RabbitCore RCM2000

C-Programmable Module

Getting Started Manual

019–0080 • 040515–F

RabbitCore RCM2000 Getting Started Manual

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1. Overview

The RabbitCore RCM2000 series is an advanced line of modules that incorporates the powerful Rabbit 2000 microprocessor, flash memory, and static RAM, all on a PCB not much larger than the size of a business card.

The RCM2000 series modules are designed for use on a motherboard that supplies power and interfaces with real-world I/O devices. Up to 40 pins of I/O and four serial ports are available for system interfacing.

To accommodate a variety of user and production needs, the RCM2000 family includes versions with varying amounts of onboard memory. All modules within the family are pin-for-pin compatible and may be installed or swapped in a matter of minutes.

1.1 RCM2000 Series Description

There are three production models in the RCM2000 series. Their standard features are summarized in Table 1.

Table 1. RCM2000 Features

Model	Features
RCM2000	Full-featured RabbitCore module with 256K flash memory and 512K SRAM
RCM2010	RCM2000 with 128K SRAM
RCM2020	RCM2000 with 18.432 MHz clock and 128K SRAM

The RCM2000 is the version that is included in the Development Kit.

1.2 Physical and Electrical Specifications

Table 2 lists the basic specifications for all models in the RCM2000 series.

Table 2. RCM2000 Specifications

Specification	Data
Power Supply	4.75 – 5.25 V DC (120 mA at 25.8048 MHz clock speed)
Size	1.90 × 2.30 × 0.55 inches (48.3 × 58.4 × 14 mm)
Environmental	–40°C to 70°C, 5–95% humidity, noncondensing

NOTE: For complete product specifications, see Appendix A in the ***RabbitCore RCM2000 User's Manual***.

The RCM2000 series modules have two 40-pin headers to which cables can be connected, or which can be plugged into matching sockets on a production device. The pinouts for these connectors are shown in Figure 1 below.

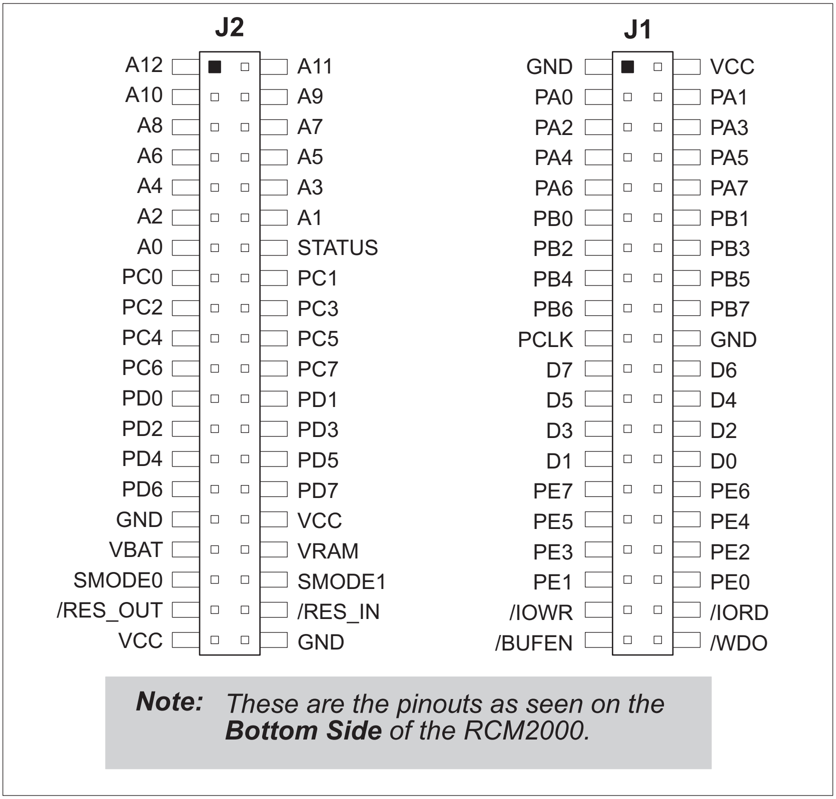


Figure 1. RCM2000 Connector Pinout

1.3 Development Software

The RCM2000 series of modules uses the Dynamic C development environment for rapid creation and debugging of runtime applications. Dynamic C provides a complete development environment with integrated editor, compiler and source-level debugger. It interfaces directly with the target system, eliminating the need for complex and unreliable in-circuit emulators.

Dynamic C must be installed on a Windows workstation with at least one free serial (COM) port for communication with the target system. See Chapter 3., “Installing Dynamic C,” for complete information on installing Dynamic C.

1.4 How to Use This Manual

This ***Getting Started*** manual is intended to give users a quick but solid start with the RCM2000 series modules. It does not contain detailed information on the module hardware capabilities or the Dynamic C development environment. Most users will want more detailed information on some or all of these topics in order to put the RCM2000 to effective use.

1.4.1 Additional Product Information

Detailed information about the RabbitCore RCM2100 series is provided in the ***RabbitCore RCM2000 User's Manual***, which is available on the accompanying CD-ROM in both HTML and Adobe PDF format.

Some advanced users may choose to skip the rest of this introductory manual and proceed directly with the detailed hardware and software information in the ***User's Manual***.

> **TIP:** We recommend that anyone not thoroughly familiar with Z-World controllers at least read through the rest of this manual to gain the necessary familiarity to make use of the more advanced information.

1.4.2 Additional Reference Information

In addition to the product-specific information contained in the ***RabbitCore RCM2000 User's Manual***, several higher level reference manuals are provided in HTML and PDF form on the accompanying CD-ROM. Advanced users will find these references valuable in developing systems based on the RCM2100 series modules:

- ***Dynamic C User's Manual***
- ***Rabbit 2000 Microprocessor User's Manual***

1.4.3 Using Online Documentation

We provide the bulk of our user and reference documentation in two electronic formats, HTML and Adobe PDF. We do this for several reasons.

We believe that providing all users with our complete library of product and reference manuals is a useful convenience. However, printed manuals are expensive to print, stock, and ship. Rather than include and charge for manuals that every user may not want, or provide only product-specific manuals, we chose to provide our complete documentation and reference library in electronic form with every Development Kit and with our Dynamic C development environment.

Finding Online Documents

The online documentation is installed along with Dynamic C, and an icon for the documentation menu is placed on the workstation's desktop. Double-click this icon to reach the menu. If the icon is missing, create a new desktop icon that points to **default.htm** in the **docs** folder, found in the Dynamic C installation folder.

The latest versions of all documents are always available for free, unregistered download from our Web sites as well.

Printing Electronic Manuals

We recognize that many users prefer printed manuals for some uses. Users can easily print all or parts of those manuals provided in electronic form. The following guidelines may be helpful:

- Print from the Adobe PDF versions of the files, not the HTML versions.

    NOTE: The most current version of Adobe Acrobat Reader can always be downloaded from Adobe's web site at **http://www.adobe.com**. We recommend that you use version 4.0 or later.

- Print only the sections you will need to refer to often.
- Print manuals overnight, when appropriate, to keep from tying up shared resources during the work day.
- If your printer supports duplex printing, print pages double-sided to save paper and increase convenience.

    NOTE: If you do not have a suitable printer or do not want to print the manual yourself, most retail copy shops (e.g., Kinkos, AlphaGraphics, etc.) will print the manual from the PDF file and bind it for a reasonable charge—about what we would have to charge for a printed and bound manual.

2. Hardware Setup

This chapter describes the RCM2000 hardware in more detail, and explains how to set up the accompanying Prototyping Board.

NOTE: This chapter (and this manual) assume that you have the RabbitCore RCM2000 Development Kit. If you purchased an RCM2000 series module by itself, you will have to adapt the information in this chapter and elsewhere to your test and development setup.

2.1 Development Kit Contents

The RCM2000 series Development Kit contains the following items:

- RCM2020 module with 256K flash memory and 128K SRAM.
- RCM2000 Prototyping Board with accessory hardware and components.
- Wall transformer power supply, 12 V DC, 500 mA (included only with Development Kits sold for the North American market. Overseas users will need a power supply compatible with their local mains power).
- 10-pin header to DE9 programming cable with integrated level-matching circuitry.
- ***Dynamic C*** CD-ROM, with complete product documentation on disk.
- This ***Getting Started*** manual.
- Registration card.

2.2 Overview of the Prototyping Board

The Prototyping Board included in the Development Kit makes it easy to connect an RCM2000 module to a power supply and a PC workstation for development. It also provides an array of basic I/O peripherals (switches and LEDs), as well as a prototyping area for more advanced hardware development.

For the most basic level of evaluation and development, the Prototyping Board can be used without modification.

As you progress to more sophisticated experimentation and hardware development, modifications and additions can be made to the board without modifying or damaging the RCM2000 itself.

The Prototyping Board is shown in Figure 2 below, with its main features identified.

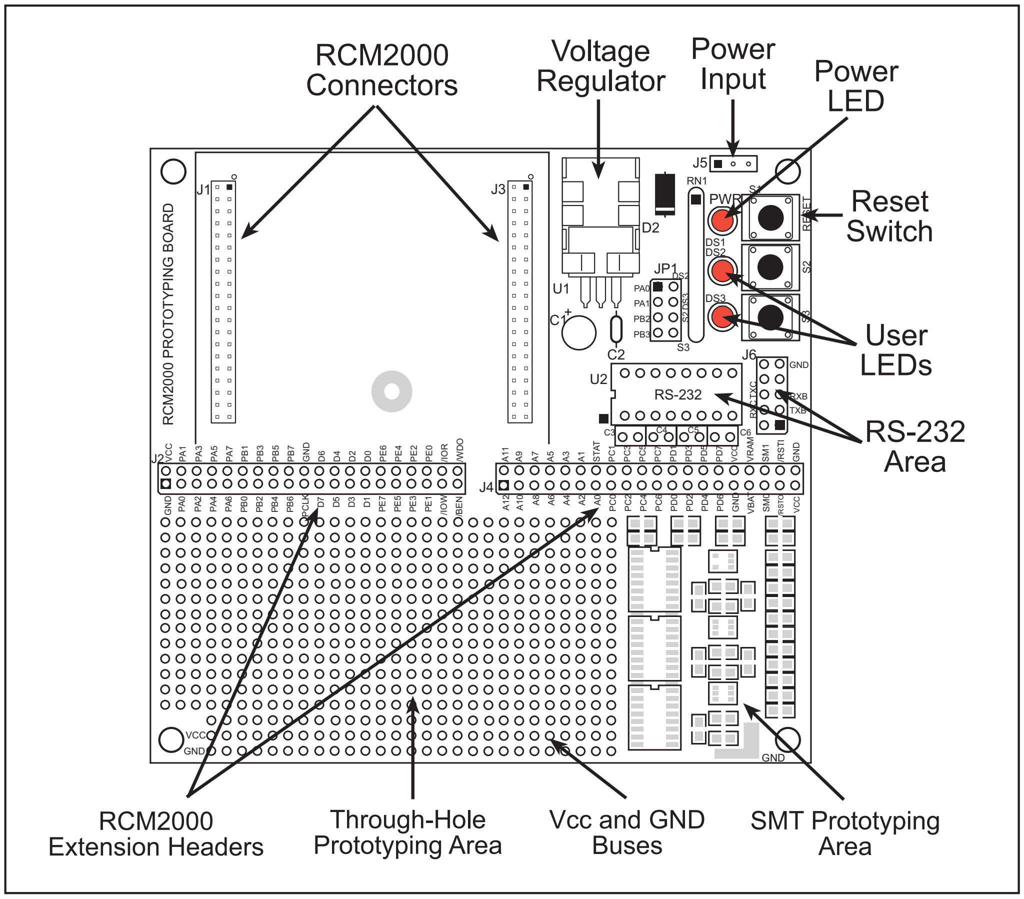


Figure 2. RCM2000 Prototyping Board

2.3 Connections

1. Attach RCM2000 to Prototyping Board

Turn the RCM2000 so that the Rabbit 2000 microprocessor is facing as shown below. Plug RCM2000 Headers J1 and J2 into the sockets of headers J1 and J3 on the Prototyping Board.

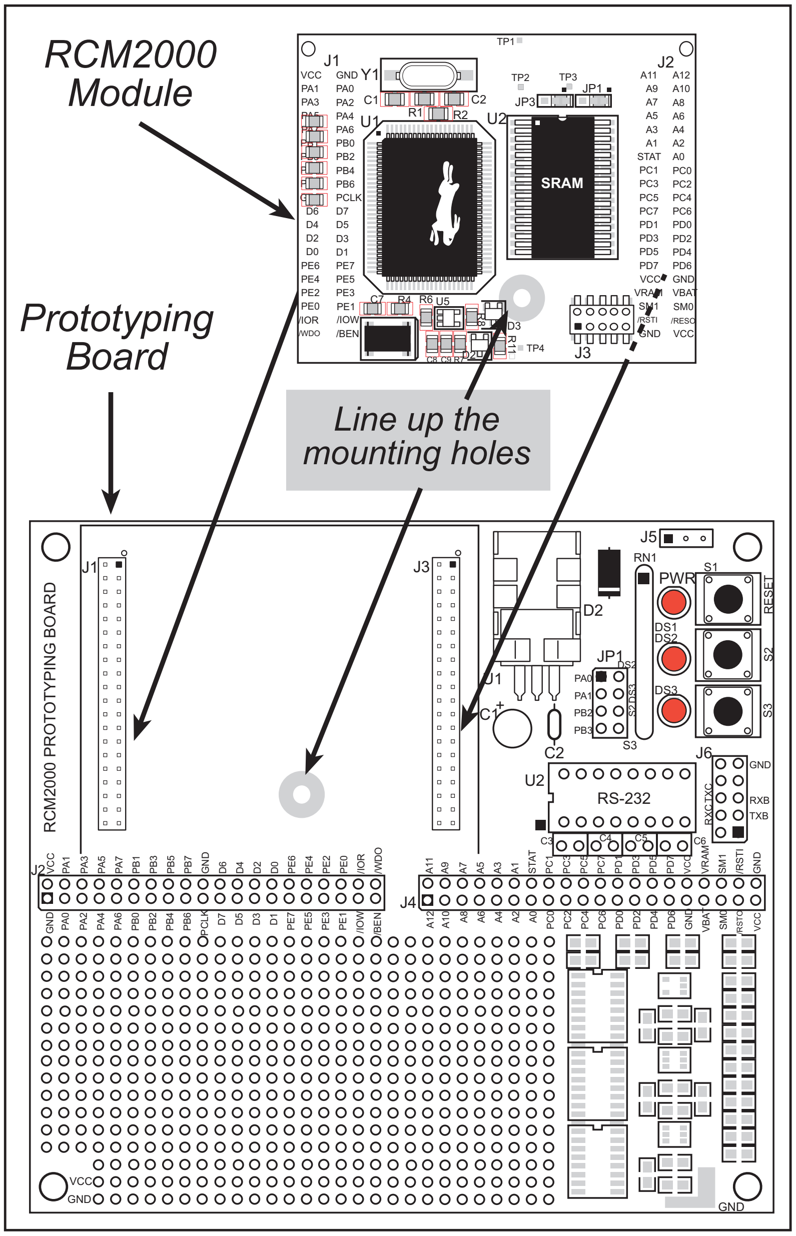


Figure 3. Attaching RCM2000 to Prototyping Board

NOTE: It is important that you line up the pins on the RCM2000 headers J1 and J2 exactly with the corresponding pins of headers J1 and J3 on the Prototyping Board. The header pins may become bent or damaged if the pin alignment is offset, and the RCM2000 will not work.

2. Connect RCM2000 to PC

Connect the 10-pin connector of the programming cable labeled **PROG** to header J3 on the RCM2000 module as shown in Figure 4 below. Be sure to orient the red edge of the cable towards pin 1 of the connector. (Do not use the **DIAG** connector, which is used for a normal serial connection.)

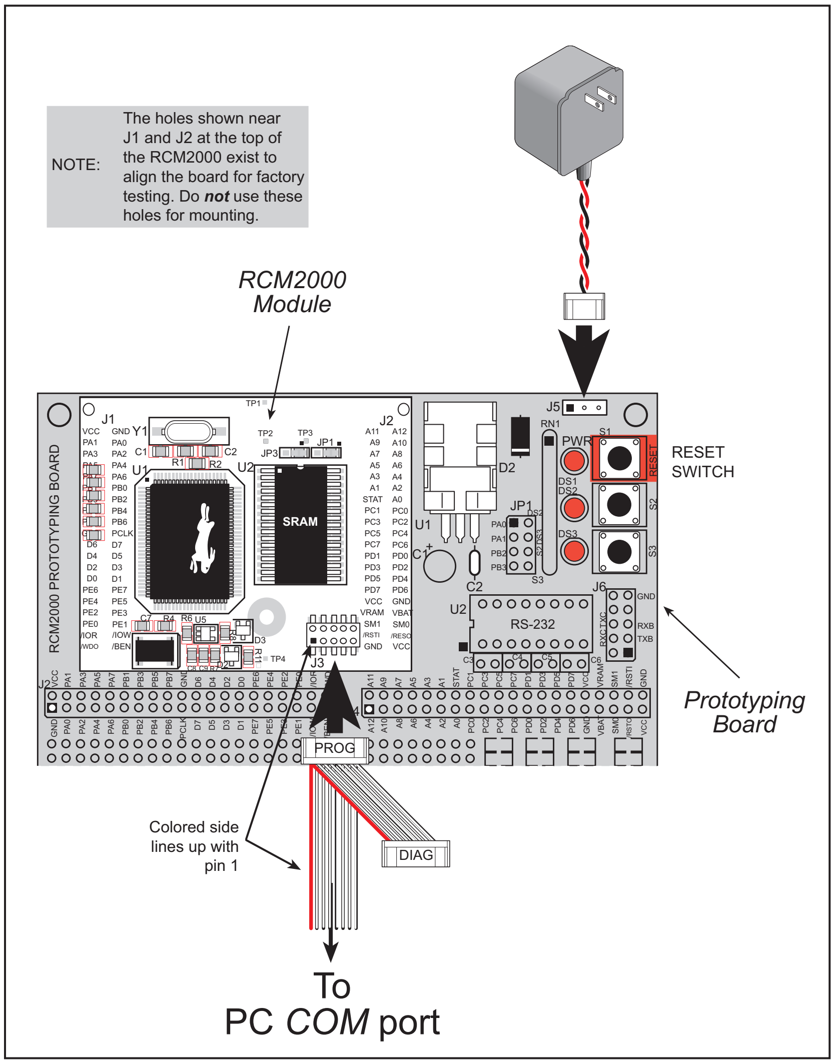

NOTE: The holes shown near J1 and J2 at the top of the RCM2000 exist to align the board for factory testing. Do *not* use these holes for mounting.
RCM2000 Module
RESET SWITCH
Prototyping Board
Colored side lines up with pin 1
PROG
DIAG
To PC *COM* port

Figure 4. RCM2000 Power and Programming Connections

3. Power Supply Connections

Hook up the connector from the wall transformer to header J5 on the Prototyping Board as shown above. The orientation of this connector is not important since the VIN (positive) voltage is the middle pin, and GND is available on both ends of the three-pin header J5.

Plug in the wall transformer. The power LED on the Prototyping Board should light up. The RCM2000 and the Prototyping Board are now ready to be used.

NOTE: A RESET button is provided on the Prototyping Board to allow a hardware reset.

2.4 Where Do I Go From Here?

We recommend that you proceed to the next chapter and install Dynamic C (if you do not already have it installed), then run the first sample program to verify that the RCM2000 and the Prototyping Board are set up and functioning correctly.

If everything appears to be working, we recommend the following sequence of action:

1. Run all of the sample programs described in Chapter 4 to get a basic familiarity with Dynamic C and the RCM2000's capabilities.
2. For further development, refer to the ***RabbitCore RCM2000 User's Manual*** for details of the module's hardware and software components.

   A documentation icon should have been installed on your workstation's desktop; click on it to reach the documentation menu. You can create a new desktop icon that points to **default.htm** in the **docs** folder in the Dynamic C installation folder.
3. For advanced development topics, refer to the ***Dynamic C User's Manual***, also in the online documentation set.

2.4.1 Technical Support

NOTE: If you purchased your RCM2000 through a distributor or through a Z-World or Rabbit Semiconductor partner, contact the distributor or partner first for technical support.

If there are any problems at this point:

- Check the Z-World/Rabbit Semiconductor Technical Bulletin Board at www.zworld.com/support/bb/.
- Use the Technical Support e-mail form at www.zworld.com/support/support_submit.html.

3. Installing Dynamic C

To develop and debug programs for the RCM2000 series (and for all other Z-World and Rabbit Semiconductor hardware), you must install and use Dynamic C. This chapter takes you through the installation of Dynamic C, and then provides a tour of its major features with respect to the RCM2000 series.

3.1 An Overview of Dynamic C

Dynamic C integrates the following development functions into one program:

- Editing
- Compiling
- Linking
- Loading
- Debugging

In fact, compiling, linking and loading are one function. Dynamic C does not use an In-Circuit Emulator; programs being developed are downloaded to and executed from the "target" system via an enhanced serial-port connection. Program development and debugging take place seamlessly across this connection, greatly speeding system development.

Other features of Dynamic C include:

- Dynamic C has an easy-to-use built-in text editor. Programs can be executed and debugged interactively at the source-code or machine-code level. Pull-down menus and keyboard shortcuts for most commands make Dynamic C easy to use.
- Dynamic C also supports assembly language programming. It is not necessary to leave C or the development system to write assembly language code. C and assembly language may be mixed together.
- Debugging under Dynamic C includes the ability to use **`printf`** commands, watch expressions, breakpoints and other advanced debugging features. Watch expressions can be used to compute C expressions involving the target's program variables or functions. Watch expressions can be evaluated while stopped at a breakpoint or while the target is running its program.

- Dynamic C provides extensions to the C language (such as shared and protected variables, costatements and cofunctions) that support real-world embedded system development. Interrupt service routines may be written in C. Dynamic C supports cooperative and preemptive multi-tasking.
- Dynamic C comes with many function libraries, all in source code. These libraries support real-time programming, machine level I/O, and provide standard string and math functions.
- Dynamic C compiles directly to memory. Functions and libraries are compiled and linked and downloaded on-the-fly. On a fast PC, Dynamic C can load 30,000 bytes of code in 5 seconds at a baud rate of 115,200 bps.

3.2 System Requirements

To install and run Dynamic C, your system must be running one of the following operating systems:

- Windows 95
- Windows 98
- Windows NT
- Windows Me
- Windows 2000

3.2.1 Hardware Requirements

The PC on which you install Dynamic C for development of RCM2000-based systems should have the following hardware:

- A Pentium or later microprocessor
- 32 MB of RAM
- At least 40 MB of free hard drive space
- At least one free COM (serial) port for communication with the target systems
- A CD-ROM drive (for software installation)

3.3 Installing Dynamic C

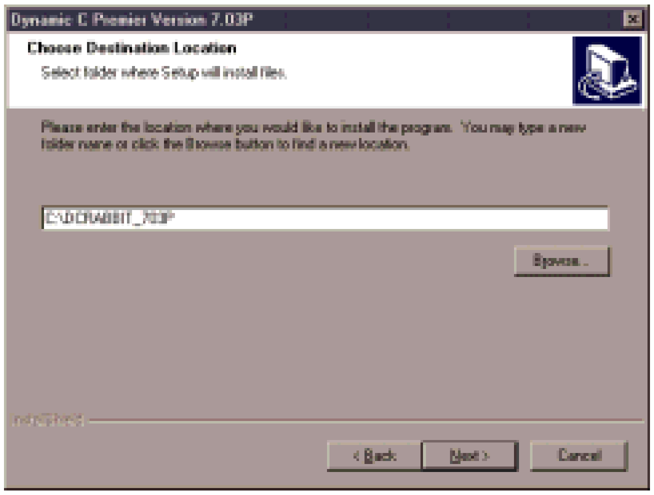
Insert the Dynamic C CD-ROM in the drive on your PC. If autorun is enabled, the CD installation will begin automatically.

If autorun is disabled or the installation otherwise does not start, use the Windows **Start > Run** menu or Windows Disk Explorer to launch **SETUP.EXE** from the root folder of the CD-ROM.

The installation program will guide you through the installation process. Most steps of the process are self-explanatory and not covered in this section. Selected steps that may be confusing to some users are outlined below. (Some of the installation utility screens may vary slightly from those shown.)

3.3.1 Program & Documentation File Location

Dynamic C's application, library and documentation files can be installed in any convenient location on your workstation's hard drives.


Dynamic C Premier Version 7.03P

Choose Destination Location

Select folder where Setup will install files.

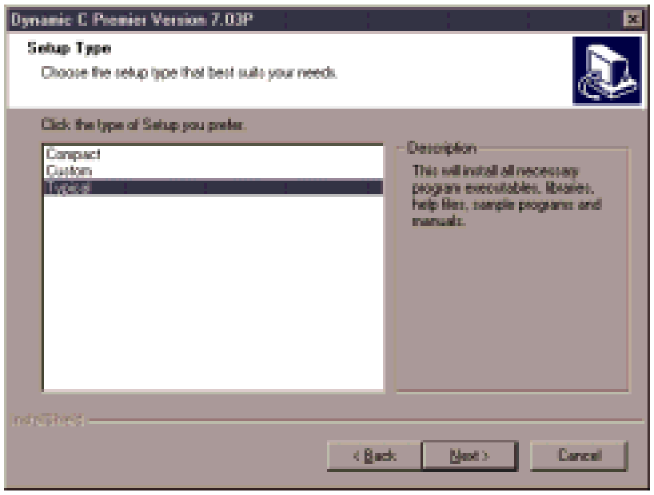
Please enter the location where you would like to install the program. You may type a new folder name or click the Browse button to find a new location.

C:\DCRABBIT_703P

The default location, as shown in the example above, is in a folder named for the version of Dynamic C, placed in the root folder of the C: drive. If this location is not suitable, enter a different root path before clicking **Next >**. Files are placed in the specified folder, so do not set this location to a drive's root directory.

3.3.2 Installation Type

Dynamic C has two components that can be installed together or separately. One component is Dynamic C itself, with the development environment, support files and libraries. The other component is the documentation library in HTML and PDF formats, which may be left uninstalled to save hard drive space or installed elsewhere (on a separate or network drive, for example).


Dynamic C Premier Version 7.03P

Setup Type

Choose the setup type that best suits your needs.

Click the type of Setup you prefer.

Description

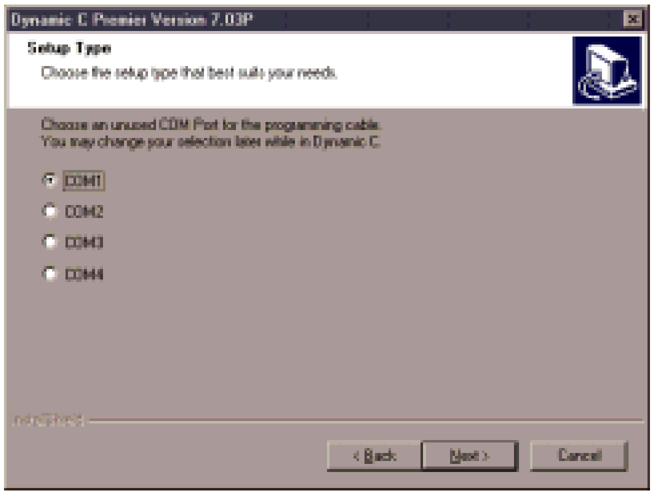
This will install all necessary program executables, libraries, help files, sample programs and manuals.

The installation type is selected in the installation menu shown above. The options are:

- **Typical Installation** — Both Dynamic C and the documentation library will be installed in the specified folder (default).
- **Compact Installation** — Only Dynamic C will be installed.
- **Custom Installation** — You will be allowed to choose which components are installed. This choice is useful to install or reinstall just the documentation.

3.3.3 Select COM Port

Dynamic C uses a COM (serial) port to communicate with the target development system. The installation allows you to choose the COM port that will be used.



Dynamic C Premier Version 7.03P

Setup Type

Choose the setup type that best suits your needs.

Choose an unused COM Port for the programming cable.
You may change your selection later while in Dynamic C.

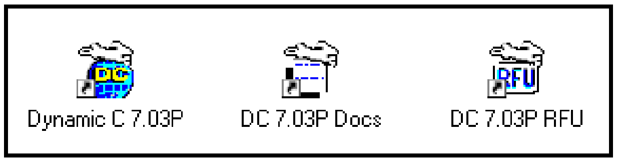
[✓ COM1] COM2 COM3 COM4

The default selection, as shown in the example above, is COM1. You may select any available port for Dynamic C's use. If you are not certain which port is available, select COM1. This selection can be changed later within Dynamic C.

NOTE: The installation utility does not check the selected COM port in any way. Specifying a port in use by another device (mouse, modem, etc.) may cause temporary problems when Dynamic C is started.

3.3.4 Desktop Icons

Once your installation is complete, you will have up to three icons on your PC desktop, as shown below.



One icon is for Dynamic C, one opens the documentation menu, and the third is for the Rabbit Field Utility, a tool used to download precompiled software to a target system.

3.4 Starting Dynamic C

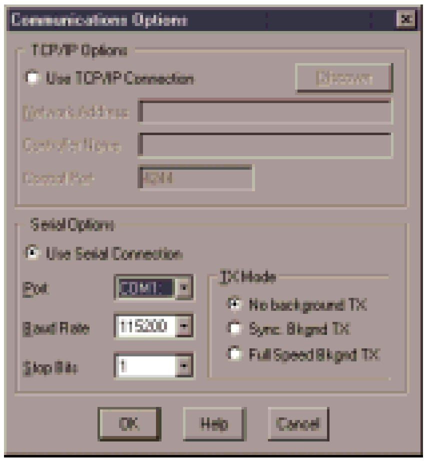
Once the RCM2000 module is set up and connected as described in Chapter 2 and Dynamic C has been installed, start Dynamic C by double-clicking on the Dynamic C icon. Dynamic C should start, then look for the target system on the COM port you specified during installation (by default, COM1). Once detected, Dynamic C should go through a sequence of steps to cold-boot the module and compile the BIOS.

If you receive the message beginning “BIOS successfully compiled …” you are ready to continue with the sample programs in the next chapter.

3.4.1 Communication Error Messages

If you receive the message “No Rabbit Processor Detected,” the programming cable may be connected to a different COM port, a connection may be faulty, or the target system may not be powered up. First, check to see that the power LED on the Prototyping Board is lit. If it is, check both ends of the programming cable to ensure that it is firmly plugged into the PC and the RCM2000’s programming port. If you are using the Prototyping Board, ensure that the module is firmly and correctly installed in its connectors.

If there are no faults with the hardware, select a different COM port within Dynamic C. From the **Options** menu, select **Project Options**, then select **Communications**. The dialog shown should appear.


Communications Options

TCP/IP Options

Use TCP/IP Connection

Network Address:

Controller Name:

Control Port: 4244

Serial Options

Use Serial Connection

Port: COM1

Baud Rate: 115200

Stop Bits: 1

TX Mode

No background TX

Sync. Bkgnd TX

Full Speed Bkgnd TX

Select another COM port from the list, then click OK. Press **<Ctrl-Y>** to force Dynamic C to recompile the BIOS. If Dynamic C still reports it is unable to locate the target system, repeat the above steps until you locate the active COM port.

If Dynamic C appears to compile the BIOS successfully, but you then receive a communication error message, it is possible that your PC cannot handle the 115,200 bps baud rate. Try changing the baud rate to 57,600 bps as follows.

- Locate the **Serial Options** dialog in the Dynamic C **Options > Project Options > Communications** menu. Change the baud rate to 57,600 bps.

If you are using Dynamic C version 7.04 or earlier, modify the BIOS source code as follows. Skip these three steps if your version of Dynamic C is 7.05 or later.

1. Open the BIOS source code file named **`RABBITBIOS.C`**, which can be found in the **`BIOS`** directory.
2. Change the line

   ```
   #define USE115KBAUD 1   // set to 0 to use 57600 baud
   ```

   to read as follows.

   ```
   #define USE115KBAUD 0   // set to 0 to use 57600 baud
   ```
3. Save the changes using **File > Save**.

Now press **<Ctrl-Y>**. You should receive the “BIOS successfully compiled …” message indicating that the target is now ready to compile a program. You should then continue with the sample programs in the next chapter.

4. Sample Programs

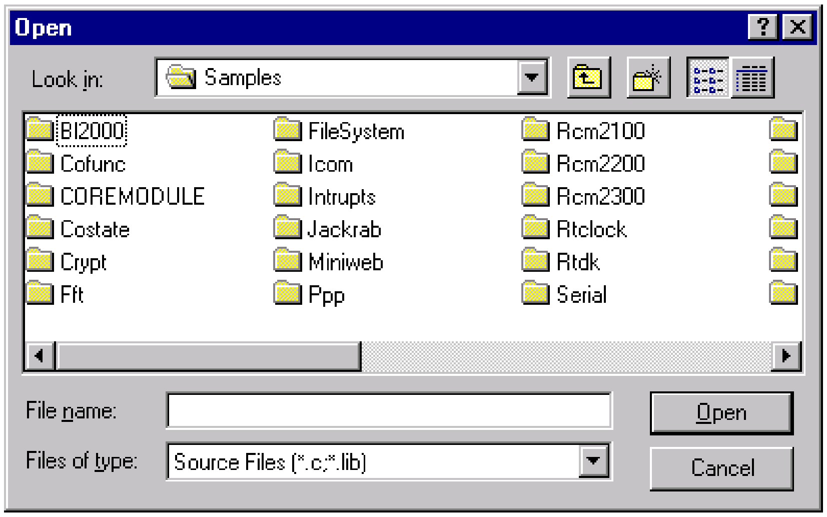
To help familiarize you with the RCM2000 modules, several sample Dynamic C programs have been included. Loading, executing and studying these programs will give you a solid hands-on overview of the RCM2000's capabilities, as well as a quick start with Dynamic C as an application development tool.

4.1 Sample Program Overview

Dynamic C comes with a large number of sample programs that illustrate many of its features. These programs are intended to serve as tutorials, but then can also be used as starting points or building blocks for your own applications.

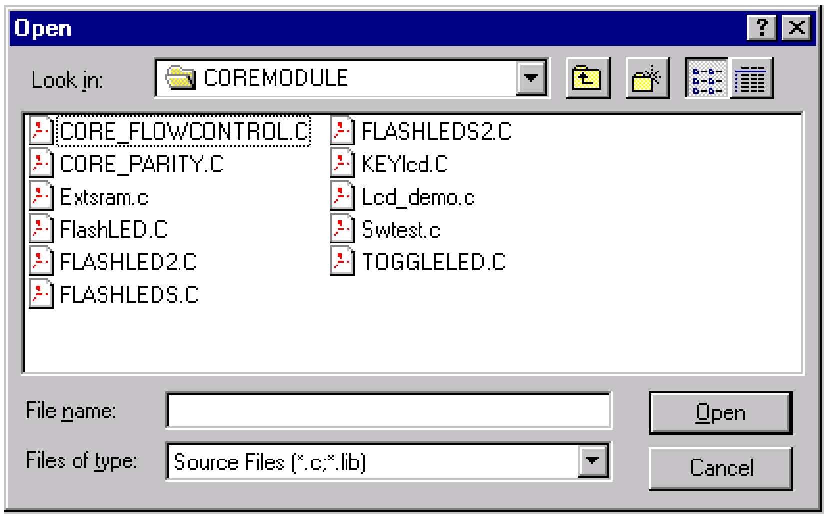
> **NOTE:** It is assumed in this section that you have at least an elementary grasp of ANSI C. If you do not, see the introductory pages of the ***Dynamic C User's Manual*** for a suggested reading list.

Sample programs are provided in the Dynamic C **`Samples`** folder, which is shown below.


Look in: Samples

Files of type: Source Files (*.c;*.lib)

The various folders contain specific sample programs that illustrate the use of the corresponding Dynamic C libraries. The sample program **PONG.c** demonstrates the output to the **STDIO** window. The **COREMODULE** folder provides sample programs specific to the RCM2000. Let's take a look at the **COREMODULE** folder.



CORE_FLOWCONTROL.C
CORE_PARITY.C
Extsram.c
FlashLED.C
FLASHLED2.C
FLASHLEDS.C
FLASHLEDS2.C
KEYlcd.C
Lcd_demo.c
Swtest.c
TOGGLELED.C

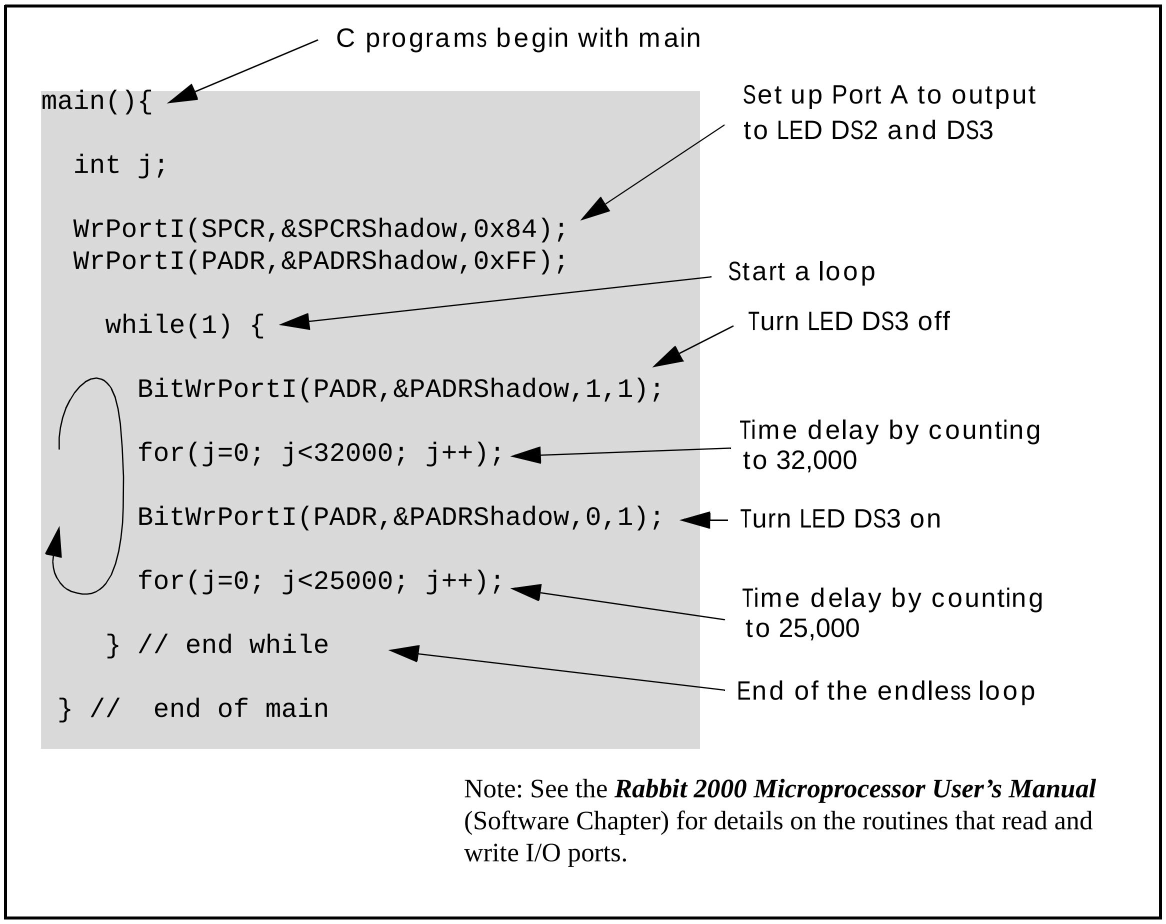
Each sample program has comments that describe the purpose and function of the program.

Before running any of these sample program, make sure that your RCM2000 is connected to the Prototyping Board and to your PC as described in Section 2.3, "Connections."

4.2 Running Sample Program FLASHLED.C

This sample program will be used to illustrate some of the functions of Dynamic C.

First, open the file **`FLASHLED.C`**, which is in the **`Samples/COREMODULE`** folder. The program will appear in a window, as shown in Figure 5 below (minus some comments). Use the mouse to place the cursor on the function name **`WrPortI`** in the program and type **<Ctrl-H>**. This will bring up a documentation box for the function **`WrPortI`**. In general, you can do this with all functions in Dynamic C libraries, including libraries you write yourself. Close the documentation box and continue.



```
main(){

  int j;

  WrPortI(SPCR,&SPCRShadow,0x84);
  WrPortI(PADR,&PADRShadow,0xFF);

    while(1) {

      BitWrPortI(PADR,&PADRShadow,1,1);

      for(j=0; j<32000; j++);

      BitWrPortI(PADR,&PADRShadow,0,1);

      for(j=0; j<25000; j++);

    } // end while

 } //  end of main
```

C programs begin with main
Set up Port A to output to LED DS2 and DS3
Start a loop
Turn LED DS3 off
Time delay by counting to 32,000
Turn LED DS3 on
Time delay by counting to 25,000
End of the endless loop

Note: See the ***Rabbit 2000 Microprocessor User's Manual*** (Software Chapter) for details on the routines that read and write I/O ports.

Figure 5. Sample Program FLASHLED.C

To run the program **`FLASHLED.C`**, load it with the **File** menu, compile it using the **Compile** menu, and then run it by selecting **Run** in the **Run** menu. The LED on the Prototyping Board should start flashing if everything went well. If this doesn't work review the following points.

- The target should be ready, which is indicated by the message "BIOS successfully compiled..." If you did not receive this message or you get a communication error, recompile the BIOS by typing **<Ctrl-Y>** or select **Recompile BIOS** from the **Compile** menu.

- A message reports “No Rabbit Processor Detected” in cases where the RCM2000 and the Prototyping Board are not connected together, the wall transformer is not connected, or is not plugged in. (The red power LED lights whenever power is connected.)
- The programming cable must be connected to the RCM2000. (The colored wire on the programming cable is closest to pin 1 on header J3 on the RCM2000, as shown in Figure 4.) The other end of the programming cable must be connected to the PC serial port. The COM port specified in the Dynamic C **Options** menu must be the same as the one the programming cable is connected to.
- To check if you have the correct serial port, select **Compile**, then **Compile BIOS**, or type **<Ctrl-Y>**. If the “BIOS successfully compiled …” message does not display, try a different serial port using the Dynamic C **Options** menu until you find the serial port you are plugged into. Don’t change anything in this menu except the COM number. The baud rate should be 115,200 bps and the stop bits should be 1.

4.3 Single-Stepping

Compile or re-compile **`FLASHLED.C`** by clicking the **Compile** button on the task bar. The program will compile and the screen will come up with a highlighted character (green) at the first executable statement of the program. Use the **F8** key to single-step. Each time the **F8** key is pressed, the cursor will advance one statement. When you get to the **`for(j=0, j< ...`** statement, it becomes impractical to single-step further because you would have to press **F8** thousands of times. We will use this statement to illustrate watch expressions.

4.3.1 Watch Expressions

Type **<Ctrl-W>** or chose **Add/Del Watch Expression** in the **Inspect** menu. A box will come up. Type the lower case letter j and click on *add to top* and *close*. Now continue single-stepping with **F8**. Each time you step, the watch expression (**`j`**) will be evaluated and printed in the watch window. Note how the value of **`j`** advances when the statement **`j++`** is executed.

4.3.2 Break Point

Move the cursor to the start of the statement:

```
        for(j=0; j<25000; j++);
```

To set a break point on this statement, type **F2** or select **Toggle Breakpoint** from the **Run** menu. A red highlight will appear on the first character of the statement. To get the program running at full speed, type **F9** or select **Run** on the **Run** menu. The program will advance until it hits the break point. Then the break point will start flashing and show both red and green colors. Note that LED DS3 is now solidly turned on. This is because we have passed the statement turning on LED DS3. Note that **`j`** in the watch window has the value 32000. This is because the loop above terminated when **`j`** reached 32000.

To remove the break point, type **F2** or select **Toggle Breakpoint** on the **Run** menu. To continue program execution, type **F9** or select **Run** from the **Run** menu. Now the LED should be flashing again since the program is running at full speed.

You can set break points while the program is running by positioning the cursor to a statement and using the **F2** key. If the execution thread hits the break point, a break point will take place.You can toggle the break point off with the **F2** key and continue execution with the **F9** key. Try this a few times to get the feel of things.

4.3.3 Editing the Program

Click on the **Edit** box on the task bar. This will set Dynamic C into the edit mode so that you can change the program. Use the **Save as** choice on the **File** menu to save the file with a new name so as not to change the demo program. Save the file as **`MYTEST.C`**. Now change the number 25000 in the **`for (..`** statement to 10000. Then use the **F9** key to recompile and run the program. The LED will start flashing, but it will flash much faster than before because you have changed the loop counter terminal value from 25000 to 10000.

4.3.4 Watching Variables Dynamically

Go back to edit mode (select edit) and load the program **`FLASHLED2.C`** using the **File** menu **Open** command. This program is the same as the first program, except that a variable **`k`** has been added along with a statement to increment **`k`** each time around the endless loop. The statement:

```
runwatch();
```

has been added. This is a debugging statement that makes it possible to view variables while the program is running.

Use the **F9** key to compile and run **`FLASHLED2.C`**. Now type **<Ctrl-W>** to open the watch window and add the watch expression **k** to the top of the list of watch expressions. Now type **<Ctrl-U>**. Each time you type **<Ctrl-U>**, you will see the current value of **`k`**, which is incrementing about 5 times a second.

As an experiment, add another expression to the watch window:

```
k*5
```

Then type **<ctrl-U>** several times to observe the watch expressions **`k`** and **`k*5`**.

4.3.5 Summary of Features

So far you have practiced using the following features of Dynamic C.

- Loading, compiling and running a program. When you load a program it appears in an edit window. You can compile by selecting **Compile** on the task bar or from the **Compile** menu. When you compile the program, it is compiled into machine language and downloaded to the target over the serial port. The execution proceeds to the first statement of main where it pauses, waiting for you to command the program to run, which you can do with the **F9** key or by selecting **Run** on the **Run** menu. If want to compile and start the program running with one keystroke, use **F9**, the run command. If the program is not already compiled, the run command will compile it first.
- Single-stepping. This is done with the **F8** key. The **F7** key can also be used for single-stepping. If the **F7** key is used, then descent into subroutines will take place. With the

F8 key the subroutine is executed at full speed when the statement that calls it is stepped over.

- Setting break points. The **F2** key is used to turn on or turn off (toggle) a break point at the cursor position if the program has already been compiled. You can set a break point if the program is paused at a break point. You can also set a break point in a program that is running at full speed. This will cause the program to break if the execution thread hits your break point.
- Watch expressions. A watch expression is a C expression that is evaluated on command in the watch window. An expression is basically any type of C formula that can include operators, variables and function calls, but not statements that require multiple lines such as *for* or *switch*. You can have a list of watch expressions in the watch window. If you are single-stepping, then they are all evaluated on each step. You can also command the watch expression to be evaluated by using the **<Ctrl-U>** command. When a watch expression is evaluated at a break point, it is evaluated as if the statement was at the beginning of the function where you are single-stepping. If your program is running you can also evaluate watch expressions with a **<Ctrl-U>** if your program has a **`runwatch()`** command that is frequently executed. In this case, only expressions involving global variables can be evaluated, and the expression is evaluated as if it were in a separate function with no local variables.

4.4 Cooperative Multitasking

Cooperative multitasking is a convenient way to perform several different tasks at the same time. An example would be to step a machine through a sequence of steps and at the same time independently carry on a dialog with the operator via a human interface. Cooperative multitasking differs from another approach called preemptive multitasking. Dynamic C supports both types of multitasking. In cooperative multitasking each separate task voluntarily surrenders its compute time when it does not need to perform any more activity immediately. In preemptive multitasking control is forcibly removed from the task via an interrupt.

Dynamic C has language extensions to support multitasking. The major C constructs are called *costatements, cofunctions,* and *slicing*. These are described more completely in the ***Dynamic C User's Manual***. The example below, sample program **`FLASHLEDS2.C`**, uses costatements. A costatement is a way to perform a sequence of operations that involve pauses or waits for some external event to take place. A complete description of costatements is in the ***Dynamic C User's Manual***. The **`FLASHLEDS2.C`** sample program has two independent tasks. The first task flashes LED DS2 2.5 times a second. The second task flashes DS3 every 1.5 seconds.

```
     #define DS2 0           // predefine for LED DS2
     #define DS3 1           // predefine for LED DS3

     //  This cofunction flashes LED on for ontime, then off for offtime
     cofunc flashled[4](int led, int ontime, int offtime) {
         for(;;) {
             waitfor(DelayMs(ontime));                        // on delay
             WrPortI(PADR,&PADRShadow,(1<<led)|PADR);         // turn LED off
             waitfor(DelayMs(offtime);                        // off delay
             WrPortI(PADR,&PADRShadow,(1<<led)^0xff&PADR);    // turn LED on
         }
     }

     main {
         // Initialize ports
         WrPortI(SPCR,&SPCRShadow,0x84);    // Set Port A all outputs, LEDs on
         WrPortI(PEFR,&PEFRShadow,0x00);    // Set Port E normal I/O
         WrPortI(PEDDR,&PEDDRShadow,0x01);  // Set Port E bits 7…1 input, 0 output
         WrPortI(PECR,&PECRShadow,0x00);    // Set transfer clock as pclk/2

         for(;;) {                          // run forever
             costate {                      // start costatement
                 wfd {                // use wfd (waitfordone) with cofunctions
                   flashled[0](DS2,200,200); // flash DS2 on 200 ms, off 200 ms
                   flashled[1](DS3,1000,500);// flash DS3 on 1000 ms, off 500 ms
                 }
             }                               // end costatement
         }                                   // end for loop
     }                                        // end of main, never come here
```

Load and run the program.

The flashing of the LEDs is performed by the costatement. Costatements need to be executed regularly, often at least every 25 ms. To accomplish this, the costatements are enclosed in a **`while`** loop or a **`for`** loop. The term **`while`** loop is used as a handy way to describe a style of real-time programming in which most operations are done in one loop.

The costatement is executed on each pass through the big loop. When a **`waitfor`** or a **`wfd`** condition is encountered the first time, the current value of **`MS_TIMER`** is saved and then on each subsequent pass the saved value is compared to the current value. If a **`waitfor`** condition is not encountered, then a jump is made to the end of the costatement, and on the next pass of the loop, when the execution thread reaches the beginning of the costatement, execution passes directly to the **`waitfor`** statement. The costatement has the property that it can wait for long periods of time, but not use a lot of execution time. Each costatement is a little program with its own statement pointer that advances in response to conditions. On each pass through the big loop, as little as one statement in the costatement is executed, starting at the current position of the costatement's statement pointer. Consult the ***Dynamic C User's Manual*** for more details.

This program also illustrates a use for a shadow register. A shadow register is used to keep track of the contents of an I/O port that is write only—it can't be read back. If every time a write is made to the port the same bits are set in the shadow register, then the shadow register has the same data as the port register.

4.5 Advantages of Cooperative Multitasking

Cooperative multitasking, as implemented with language extensions, has the advantage of being intuitive. Unlike preemptive multitasking, variables can be shared between different tasks without having to take elaborate precautions. Sharing variables between tasks is the greatest cause of bugs in programs that use preemptive multitasking. It might seem that the biggest problem would be response time because of the big loop time becoming long as the program grows. Our solution for that is called slicing, which is further described in the ***Dynamic C User's Manual***.

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The schematics included with the printed manual were the latest revisions available at the time the manual was last revised. The online versions of the manual contain links to the latest revised schematic on the Web site. You may also use the URL information provided above to access the latest schematics directly.