUT# signal is activated. For specific applications, the user may alter the operation of the bootstrap logic by changing the GAL equations.

Once the bootstrap loader is invoked the serial port S0 is used to communicate with the C167. The host must first send a 0 byte with 8 data bits, 1 stop bit and no parity bits. The C167 responds with the byte A5h . Then the host expects 32 bytes of code to be downloaded to internal RAM starting at address 0FA40h and run.

Since 32 bytes is not enough to initialize and configure the C167 and then download a user program, a secondary loop is used. This loop is a short piece of code that is placed starting at address 0FA60h, so that when the 32 bytes of primary code are executed, the program continues with the secondary loop. The approach is described in more detail below.

The 32 bytes downloaded are, in hexadecimal,

```
          E6 F0 60 FA
          9A B7 FE 70
          A4 00 B2 FE
          7E B7
          B4 00 B0 FE
          86 F0 BB FC
          3D F6
          CC 00
          CC 00
          CC 00
          CC 00
```

which correspond to the following short code.

```
          ; origin is 0FA40h

          mov     R0, #0fa60h
     W0:
          jnb     S0RIR, W0
          movb    [R0], S0RBUF
          bclr    S0RIR
          movb    S0TBUF, [R0]
          cmpi1   R0, #0fcbb  ; read 604 bytes
          jmpr    cc_NE, W0
          nop
          nop
          nop
          nop
```

Note that the NOP (no operation) operations are required to fill the 32 bytes, since the bootstrap loader remains active until all 32 bytes are received. When the bootstrap loader receives its last byte and places it in address 0FA5Fh, it makes a jump to 0FA40h and starts executing the code. This is the short loop given above. Note that at this time the internal RAM starting from 0FA60h does not contain any relevant code.

The short loop takes advantage of the serial port S0 which is already initialized. It waits for a user specified number of bytes, 604 bytes in this case, and places these bytes consecutively starting from internal RAM location 0FA60h. When the loop is done (all 604 bytes received) the program continues by executing the NOP operations, and then executing code from 0FA60h on. Thus the 604 bytes loaded by the secondary loop are also interpreted as code.

The user may alter the number of bytes to be loaded by changing the 21st and 22nd bytes (BB and FC) which give the address (the low byte, followed by the high byte) of the last byte to be read by the loop. Note that there is a practical limit to the number of bytes that can be downloaded by this loop: the PEC source and destination pointers as well as the SFRs which occupy addresses FDE0h and above must not be overwritten by data bytes.

Due to the powerful instruction set of the C167, a lot of functionality can be implemented within 604 bytes of code. The 604 bytes contained in the file BTL67.DAT downloads a minimal monitor program. This program contains an initialization routine, subroutines to send and receive characters through the serial port, a subroutine to download code in the Intel Hex format, and a subroutine to jump to any location within the 64K segment. The latter two are invoked by single-letter commands.

The 604 byte-code may be broken down into four sections.

1. Initialization code to be executed after the 32-byte bootstrap
2. Code to be written starting at address 0 to be executed after the software reset.
3. The minimal monitor to be placed starting at address 8000h
4. The software reset (SRST) instruction to leave the bootstrap mode.

Sections 1 and 4 are somewhat different than sections 2 and 3. The bytes downloaded in sections 1 and 4 are actual instructions which are executed after the 32-byte bootstrap load is completed. Sections 2 and 3 are instructions to poke bytes into memory. More specifically, in section 2, bytes are written to memory locations starting from address 0. In section 3, from address 8000h. The bytes placed into memory locations starting from address 0 is executed after the software reset instruction. This is an initialization program which, upon completion, branches to address 8000h to execute the minimal monitor program.

For example, the initialization code starting at address 0 begins with the two instructions

```
DISWDT
EINIT
```

whose machine instructions are (`A5 5A A5 A5`) and (`B5 4A B5 B5`), respectively. The code within the 604-byte download block pokes these bytes starting from address 0. That is, these instructions are placed into memory, one word at a time, as data. The following instructions are used.

```
    mov     R1, #0A55Ah       ; begin: DISWDT
    mov     0, R1
    mov     R1, #0A5A5h
    mov     2, R1

    mov     R1, #0B54Ah       ;        EINIT
    mov     4, R1
    mov     R1, #0B5B5h
    mov     6, R1
```

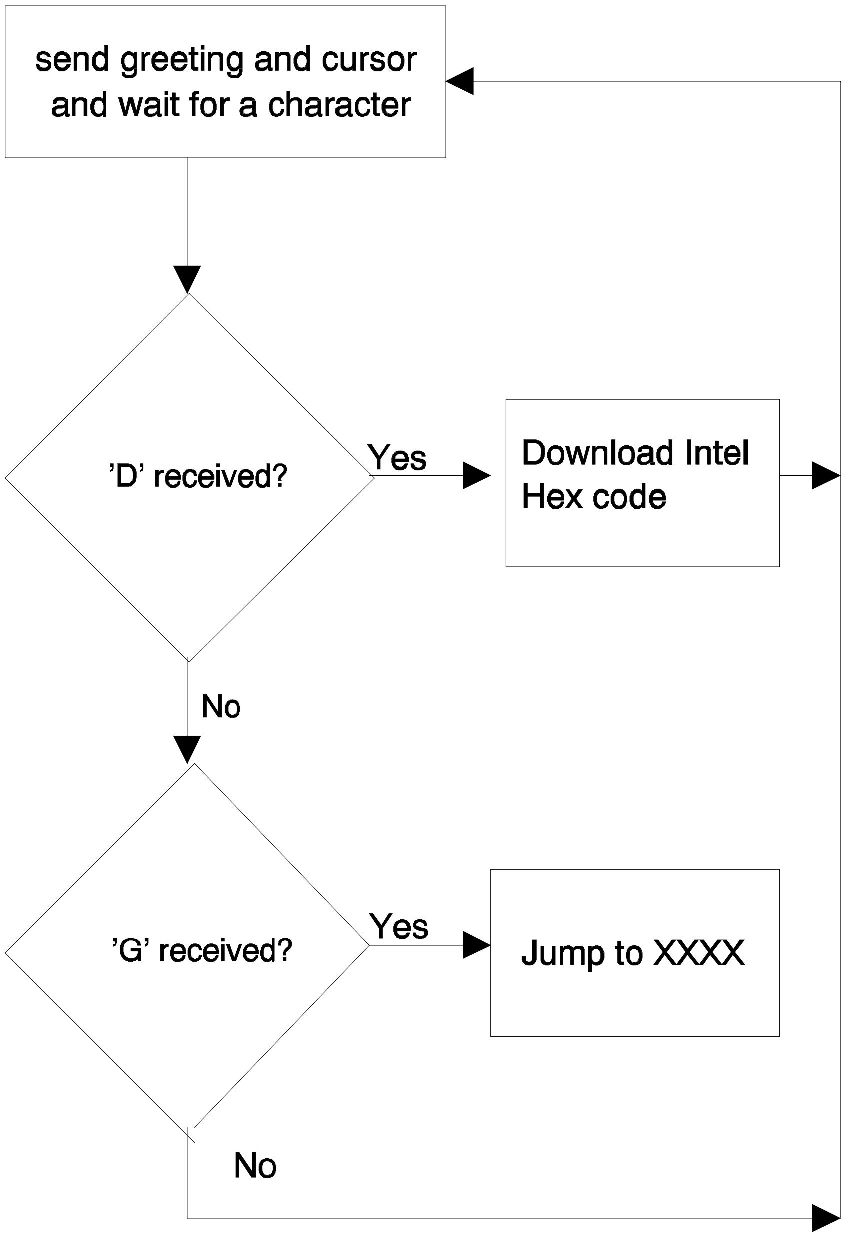
This pattern is used throughout sections 2 and 3. First the word is written to register R1. Then the register is copied to memory. The file BTL67.DAT contains the bytes downloaded to the RMB-167 board during bootstrapping. The file BTL.SRC contains the source code.

The initialization routines configure the SYSCON register. The internal ROM is disabled and the external bus is activated. Next the CSP and DPP registers are initialized. These steps need to be completed before the EINIT instruction. Note that if the watchdog timer is to be disabled; this too must be done before the EINIT instruction.

9 THE MINIMAL MONITOR

The minimal monitor is placed by the bootstrap loader starting at address 8000h. The monitor responds to two single-letter commands 'D' and 'G'. The 'D' command places the monitor in a download mode. Code in the Intel Hex format is expected. Code may be downloaded anywhere in the first 64L segment. The 'G' (Go) command expects 4 hexadecimal characters. These 4 characters specify an address within the first 64K segment. A jump is performed to this address. If a user program is downloaded (using the 'D' command), say at address 0C000h, then the GC000 command branches to the user program. In many cases, the user program is the application program or a monitor program, such as RMON167, and hence, the minimal monitor is no longer required. If, however, the user program wishes to return to the minimal monitor, it should branch to address 8000h. Note that the minimal monitor initializes the stack, so either a call or a jump to address 8000h would work.

The minimal monitor is a loop that executes the following flowchart:



9.1 MON167 Monitor

The monitor program RMON167 allows inspecting and modifying the first 64K segment of RMB-167 memory, configuring the ports, inputting and outputting from the general purpose ports, downloading code in the Intel Hex format, and branching to user code. RMON167 features are invoked by single-letter commands. RMON167 assumes a 20MHz (40 MHz) system crystal. Serial port 0 is initialized to run at 9600 Baud with 8 bits of data, 1 stop bit and no parity bits.

RMON167 is intended to be downloaded after bootstrapping the RMB-167 board. RMON167 is placed starting at address 0C000h. The first 256 bytes are reserved for monitor variables. The entry point to RMON167 is at address C100h. To set up RMON167, initialize READS166 and the RMB-167 board and invoke the Bootstrap command as explained in the previous section. From the TTY menu, select **Download** to download RMON167.HEX. Branch to and execute RMON167 using the **Run** command under the TTY menu. Specify address C100 since the entry point to RMON167 is at 0C000h. Note that RMON167 places a jump to C100 at the nonmaskable interrupt vector. Thus, RMON167 may subsequently be invoked by pressing the NMI pushbutton on the RMB167-CRI. RMON167 initializes the stack and resets the interrupts. Thus, even after the NMI button is pressed, RMON167 clears the NMI interrupt by executing a dummy 'return from interrupt' instruction.

Alternatively, RMON167 may be placed in EPROM and invoked upon reset. The source code for RMON167 is given on the distribution disk. RMON167 is not optimized for speed or size, but rather for clarity and pedagogical value. The legal users are encouraged to modify RMON167 and use portions of it in applications programs.

The single-letter commands of RMON167 are explained below.

D Download HEX file

The D command places RMON167 in a download mode. The monitor expects to receive code in the Intel Hex format through serial port 0. The download mode is terminated when the last line of Intel Hex code is received (when the byte count is 0).

C Port Configuration

The C command is used to configure the ports, i.e., the port direction registers DPnn. Cn displays the current setting of DPn. Cn=mmmm writes the word mmmm to register DPn.

G Go

The user code at address xxxx is branched to by the Gxxxx command. Note that the user program may return to RMON167 by a branching instruction to address 0C000h. RMON167 initializes the stack, thus, either a jump or a call instruction may be used to return to RMON167.

H Help

The H command displays a summary of available monitor commands.

M Memory

The first 64K segment of the RMB167-CRI memory may be inspected or modified by the M command. The M command is also useful to poke short programs into memory.

M XXXX displays the current contents of memory address XXXX.

M XXXX=nn inserts the byte nn into memory address XXXX. When this command is used, RMON167 displays the current contents as well as the new contents. The address XXXX is incremented and the current contents of (XXXX+1) are displayed. Consecutive bytes may be written starting at XXXX. The process is terminated if a carriage return or an illegal hexadecimal digit is keyed in.

M XXXX-YYYY displays the block of memory between addresses XXXX and YYYY.

M XXXX-YYYY=nn fills the memory block XXXX to YYYY with byte nn.

**P	Port Data**
The P command is used to read from or write to the ports. Pn displays the current value of port n. If port n is an input port, then the value read is the current voltage levels applied to the ports. If port n is an output port, Pn returns the current output value to port n. Pn=mmmm sets the current value of output port n to mm.

Note that individual bits of the ports may be programmed as input or output. Thus, the word returned by Pn gives the external voltage levels applied to the input bits and the current values of the output bits.

**W	Word Memory**
This command is identical to the M command, except that the memory contents are displayed and modified as words (2 bytes). Words start at even address.

10 READS166 VERSION 3.0

READS166, version 3.00, is Rigel Corporation's Integrated Development Environment for the SGS Thomson 16-bit processors. READS166 includes an editor, a host-to-board communications system, an assembler, and a C compiler. READS166 is completely rewritten in native 32-bit code to run on Windows95 and WindowsNT. READS166 includes a sophisticated project management system to simplify code reusability and version control. The C compiler is rewritten to support a full debugger. The debugger allows you to step through your code with breakpoints and variable watches as the compiled code runs on the target board, similar to the operation of an in-circuit emulator.

RMON166 - The READS166 monitor program

RMON 166 is downloaded after bootstrapping (or it may be placed into ROM) and supports basic memory and port functions. RMON166 allows downloading and running applications programs. The complete source code for user modifications or upgrades is included on disk.

Ra66 - The READS166 Assembler

Ra66 is a cross assembler for the C166 family of microcontrollers. It is intended to be used by the hardware and software products available from Rigel Corporation. Ra66 is a two-pass assembler. Forward references are resolved during the second pass. The second pass is used only when necessary. If no forward references are used, Ra66 completes assembly in a single pass.

Rc66 - The READS166 C Compiler

Rc66 is a C Compiler for the C166 family of processors. It compiles code for the tiny memory model which fully resides in the first segment of memory. Rc66 is a designed as a low-cost C compiler which provides a quick development cycle for simpler applications which do not need more than 64K of code, or the use of standard C libraries. Rc66 implements a subset of ANSI C. Rc66 works in conjunction with Ra66: first an assembly language program is generated from the C source then a HEX file is created.

The READS166 software has the following distinctive features:

- Project management for organized software development
- Archive storage for source code modules
- Multiple project management with drag and drop module transfers
- Enhanced graphical user interface for easy monitoring
- Stand alone compiler and editor applications connected to READS166 in a client/server fashion
- Drag and drop code development
- Mixed mode projects (C and assembler)
- Wizard code generator

10.1 READS166 V3.00 CONCEPTS

READS166 introduces a project-oriented code development and management system. The new concepts are defined below.

10.1.1 Project

A project is collection of files managed together. Each file in a project corresponds to a code module. All projects are kept in their individual subdirectories. You may copy or save projects as a single entity. When saved under a different name, a new subdirectory is created and all components of the project are duplicated in the new subdirectory.

By using the long names provided by the 32-bit Windows operating systems, you may use this feature to keep different versions of your software in a controlled manner. For example, the project “Motor Control 07-20-1997” may be saved under the name “Motor Control 07-25-1997” as new features are added. This way, if needed, you may revert to an older version.

A project may either be an “executable project” or an “archive project.”

10.1.1.1 Executable Projects

Executable projects are meant to be compiled into code which is eventually run on the target system. Components of an executable project are the code modules containing subroutines or functions which make up the entire program.

10.1.1.2 Archive Projects

Archive projects are never compiled. They are intended to facilitate code reusability by organizing and keeping code modules together.   An archive project acts as a repository which you may add modules to, or copy modules from.   Executable projects can be quickly constructed using already written and debugged modules from an archive project.

10.1.2 Module

A module is a single file which belongs to a project. Typically modules are either assembly language subroutines or C language functions. You may copy modules from one project to another, or share modules in different projects. For example, you may copy a previously developed module from an archive project to an executable project by simply dragging its icon from one project window to the other. By using existing or previously developed and debugged modules, you may significantly improve code reusability, much in the same manner as libraries. Reusing modules differs from using library functions of existing routines in that modules are kept in source form rather than object form.

For more information on the READS166 software please refer to the READS166 Version 3.0 Users Manual. The manual is also available in PDF format from our Web site www.rigelcorp.com.

11 CIRCUIT DIAGRAMS