TMS320C3x DSP Starter Kit
User’s Guide

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Preface

Read This First

About This Manual

This book describes the DSP (digital signal processing) Starter Kit (DSK) and how to use the DSK with these tools:

- The DSK assembler
- The DSK debugger

How to Use This Manual

The goal of this book is to help you learn how to use the DSK assembler and debugger. This book is divided into four distinct parts:

- **Part I: Hands-On Information** is presented first so that you can start using your DSK the same day you receive it.
  - Chapter 1 describes the features and provides an overview of the TMS320C3x DSP Starter Kit.
  - Chapter 2 contains installation instructions for your assembler and debugger. It lists the hardware and software tools you’ll need to use the DSK and tells you how to set up its environment.
  - Chapter 3 lists the key features of the assembler and debugger and tells you the steps you need to take to assemble and debug your program.

- **Part II: Functional Description** contains a functional overview of the DSK, which includes the TMS320C3x DSK functional diagram, a description of the DSK hardware components and software operation.

- **Part III: Assembler Description** contains detailed information about using the assembler.
  - Chapter 5 explains how to create DSK assembler source files and invoke the assembler.
  - Chapter 6 discusses the valid directives and gives you an alphabetical reference to these directives.
Part IV: Debugger Description contains detailed information about using the debugger. Chapter 7 explains how to invoke the DSK debugger, and use its function keys, and debugger commands.

Part V: Appendices contains a description of the communications kernel source code, the DSK circuit board dimensions and schematic diagrams, the data sheet of the TLC32040 that provides all specifications of the analog interface circuit, and a glossary.

Notational Conventions

This document uses the following conventions.

Program listings, program examples, and interactive displays are shown in a special typeface similar to a typewriter’s. Examples use a bold version of the special typeface for emphasis; interactive displays use a bold version of the special typeface to distinguish commands that you enter from items that the system displays (such as prompts, command output, error messages, etc.).

Here is a sample program listing of a bit file generated by the accumulator:

```
0x00809800 directive .word 1,2,3
0x00809800 0x00000001 <word>
0x00809801 0x00000002 <word>
0x00809802 0x00000003 <word>
```

Here is an example of a system prompt and a command that you might enter:

```
C:\dsk3a testa
```

In syntax descriptions, the instruction, command, or directive is in a bold typeface font and parameters are in an italic typeface. Portions of a syntax that are in bold should be entered as shown; portions of a syntax that are in italics describe the type of information that should be entered. Syntax that is entered on a command line is centered in a bounded box. Syntax that is used in a text file is left-justified in an unbounded box. Here is an example of command-line syntax:

```
dsk3a filename
```

dsk3a is a command. The command invokes the assembler and has one parameter, filename, which is required. When you invoke the assembler, you supply the name of the file that the assembler uses as input.
In assembler syntax statements, column 1 is reserved for the first character of a label or symbol. If the label or symbol is optional, it is usually not shown. If it is a required parameter, it is shown starting against the left margin of the shaded box, as in the example below. No instruction, command, directive, or parameter, other than a symbol or label, should begin in column 1.

```
symbol .set value
```

The `symbol` is required for the `.set` directive and must begin in column 1. The `value` is also required.

Square brackets ([ and ]) identify an optional parameter. If you use an optional parameter, you specify the information within the brackets; you don’t enter the brackets themselves. Here’s an example of a directive that has an optional parameter:

```
.entry [value]
```

The `.entry` directive has one parameter, which is optional.

Some directives can have a varying number of parameters. For example, the `.int` directive can have up to 100 parameters. The syntax for this directive is:

```
.int value1 [, ... , valueN]
```

This syntax shows that `.int` must have at least one value parameter, but you have the option of supplying additional value parameters, each separated from the previous one by a comma.

---

### Information About Warnings

This book contains warnings.

This is an example of a warning statement.

A warning statement describes a situation that could potentially cause harm to you.
The following books describe the TMS320C3x and related support tools. To obtain a copy of any of these TI documents, call the Texas Instruments Literature Response Center at (800) 477–8924. When ordering, please identify the book by its title and literature number.

**TMS320C3x User’s Guide** (literature number SPRU031) describes the 'C3x 32-bit floating-point microprocessor (developed for digital signal processing as well as general applications), its architecture, internal register structure, instruction set, pipeline, specifications, and DMA and serial port operation. Software and hardware applications are included.

**TMS320C32 Addendum to the TMS320C3x User’s Guide** (literature number SPRU132) describes the TMS320C32 floating-point microprocessor (developed for digital signal processing as well as general applications). Discusses its architecture, internal register structure, specifications, and DMA and serial port operation. Hardware applications are also included.

**TMS320 Floating-Point DSP Assembly Language Tools User’s Guide** (literature number SPRU035) describes the assembly language tools (assembler, linker, and other tools used to develop assembly language code), assembler directives, macros, common object file format, and symbolic debugging directives for the 'C3x and 'C4x generations of devices.

**TMS320 Floating-Point DSP Optimizing C Compiler User’s Guide** (literature number SPRU034) describes the TMS320 floating-point C compiler. This C compiler accepts ANSI standard C source code and produces TMS320 assembly language source code for the 'C3x and 'C4x generations of devices.

**TMS320C3x C Source Debugger User’s Guide** (literature number SPRU053) tells you how to invoke the 'C3x emulator, evaluation module, and simulator versions of the C source debugger interface. This book discusses various aspects of the debugger interface, including window management, command entry, code execution, data management, and breakpoints. It also includes a tutorial that introduces basic debugger functionality.

**TMS320C30 Evaluation Module Technical Reference** (literature number SPRU069) describes board-level operation of the TMS320C30 EVM.

**TMS320 DSP Designer’s Notebook Volume 1** (literature number SPRT125) collection of designer’s notebook pages.

**TMS320C40 Data Sheet** (literature number SLAS014) describes the analog interface circuit device and gives its electrical specifications.
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This chapter provides an overview of the TMS320C3x DSP Starter Kit (DSK). The 'C3x DSK is a low-cost, simple, high-performance stand-alone application development board that lets you experiment with and use TMS320C3x DSPs for real-time signal processing. The DSK has a TMS320C31 on board to allow full-speed verification of the TMS320C3x code. The DSK also gives you the freedom to build new boards, create your own software on a host PC, download the software to the DSK, and run the software on the DSK board. The supplied debugger is windows-oriented, simplifying code development and debugging capabilities.

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<td>1.2 DSK Overview</td>
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1.1 Key Features of the DSK

This section details the key features of the TMS320C3x DSP Starter Kit.

- Industry-standard TMS320C31 floating-point DSP
- 40-ns instruction cycle time, 50 MFLOPS, 25 MIPS
- Standard or enhanced parallel printer port interface which connects to a host PC™ and allows the TMS320C31 to communicate with PC programs
- Analog data acquisition via the TLC32040 analog interface circuit (AIC):
  - Variable rate analog-to-digital converter (ADC) and digital-to-analog converter (DAC) with 14-bit dynamic range at 20 000 samples per second
  - Output reconstruction filter and bypassable, switched-capacitor anti-alias input filter
- Standard RCA plug connectors for analog input and output that provide a direct connection to microphone and speaker
- XDS510 emulator connector

Note:
Jumper and header are not installed.

Expansion connectors, which route all the TMS320C31 pins for use with DSK daughterboards
1.2 DSK Overview

Figure 1–1 depicts the block diagram of the TMS320C3x DSK hardware. The basic components are the TMS320C31 DSP, the TLC32040 AIC, expansion connectors, system clock, parallel printer port interface, and tri-color LED. The parallel printer port connects the DSK to a host PC and allows the TMS320C31 to communicate with PC programs.

All of the signals for the 'C3x are routed to expansion connectors. The expansion connectors include four 32-pin headers, an 11-pin jumper block, and a 12-pin XDS510 header.

The TLC32040 AIC interfaces to the TMS320C3x serial port. A jumper block allows removal of this connection to route the serial port to a DSK daughter-card that you supply. Two RCA connectors provide analog input and output on the board.

See Appendix B, DSK Circuit Board Dimensions and Schematic Diagrams, for an explanation of the basic DSK components.
Chapter 2

Installing the DSK Assembler and Debugger

This chapter describes how to install the DSP Starter Kit (DSK) on a PC system running under DOS™.

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</table>
2.1 What You Need

The following checklists detail items that are shipped with the DSK assembler and debugger and any additional items you’ll need to use this tool. The DSK module connections with a parallel printer port are also discussed in this section.

**Hardware checklist**

- **Host**
  - An IBM® PC/AT™ or 100%-compatible PC with a hard disk system and a 1.2 megabyte floppy-disk drive and parallel printer port communication link

- **Memory**
  - Minimum of 640K bytes

- **Display**
  - Monochrome or color (color recommended)

- **Power requirements**
  - A UL Class II power supply with a 2.1-mm power jack connector that provides 7–12 Vdc or 6–9 Vac and at least 400–1500 mA, which is common to most wall-mounted DC transformers. For isolated wall mount supplies, the polarity of the 2.1 mm power jack does not matter. Laboratory-type power supplies with case grounds are not recommended since they can create ground loops and possibly create a short circuit through the DSK full-wave rectifier.

**Note:**

- You may want to use the DSK’s on-board power supply and regulators for external circuits. If so, do not overload the circuit. External loads will cause the regulators to operate at a higher temperature. Loads >50 mA are not recommended.

- If you make modifications or you are using an external laboratory power supply, be sure you connect it to the DSK correctly; the DSK is not warranted after you make modifications to it.

**Warning:**

To minimize risk of electric shock and fire hazard, the power supply adapter should be rated UL class 2. The adapter and personal computer providing energy to this product should be certified by one or more of the following: UL, CSA, VDE, TUV.
### What You Need

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
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<tr>
<td><strong>Board</strong></td>
<td>DSK circuit board</td>
</tr>
<tr>
<td><strong>Cable</strong></td>
<td>Pass-through parallel printer port cable</td>
</tr>
<tr>
<td><strong>Optional hardware</strong></td>
<td>An EGA- or VGA-compatible graphics display card and monitor.</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>Blank, formatted disks</td>
</tr>
</tbody>
</table>

### Software checklist

<table>
<thead>
<tr>
<th>Operating system</th>
<th>MS-DOS™ or PC-DOS™ (version 5.0 or later), Windows™ or OS/2™</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Files</strong></td>
<td><em>dsk3a.exe</em> is an executable file for the DSK assembler. Executing <em>dsk3a.exe</em> produces all the files needed to use the DSK. <em>dsk3d.exe</em> is an executable file needed for running the DSK debugger interface.</td>
</tr>
<tr>
<td><strong>Miscellaneous files</strong></td>
<td>Other files are included in your DSK package, such as sample source files and additional documentation. You can find a brief description of these files in the Readme file included on your disk. Be sure to check the Readme file for the latest information on software changes and DSK operation.</td>
</tr>
</tbody>
</table>

#### Note:

Other applications for the DSK can also be downloaded from the TMS320 BBS or Internet FTP site. See the If You Need Assistance subsection on page vii, for the Internet address.

### DSK module connections

You need a parallel printer port cable to connect your PC to your DSK board. The DSK board is designed with a DB25 parallel printer port connection mounted on the board.
2.2 Step 1: Connecting the DSK to Your PC

Follow these steps to connect your DSK board to your PC:

1) Turn off your PC’s power.

2) Connect your parallel printer port cable to the parallel communication port (LPT) on your PC. This port can be identified by its size and pin type, which should be the female matching equivalent to the DSK. (RS232 ports which use DB25 connectors use the opposite pin configuration).

3) Plug the parallel printer port cable into the DSK DB25 connector.

4) Plug 7–12 Vdc or 6–9 Vac power supply into the DSK power supply connector. See Figure 2–1 for details.

Figure 2–1. Connecting Your Parallel Printer Port Cable and Transformer Into Your DSK Board

5) Plug the transformer into a wall socket.

6) Turn on your PC’s power.

7) The LED will illuminate either red or green.

Note:

Some manufacturers of plug-in cards may also use DB25 connectors that appear to be of the same type. If this is the case, be sure to check the PC configuration thoroughly before continuing.
2.3 Step 2: Installing the DSK Software

This section explains how to install the debugger software on a hard disk system.

1) Make a backup copy of the product disk. (If necessary, refer to the DOS manual that came with your computer).

2) On your hard disk or system disk, create a directory named dsktools. This directory will contain the DSK assembler and debugger software. To create this directory, enter:

   `md c:\dsktools`

3) Insert your product disk into drive A. Copy the contents of the disk using the following command:

   `copy a:\*.*c:\dsktools\*.\*/v`

2.4 Step 3: Modifying Your config.sys File

When using the debugger and assembler, you can open multiple files. To allow enough environment room, it is recommended that the following line be added to the config.sys file:

```
FILES=20
```

Once you edit your config.sys file and add the line, invoke the file by rebooting the PC (press the reset switch, or turn off the PC’s power and turn it on again).
Step 4: Modifying the PATH Statement

2.5 Step 4: Modifying the PATH Statement

To ensure that your debugger and assembler are invoked from any directory in your PC, you must modify the PATH statement to identify the dsktools directory. Not only must you do this before you invoke the debugger for the first time, you must do it any time you power up or reboot your PC.

You can accomplish this by entering individual DOS commands, but it's simpler to put the commands in your system's autoexec.bat file. The general format for doing this is:

```
PATH=C:\dsktools;pathname2;pathname3
```

This allows you to invoke the debugger without specifying the name of the directory that contains the debugger executable file.

If you are modifying your autoexec.bat file and it already contains the PATH statement, simply include ;C:\dsktools at the end of the statement as shown in Figure 2–2.

```
DATE
TIME
ECHO OFF
PATH=C:\dos;C:\dsktools
CLS
```

If you modify the autoexec.bat file, be sure to invoke it before invoking the debugger for the first time. To invoke this file, enter:

```
autoexec
```
Step 5: Verifying the Installation

2.6 Step 5: Verifying the Installation

To ensure that you have correctly installed your DSK board, assembler, and debugger, enter the following command at the system prompt to start the DSK debugger:

dsk3d

After entering the dsk3d command, you should see a display similar to the one shown in Figure 2–3.

Figure 2–3. Basic Debugger Display

Note:

When the communications kernel is first loaded, the on-chip timers are initialized causing the LED to cycle through several colors. The sequence is red–yellow–green–yellow–red, etc.
Step 5: Verifying the Installation

If you see a display similar the one shown in Figure 2–3, you have correctly installed your DSK board, assembler, and debugger. If you see the display shown in Example 2–1, then your software or cable may not be installed properly. Go through the installation instructions again and make sure that you have followed each step correctly; then reenter the `dsk3d` command above.

**Installation errors**

If you still do not see the debugger display, one or more of the following conditions may be the cause:

- You may have used an incorrect communication port (LPT1 versus LPT2).
- A printer driver or other software may be using the same communication port that you are attempting to use with the DSK. If so, try another communication port for the DSK.
- Your printer port cable and connectors may not be connected snugly.
- Your power transformer may not be plugged in on both ends. If the DSK is receiving power, then the LED will illuminate either red or green.

Some operating systems do not use conventional AT I/O port addresses when mapping port names to addresses. For example, an EISA PC or IBM PS/2 might assign port 0x3BC as LPT1 instead of LPT3. If this is the case, you should use LPT3 to start the DSK, since the DSK works from a physical address instead of the port name LPTx. The last three lines of Example 2–1 show the operating system’s lookup table (located at RAM address 0000 0040) that maps physical addresses to port names. This may help you to determine which ports are in use and which name is associated with each port for a particular address. The information in the lookup table in Example 2–1 may not be accurate since network and operating system software also uses this table for redirecting printer output.
Step 5: Verifying the Installation

Example 2–1. Port Selection Display

| Testing TMS320C3x DSK reset at PORT 0x378 (LPT1) |
| SSP > HPACK (ERROR pin) did not go high during reset |
| SELECT: 1) LPT1 0x378 (alternate LPT2) |
| 2) LPT2 0x278 (alternate LPT3) |
| 3) LPT3 0x3BC (alternate LPT1) |
| H) Additional online help |

CHECK: TARGET POWER (LED IS RED OR GREEN)  
PORT SELECTION  
I/O CONNECTIONS AND CABLES  
POWER CONSERVATION SOFTWARE (LAPTOPS!)  
AUTOEXEC.BAT, CONFIG.SYS AND BIOS  
DAUGHTER CARDS  
VERY OLD PRINTER PORTS WITHOUT PULLUPS (PRE 1986)  
IF THE LED IS CYCLING R–Y–G THE KERNEL HAS LOADED

The LPTx name or handle for a port address depends on the operating system and installed drivers. The DSK uses standard port conventions so you might need to use a different port name to get the correct port address. For reference, the systems LPT cross reference table is given below

SYSTEM TABLE LOCATED AT  
LPT1 @0x378  
RAM ADDRESS 0000:0400  
LPT2 @0x278  
LPT3 @0x002

Installing the DSK Assembler and Debugger 2-9
The DSP Starter Kit (DSK) lets you experiment with, and use a DSP for real-time signal processing. The DSK gives you the freedom to create your own software to run on the board as is, or to build new boards and expand the system in any number of ways.

The DSK assembler and debugger are software interfaces that help you to develop, test, and refine DSK assembly language programs.

This chapter provides an overview of the assembler and debugger and describes the overall code development process.

### Topics

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<td>3.3 Developing Code for the DSK</td>
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<td>3.4 Getting Started</td>
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3.1 Description of the DSK Assembler

The DSK assembler is a simple and easy to use tool. Only the most significant features of an assembler have been incorporated. However, if you want, you can create and load COFF files by using the TMS320 floating-point DSP assembly language tools that will also load and run on the DSK.

Key features of the assembler

- **Quick.** The DSK assembler differs from many other assemblers because it does not go through a linker phase to create an output file. Instead, the DSK uses special directives to assemble code at an absolute address during the assembly phase. As a result, you can create small programs quickly and easily.

- **Easy-to-use.** If you want to create larger programs, you can do this by chaining files together with the .include directive.

3.2 Description of the DSK Debugger

The debugger is easy to learn and use. Its friendly, window-oriented interface reduces learning time and eliminates the need to memorize complex commands. The debugger can load and execute code with single-step, breakpoint, and run-time halt capabilities.

The debugger can run and debug your code on an actual 'C3x DSP (as opposed to a simulator, which uses a PC to only simulate a DSP).
Figure 3–1 identifies several debugger display features. When you invoke the debugger by typing in `dsk3d`, you should see a display similar to this one (it may not be exactly the same, but it should be close).

**Figure 3–1. Basic Debugger Display**

- **DISASSEMBLY window**
- **REGISTER window**

<table>
<thead>
<tr>
<th>809c03</th>
<th>50700080 start</th>
<th>LDIU 00080h, DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>809c04</td>
<td>08349c2c</td>
<td>LDI @09c2cH, SP</td>
</tr>
<tr>
<td>809c05</td>
<td>07608000</td>
<td>LDF 0.000000e+00, R0</td>
</tr>
<tr>
<td>809c06</td>
<td>c610c1c0</td>
<td>LDI *AR0, R0</td>
</tr>
<tr>
<td>809c07</td>
<td>c610c1c0</td>
<td>LDI *AR0, R0</td>
</tr>
<tr>
<td>809c08</td>
<td>08600100</td>
<td>LDI 256, R0</td>
</tr>
<tr>
<td>809c09</td>
<td>09a09c00</td>
<td>LSH @09c00H, R0</td>
</tr>
<tr>
<td>809c0a</td>
<td>61809c0e</td>
<td>BRD jump</td>
</tr>
<tr>
<td>809c0b</td>
<td>07618000</td>
<td>LDF 0.000000e+00, R1</td>
</tr>
<tr>
<td>809c0c</td>
<td>07628000</td>
<td>LDF 0.000000e+00, R2</td>
</tr>
<tr>
<td>809c0d</td>
<td>07630000</td>
<td>LDF 1.000000e+00, R3</td>
</tr>
<tr>
<td>809c0e</td>
<td>07640000</td>
<td>jump LDF 1.000000e+00, R4</td>
</tr>
<tr>
<td>809c0f</td>
<td>087b0003</td>
<td>loop LDI 3, RC</td>
</tr>
<tr>
<td>809c10</td>
<td>64809c1a</td>
<td>RPTB block</td>
</tr>
<tr>
<td>809c11</td>
<td>02640001</td>
<td>ADDI 1, R4</td>
</tr>
</tbody>
</table>

- **MEMORY window**

| 809800 | 00000007 | ffffffff |
| 809804 | 0080982c | 00809839 |
| 809808 | 00809843 | 00809868 |
| 80980c | 008098a9 | 10800000 |
| 809810 | 0f200000 | 0f320000 |
| 809814 | 1a770004 | 6a050006 |

**Key features of the debugger**

- **Easy-to-use, window-oriented interface.** The DSK debugger separates code, data, and commands into manageable portions.

- **Powerful command set.** Unlike many other debugging systems, this debugger doesn’t force you to learn a large, intricate command set. The DSK debugger supports a small, but powerful, command set.

- **Flexible command entry.** There are two main ways to enter commands. You can enter commands at the command line or use the function keys; choose the method that you like better.
3.3 Developing Code for the DSK

Figure 3–2 illustrates the DSK code development flow.

Figure 3–2. DSK Software Development Flow

The following list describes the tools shown in Figure 3–2.

The **assembler** translates DSK assembly language source files into machine language object files for the TMS320C3x family of processors. Only the most essential assembler features are incorporated. This is *not* a COFF assembler, although executable object files created by the TI TMS320 floating-point DSP assembly language tools will also load and run on the DSK.

The main purpose of the development process is to produce a module that can be executed in a **DSK target system**. You can use the debugger to refine and correct your code.
3.4 Getting Started

This section provides a quick walkthrough so that you can get started without reading the entire user’s guide. These examples show the most common methods for invoking the assembler and debugger.

1) Create a source file to use for the walkthrough; call it rand.asm. You do not need to enter the information following a semicolon; such information is comments to help you understand what the program is doing.

Example 3–1.File rand.asm

```
; RAND.ASM
; This example shows nested loops with a call to a random number
; within the inner loop.
; NOTE: This file can be loaded either by using the debugger or a bootloader. This example does not use 0x809800 and 0x809801 since the bootloader uses these locations for stack space.

.start "CODE",0x809802 ; Start assembling CODE section here
.sect "CODE"
.entry SAMPLE ; Debugger entry point

SAMPLE  ldp @stack ; Load a data page  
ldi @stack,SP ; Load a stack pointer

ldi 0,R0 ; Start with SEED = 0
ldi 0,R1 ; Inner loop counter
ldi 0,R2 ; Outer loop counter

OUTER  ldi 3,RC ; Start ‘OUTER’ loop
rptb INNER ; Repeat block ‘INNER’ (RC+1) times
call RAND ; Call function
addi 1,R1 ; Count ‘INNER’ loops
b OUTTER ; Do it again!

INNER addi 1,R2 ; Count ‘OUTER’ loops

; Fast 32 bit random number generator

RANDX:  ldi @SEED,R0 ; Calculate RAND(SEED)
RAND:   mpyi @A,R0 ; Calculate RAND(R0)
        addi @C,R0 ;
sti R0,@SEED ; Result is returned in R0
        rets 

A .word 0107465h ; Constants needed for RAND
C .word 0234567h 
SEED .word 0 

stack .word $+1 ; Begin stack here 
.end
```
2) Enter the following command to assemble rand.asm:

```
dsk3a rand
```

This command invokes the TMS320C3x DSK assembler. If the input file extension is .asm (for example, rand.asm), you don’t have to specify the extension; the assembler uses .asm as the default. For more information about invoking the assembler, refer to Section 5.6, Assembling Your Program, on page 5-15.

When you enter this command, the assembler creates an executable file called rand.dsk. This file is used for directly loading executable code into the DSK.

The executable file includes a listing of all errors and warnings that may have occurred during assembly of your program. This listing is helpful because it contains a list of all unresolved symbols and opcodes.

3) Now you are ready to debug your program. Enter the following command to invoke the debugger:

```
dsk3d
```

4) This command brings up the TMS320C3x DSK debugger on your screen. From here, you can load your rand.dsk sample program by using the LOAD command. For more information on using the debugger, refer to Chapter 7.
Functional Overview

The TMS320C3x DSK hardware and software work together to create a low-cost development platform that lets you develop real-time signal processing applications. In addition to performing full-speed verification of your TMS320C3x code, the DSK has expansion headers that allow you to build new daughterboards to expand your system.

This chapter details the functionality of the hardware and the software.

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<td>4.3 TLC32040 AIC Initialization</td>
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<tr>
<td>4.4 Host Software</td>
<td>4-23</td>
</tr>
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</table>
4.1 DSK Hardware Interface

The 'C3x DSK starts up by responding to a host reset command and bootloading a communications kernel or a program that you supply. The communications kernel provides the necessary I/O for interfacing the DSK board and the host system. Host communications occur through the parallel bus of the 'C31, while analog I/O is handled by the TLC32040 analog interface circuit (AIC) and sent to the 'C31’s serial port.

See Appendix A, Communications Kernel Source Code, for more information.

Host hardware interface

The host interface connects the 'C31 parallel bus to the host PC parallel printer port. It consists of three devices:

- A programmable array logic (TICPAL22V10Z)
- Two high-speed octal bus transceivers with tri-state outputs (74ACT245)

The programmable array logic (PAL) determines when the 'C31 is accessing the host interface by using the STROBE A23, A22, A21, and A20 signals to decode the address of the 'C31.

The PAL provides one input (TRI) that disconnects the host interface by tri-stating the PAL INT2 and READY signals. The PAL provides five address decode outputs: USER_IOR, USER_IOW, USER_IO, USER_RAM, USER_BOOT; and three outputs: READY, INT2, and EN signals. When the DEMO signal is pulled high, two of the address decode outputs, USER_IO and USER_BOOT, drive the tri-color LED.

The bus transceivers buffer data between the PC parallel printer port and the 'C31 parallel bus. The host interface supports two types of transfers:

- The 8-bit bidirectional mode allows faster transfers on parallel printer ports that support bidirectional transfers.
- Unidirectional printer ports support an 8-bit transfer from the host to the 'C31 while supporting 4-bit transfers from the 'C31 to the host.

Figure 4–1 shows a high-level circuit diagram of the 'C3x DSK.
Figure 4–1. TMS320C3x DSK Functional Circuit Diagram
**Host communications**

The host communicates with the 'C31 through the parallel printer port. The PC manipulates the parallel port's signals by writing to and reading from the host's parallel port control and status registers. Figure 4–2 and Figure 4–3 show the parallel port control and status register bit fields used by the DSK host software. (The labels below the printer port signal names refer to signal names as used by the DSK board as shown in Figure 4–1.)

**Figure 4–2. Parallel Port Control Register (0x37A)**

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIR0</td>
<td>X</td>
<td>DIR1</td>
<td>INT</td>
<td>SLCTIN</td>
<td>INIT</td>
<td>AUTOFD</td>
<td>PSTROBE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>R/W</td>
<td>W</td>
<td>R/W</td>
<td>W</td>
<td>R/W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4–3. Parallel Port Status Register (0x379)**

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUSY</td>
<td>ACK</td>
<td>PAPER</td>
<td>SELECT</td>
<td>ERROR</td>
<td>ACK</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D3</td>
<td>D2</td>
<td>D1</td>
<td>D0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPACK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The host initializes the 'C31 by pulsing the INIT signal (writes a 0 followed by a 1 to the INIT bit field of the parallel port control register). This signal resets the 'C31 and activates the bootloader mode. The host then downloads your program or the communications kernel to the 'C31. The parallel port is mapped into the 'C31 memory to the address range 0xFFF000–0xFFFFFF, as shown in Figure 4–4, page 4-7.

The host sends data to the 'C31 in the following way:

1) The host writes the byte to be transmitted to the I/O-mapped area of the host's parallel port data lines (I/O address 0x378 for LPT 1).

2) The host drives the HPSTB signal low and waits for an acknowledgement. The HPSTB signal interrupts the 'C31 by pulsing the INT2 signal, indicating that the host is requesting the transfer of a packet. The INT2 signal is needed only for the initial packet transfer request and is ignored during subsequent packet requests.

3) The 'C31 starts a one-wait-state read access to location 0xFFF000. The PAL decodes this address as the host interface active (HPACK) signal, drives the host's ERROR signal low, and drives the 'C31's READY signal high. This prevents the 'C31 from completing its read access. The host uses the ERROR (HPACK) signal to acknowledge that the 'C31 is “locked” and waiting to receive the data.
4) The host drives the HPSTB signal high, indicating to the 'C31 that the data is ready. The PAL detects the rising edge of HPSTB and drives the 'C31’s READY signal low, unlocking (freeing) the locked-bus access, and concluding the 'C31 read cycle.

5) This process is repeated until all four bytes are transferred (least significant byte first). At each transfer, the 'C31 pieces the bytes together to form a 32-bit word.

The host receives data in a similar manner:

1) The host waits for the HPACK signal, indicating that the 'C31 understands the host request for a packet transfer.

2) The 'C31 starts a one-wait-state write access to location 0xFFF000. The PAL decodes this address as the HPACK signal, drives the host’s ERROR signal low, and drives the 'C31’s READY signal high. This prevents the 'C31 from completing its write access. The host uses the ERROR signal to acknowledge that the 'C31 is already sending data.

3) When the host receives the HPIA signal, it drives PSTROBE low and the host reads a byte or 4-bit nibble, depending on whether a bidirectional parallel printer is present in the host.

4) The host drives the HPSTB signal high, indicating to the 'C31 that the data was read. The PAL detects the rising edge of HPSTB and drives the 'C31’s READY signal low, concluding the 'C31 write cycle. This completes the 'C31 read cycle.

5) This process is repeated until all four bytes or eight nibbles are transferred (least significant byte first). During each transfer, the host pieces the bytes together to form a 32-bit word.

Note:

During the bootload process, the 'C31 does not read the third and fourth bytes of the first 32-bit word. The bootloader acts as if it is reading from an EPROM and skips these bytes.
TLC32040 AIC hardware interface

The TLC32040 analog interface circuit (AIC) on the DSK provides:

- A single-channel, input/output, analog interface with 14-bit dynamic range ADC and DAC
- Variable ADC and DAC sampling rate with 14-bit precision at 20,000 samples per second
- Output reconstruction filter
- Bypassable, switched-capitor, antialiasing input filter
- Selectable auxiliary analog input channel

The DSK connects the TLC32040 AIC to the 'C31 serial port through a header and 100 Ω isolation resistors. The header lets you disconnect the AIC and use the 'C31's serial port in the daughterboard. Two additional pins from the 'C31 control resetting and clocking signals to the AIC:

- The 'C31's TIMER0 pin drives the master input clock to the AIC.
- The 'C31's XF0 signal resets the AIC.

The AIC's analog input and output are connected to RCA plugs. These signals are line-level compatible (+/−3 V peak) and can be connected to audio line-level inputs and outputs.

The output can also be connected directly to a speaker, but it does not have a significant output level as the output drive is limited by the AIC output driver and a series isolation resistor. For best results, use an external amplifier or high impedance speaker, such as a headphone.

Note:

If the AIC is used with parameters outside the tested range, the AIC performance may be degraded from that specified in the data sheet. See the TLC32040 Data Sheet (SLAS014) for more information.
**DSK memory map**

Because host communications occur through the `C31 parallel bus, the PAL decodes the address of the `C31 to determine when it is accessing the host interface according to the memory map shown in Figure 4–4.

**Figure 4–4. DSK Memory Map**

The kernel, interrupt, and trap tables occupy the last 256 words of RAM 1.
4.2 DSK Communications Kernel

Upon reset, the host downloads a communications kernel to the 'C31 using the bootloader. This communications kernel provides a set of low-level routines that allow the host and the 'C31 to exchange information and perform debugging functions.

Data packets

The host and the 'C31 communicate by exchanging packets of data. Figure 4–5 shows the structure for data packets. The data-packet headers (shaded section) typically consist of four fields: command, data-stream length, target address, and target index. This header is followed by the data stream as shown in Figure 4–5. The header fields are described as follows:

- **Command** directs the handling of the packets. See the *Commands* section, page 4-9, for more information.
- **Data-stream length** indicates the length of data in the data stream.
- **Target address** points to the memory location where data is read from or written to.
- **Target index** post-increments the value of the target address after a read or write of a single data item.

*Figure 4–5. Data-Packet Structure*
Commands

When the 'C31 receives an interrupt from the host (INT2), the 'C31 saves the current state of the CPU and then receives a packet. Once the 'C31 receives the packet, the communications kernel analyzes the command entry in the header to direct the handling of the packet. The command entry provides the low-level routines necessary to communicate with the host and debug the system. The communications kernel supports these commands:

**XWRIT**  
Write a block of data from the host to the DSK. This command takes data-stream-length items from the host and writes them into the 'C31’s memory location pointed to by the target address. The target address is incremented by the target index after each write operation.

**XREAD**  
Read a block of data from the DSK to the host. This command reads data-stream-length items from the 'C31’s memory location pointed at by the target address and sends them to the host. The target index increments the target address after each read operation.

**XCTXT**  
Get the 'C31 context save buffer address.

**XRUNF**  
Restore the context of the CPU and execute code until a breakpoint is encountered or a halt command is issued. This command is used for debugging.

**XSTEP**  
Restore the context of the CPU, execute a single instruction, and then save the context of the CPU. This command is used for debugging.

**XHALT**  
Save the context of the CPU and wait for a new command. This command is used for debugging.
Debugging functions

Several debugging functions are implemented within the communications kernel by building upon the low-level communications commands. The kernel’s debugging functions can execute as a background task that is integrated into the system. Debugging does not halt the system, but allows concurrent execution of other tasks. Debugging is fast and efficient and requires only a host interface, although it does consume some amount of processor memory and bandwidth.

In contrast, scan-based emulation, which is another popular debugging methodology, is extremely helpful since it does not consume system memory and it provides a snapshot in time of the processor(s) in the system. The DSK board has an MPSD header that allows the use of the XDS510 scan-based emulator. However, scan-based emulation is a non real-time emulation that requires the complete system to halt. Due to the low data-transfer rates, it is often inadequate for application data transfers. Also, external interrupts are often masked, and can effectively freeze communications and other interrupt-driven tasks. Halting and restarting the processor causes many breaks in the CPU pipeline, which defeats the purpose of real-time operation.

Debugging functions provided in the communications kernel operate as a background task, and they never disable the CPU or force a pipeline flush. For example, single-stepping an opcode in scan-based emulation executes the opcode, flushes the pipeline, and freezes the timers and DMA. On the other hand, real-time debugging follows standard interrupt service routine rules for context switching.

Due to the real-time nature of the debugging session, debugging functions save and restore the context of the CPU before and after executing the debugging function. The kernel implements this context save similar to a typical interrupt service routine that saves and restores all CPU registers (28 registers). Peripheral control registers are not preserved, because the communications kernel does not modify them. Note that the extended-precision CPU registers require two memory locations to store the most significant 8 bits and the least significant 32 bits. After saving the context, the CPU enters a spin mode, where it waits for additional commands. During this time, the context area can be downloaded, displayed, or modified, usually under the supervision of a host debugger routine. An XRUNF or XSTEP command indicates to the CPU that it needs to restore the context area to its correct running state and then continue execution. The host accesses the ’C31’s context-save area by looking up the pointer to the context through the XCTXT command.
Interrupts

The communications kernel implements breakpoints by replacing the code at the desired location with a TRAPn opcode. When the CPU encounters a TRAP, the context-save routine is invoked, the CPU enters spin mode, writes an acknowledge to the host, and waits for a new command. While in spin mode, the CPU can receive new interrupts.

The communications kernel implements CPU halt (XHALT) in a manner similar to breakpoint halts, but the interrupt source originates from the host, not a TRAP opcode. The main difference is that the registers used by the communications kernel are restored before invoking a full context save and falling into spin mode.

The kernel implements XRUN by restoring the context followed by a standard return from interrupt. The processor is then free to execute code.

The communications kernel implements the opcode XSTEP by using a reserved interrupt in the 'C31: Serial Port 1 transmit interrupt (XINT1). Figure 4–6, on page 4-12, shows the single-step routine flow diagram. The communications kernel:

- Restores the context of the CPU
- Places the program counter into R5
- Clears INT2
- Sets the XINT1 interrupt
- Restores the status register
- Sets a delayed branch on R5

The delayed branch executes the next three instructions:

1) Sets the global interrupt enable
2) Restores R5
3) Restores the data page pointer

By coordinating the setting of the XINT1 interrupt and the branch-to-the-user program, the kernel allows only a single instruction to execute before servicing the pending interrupt. When the interrupt is recognized, the kernel saves the CPU context, sends an acknowledge to the host, branches to the spin mode, and waits for a new command.
Figure 4–6. Single-Step Flow Diagram

```
ldi 0_PC,R5 ; return to PC from TOS return
and CINT2,IF ; Clear/Poll INT2 before SSTEP or RUNF
tstb 4,IF ; Set XINIT1 interrupt
bnz $-3 ;
ldiu 0_ST,ST ; restore Status
BUD R5 ;
or 2000h,ST ; turn on INT’s
ldi 0_R5,R5 ;
ldiu 0_DP,DP ; restore DP
```

- Fetch one user opcode
- XINT1 occurs
- Context save
- Send trap acknowledge to host
- Wait in spin loop
Table 4–1. Single-Step Pipeline Flow

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Description</th>
<th>Fetch</th>
<th>Decode</th>
<th>Read</th>
<th>Execute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>BUD R5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>or 2000h,ST</td>
<td>BUD R5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>ldi @R5, R5</td>
<td>or 2000h,ST</td>
<td>BUD R5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>ldp @DP,DP</td>
<td>ldi @R5,R5</td>
<td>or 2000h,ST</td>
<td>BUD R5</td>
</tr>
<tr>
<td>5</td>
<td>Set global interrupt enable</td>
<td>USER1</td>
<td>ldp @DP,DP</td>
<td>ldi @R5,R5</td>
<td>or 2000h,ST</td>
</tr>
<tr>
<td>6</td>
<td>Interrupt recognized</td>
<td>USER2</td>
<td>USER1</td>
<td>ldp @DP,DP</td>
<td>ldi @R5,R5</td>
</tr>
<tr>
<td>7</td>
<td>Jam interrupt in pipeline (discard USER2 fetch)</td>
<td>---</td>
<td>XINT1</td>
<td>USER1</td>
<td>ldp @DP,DP</td>
</tr>
<tr>
<td>8</td>
<td>Execute USER1 instruction</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>USER1</td>
</tr>
<tr>
<td>9</td>
<td>Clear interrupt flag; clear GIE; store return address on stack; read vector table</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>XINT1</td>
</tr>
<tr>
<td>10</td>
<td>Pipeline begins to fill with interrupt service routine</td>
<td>XSTEP ISR</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>11</td>
<td>Pipeline continues to fill with ISR</td>
<td>ISR2</td>
<td>XSTEP ISR</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>12</td>
<td>Pipeline continues to fill with ISR</td>
<td>ISR3</td>
<td>ISR2</td>
<td>XSTEP ISR</td>
<td>---</td>
</tr>
<tr>
<td>13</td>
<td>Execute first instruction of ISR</td>
<td>ISR4</td>
<td>ISR3</td>
<td>ISR2</td>
<td>XSTEP ISR</td>
</tr>
</tbody>
</table>

Table 4–1 describes the pipeline flow that sets the XINT1 interrupt and branches to your code. This table shows that the activities in the pipeline are coordinated so that the code is fetched at the same time global interrupts are enabled. In this way, the interrupt is placed in the pipeline right after fetching the second instruction. This instruction is discarded and the pipeline is filled with the interrupt service routine (ISR).

**Note:**

Another way of interpreting CPU interrupts is to treat them as a special kind of opcode that is inserted into the pipeline. Instructions that are in the pipeline before the interrupt occurs must complete execution.
4.3 TLC32040 AIC Initialization

To use the TLC32040 analog interface circuit (AIC), you must follow a sequence of steps to initialize and set up the 'C31’s timer and serial port, and to reset and program the AIC. The following subsections describe this process.

**Resetting the AIC**

As shown in Figure 4–1, page 4-3, the 'C31’s XF0 signal is connected to the RESET signal of the AIC. By toggling the RESET signal, the 'C31 can reset the AIC. This is achieved by executing the following instructions:

```
  rpts 40    ; Execute next instruction 40x
  ldi 2h,IOF ; Pull AIC into reset
  ldi 6h,IOF ; Pull AIC out of reset
```

**Initializing the 'C31 timer**

As shown in Figure 4–1, page 4-3, the 'C31’s timer (TCLKO) signal is connected to the AIC’s master clock (MCLK) signal. The MCLK signal drives all the key logic signals of the AIC, such as the shift clock, the switched-capacitor filter clocks, and the A/D and D/A timing signals. The timer pulses the TCLKO signal whenever the 'C31 timer counter register (memory mapped to 0x0080 8024h) counts up to the timer period register (memory mapped to 0x0080 8028h) value. Then, the timer counter registers reset to zero and repeat. (For a detailed description of the 'C31 timer, refer to the TMS320C3x User’s Guide). Because of differences between the maximum frequency of the 'C31’s timer and the maximum and minimum frequencies of the AIC, the following constraints should be observed:

- **Minimum Timer Period Register Value.** The 'C31 50 MHz can generate a maximum timer frequency of 12.5 MHz (CLKIN/4), which is above the AIC’s tested master clock frequency maximum of 10 MHz. If you use frequencies beyond those listed in the TLC32040 data sheet the resulting performance may not be predictable. If the timer is run in pulse mode (control value is 0x2C1) the minimum period of 1 results in 12.5-MHz master pulse rate and 2 results in 6.25 MHz. See the TLC32040 Data Sheet (SLAS014) for more information.
Maximum Timer Period Register Value. The AIC’s minimum master clock frequency is 75 kHz. Taking into account the 'C31 maximum timer frequency of 12.5 MHz and the AIC’s minimum master clock frequency, the 'C31’s timer counter register maximum value should be 165 (12.5 MHz / 75 kHz = 166.7). The 'C31’s timer counts down to 0, therefore, you need to subtract 1 from this number (166 – 1 = 165). Note that the TLC32040 specification describes a minimum clock frequency since the internal signals of the AIC are stored in capacitors that must be periodically updated.

Timer Initialization. The following 'C31 assembly code initializes the timer in clock mode with a timer period of 1. The following code initializes timer 0 to generate a square wave (clock mode) on the TCLK0 pin at a frequency of 6.25 MHz (timer period = 1):

```
TGCR0 .set 808020h ; Timer 0 global control register
TCNT0 .set 808024h ; Timer 0 counter register
TPR0 .set 808028h ; Timer 0 period register
TIMVAL .word 3c1h ; Timer global control register value
ldp @TGCR0     ; Set Data Page
ldi 0h,R4      ; Initialize R4 to zero
ldi 1h,R0      ; Initialize R0 to 1
sti R4,@TGCR0  ; Reset timer0
sti R0,@TPR0   ; Store timer0 period
sti R4,@TCNT0  ; Reset timer0 counter
ldi @TIMVAL,R7 ; Load timer control value
sti R7,@TGCR0  ; Start timer 0
```

A period of zero is not allowed in pulse mode. If the timer is run in clock mode, the resulting output is a square wave with a frequency of half that of pulse mode. A period of zero is allowed in this mode resulting in a 12.5-MHz clock.

Initializing the 'C31 serial port

This subsection explains how to initialize the following:

- 'C31 serial port
- 'C31 serial-port control register (memory-mapped to 0x0080 8040h)
- FSX/DX/CLKX control register (memory-mapped to 0x0080 8042h)
- FSR/DR/CLKR control register (memory-mapped to 0x0080 8043h)

For a detailed description of the 'C31 serial port, see the TMS320C3x User’s Guide.
The 'C31 assembly code in Example 4–1 initializes the serial port global control register (SGCR0) in the following manner:

- Issuing transmit and receive resets
- Enabling receive and transmit interrupts
- Setting 16-bit receive and transmit transfers
- Setting FSX and FSR, CLKX and CLKR active low
- Setting continuous mode
- Setting variable data rate transfers:

**Example 4–1. Initialize the Serial Port Global Control Register**

```
SGCR0 .set 808040h ; Serial port 0 global control register 
SPCX0 .set 808042h ; Serial port 0 FSX/DX/CLKX control reg. ;
SPCR0 .set 808043h ; Serial port 0 FSR/DR/CLKR control reg. ;
SINIT0 .word 0e973300h ; Enable RINT & 16-bit transfers
SINIT1 .word 111h ; Configure as serial port pins
ldp @SGCR0 ; Set Data Page
ldi 0h,R4 ; Initialize R4 to zero
sti R4,@SGCR0
ldi @SINIT1,R7 ; Reset and
sti R7,@SPCX0 ;   initialize serial port
sti R7,@SPCR0 ;   initialize serial port
ldi @SINIT0,R7 ; Reset and
sti R7,@SGCR0 ;   initialize serial port
```

Refer to the example code supplied with the DSK for help on setting up the AIC.

**Initializing the AIC**

Once the 'C31 supplies MCLK, initializes its serial port, and resets the AIC, you can initialize the AIC to a specified sample rate. The AIC sampling rate is determined by the values of two registers called A and B in the AIC’s transmit and receive sections. These values are loaded into the respective counter whenever the counter counts down to 0. Tx counter A and B determine the D/A conversion timing, Rx counter A and B determine the A/D conversion timing. For more information, refer to the TLC32040 AIC Data Sheet (Literature number SLAS014). The formula for the conversion frequency is given in Equation 4–1.

**Equation 4–1. Conversion Frequency**

\[
\text{Conversion frequency} = \frac{MCLK}{2 \times A \times B}
\]
To ensure that the switched-capacitor lowpass and bandpass filters meet their transfer function characteristics, the frequency of the clock inputs of the switched-capacitor filter must be 288 kHz; otherwise, the upper and lower cut-off frequencies of the low-pass and band-pass are scaled accordingly. Equation 4–2 shows the switched capacitor filter frequency,

**Equation 4–2. Switched Capacitor Filter Frequency**

\[
SCF\_\text{Clock}\_\text{frequency} = \frac{MCLK}{2 \times A}
\]

For example, using this equation for an 8-kHz sampling rate with a MCLK of 6.25 MHz, results in a Tx counter A of 11 \([A = MCLK/(2 \times SCF)]\). Using Equation 4–2, Tx counter B results in 36 \([B = MCLK/(2 \times A \times \text{Conversion}\_\text{Frequency})]\).

To initialize the AIC’s Tx counter A and B registers, you must send a primary communication followed by a secondary communication (explained in the Primary communications subsection below, and Secondary communications subsection, on page 4-18.) Primary communications load values into the D/A while secondary communications load A/D internal registers, such as the control register, Tx counters A and B, and Rx counters A and B.

**Primary communications**

Primary communications have a data value in the 14 MSBs (D15–D2) of data and a mode selection in the two LSBs (D1–D0). This format is shown in Figure 4–7.

**Figure 4–7. Primary Communication Data Format**

<table>
<thead>
<tr>
<th>D15</th>
<th>D14</th>
<th>D13</th>
<th>D12</th>
<th>D11</th>
<th>D10</th>
<th>D9</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D/A converter value</th>
<th>mode selection</th>
</tr>
</thead>
</table>

The AIC sends the data value to the D/A converter and enables one of the modes shown in Table 4–2 depending on the two LSBs.
Table 4–2. Primary Communications Mode Selection

<table>
<thead>
<tr>
<th>LSBs</th>
<th>Mode</th>
</tr>
</thead>
</table>
| 00   | Tx Counter A ← TA, Rx Counter A ← RA  
      |      | Tx Counter B ← TB, Rx Counter B ← RB |
| 01   | Tx Counter A ← TA + TA’, Rx Counter A ← RA + RA’  
      |      | Tx Counter B ← TB, Rx Counter B ← RB |
| 10   | Tx Counter A ← TA - TA’, Rx Counter A ← RA + RA’  
      |      | Tx Counter B ← TB, Rx Counter B ← RB |
| 11   | Tx Counter A ← TA, Rx Counter A ← RA  
      |      | Tx Counter B ← TB, Rx Counter B ← RB |

The second and third modes use the TA’ and RA’ registers to advance or slow down the sampling frequency by shortening or lengthening the sample period. This is particularly useful in modem applications. It can also enhance the signal-to-noise performance, perform frequency-tracking functions, and generate nonstandard modem frequencies.

Secondary communications

Secondary communication follows a primary communication that has the two LSBs set to 11. This secondary communication programs the AIC by loading the A, A’, B, or control registers. Figure 4–8 shows the secondary communication data format. The TA, RA, TB, and RB values are unsigned. The TA’ and RA’ values are in signed 2s-complement format. The control register enables and disables auxiliary inputs, bandpass filters, and so forth.

Figure 4–8. Secondary Communication Data Format

<table>
<thead>
<tr>
<th>D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 D1 D0</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X X TA register value (unsigned) X X RA register value (unsigned) 0 0</td>
<td></td>
</tr>
<tr>
<td>X TA’ register value (signed 2s complement) X RA’ register value (signed 2s complement) 0 1</td>
<td></td>
</tr>
<tr>
<td>X TB register value (unsigned) X RB register value (unsigned) 1 0</td>
<td></td>
</tr>
<tr>
<td>X X X X X X X X Control register 1 1</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4–9 describes the control register bit fields.

**Figure 4–9. Control Register Bit Fields**

<table>
<thead>
<tr>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Gain</td>
<td>Transmit/Receive</td>
<td>AUX IN Pins</td>
<td>Loopback Function</td>
<td>Bandpass Filter</td>
<td></td>
</tr>
<tr>
<td>0 0 = 1X for ± 6V analog input</td>
<td>0 = asynchronous</td>
<td>0 = disables</td>
<td>0 = deletes</td>
<td>0 = deletes</td>
<td></td>
</tr>
<tr>
<td>0 1 = 2X for ± 3V analog input</td>
<td>1 = enables</td>
<td>1 = enables</td>
<td>1 = inserts</td>
<td>1 = inserts</td>
<td></td>
</tr>
<tr>
<td>1 0 = 4X for ± 1.5V analog input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1 = 1X for ± 6V analog input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The assembly code in Example 4–2 sets the TA and TB registers of the AIC. This code transmits a 16-bit word to the AIC and then waits until the transmit interrupt is generated by the serial port. Four commands are transmitted starting with a 0, then the TB and RB values, followed by the TA and RA values, and finally the control word. TA and RA values should be the last values transmitted, since they change the AIC sample rate. By transmitting these values last, the sample rate is not changed until the AIC receives the last program word. In this way, very high sample rates can be achieved. Each command transmits three 16-bit words: a primary communication, a secondary communication, and a 0-data word.
Example 4–2. Setting the TA and TB Registers

```assembly
; LOOPAIC.ASM is an example program which shows how to initialize and use
; the TLC32040. The analog output (DAC output) is either a ramp signal
; (RAMPEN=1) or a loopback of the analog input (RAMPEN=0).
 ;------------------------------------------------------------------------------
.start "AICTEST",0x809802 ; Start assembling here
.sect "AICTEST"
;------------------------------------------------------------------------------

; Define constants used by program
;------------------------------------------------------------------------------
RAMPEN .set 1 ; Set to 1 to generate ramp at AOUT
T0_ctrl .set 0x808020 ; TIM0 gl control
T0_count .set 0x808024 ; TIM0 count
T0_prd   .set 0x808028 ; TIM0 prd
S0_gctrl .set 0x808040 ; SP 0 global control
S0_xctrl .set 0x808042 ; SP 0 FSX/DX/CLKX port ctl
S0_rctrl .set 0x808043 ; SP 0 FSR/DR/CLKR port ctl
S0_xdata .set 0x808048 ; SP 0 Data transmit
S0_rdata .set 0x80804C ; SP 0 Data receive
TA      .set 12 ; AIC timing register values
TB      .set 15 ;
RA      .set 12 ;
RB      .set 15 ;
GIE     .set 0x2000 ; This bit in ST turns on interrupts
;------------------------------------------------------------------------------

; Define some constant storage data
;------------------------------------------------------------------------------
A_REG  .word (TA<<9)+(RA<<2)+0 ; A registers
B_REG  .word (TB<<9)+(RB<<2)+2 ; B registers
C_REG  .word 10000011b ; control
S0_gctrl_val .word 0xE970300 ; Serial port control register
S0_xctrl_val .word 0x00000111 ; values
S0_rctrl_val .word 0x00000111 ;
RAMP    .word 0 ; RAMP count value
ADC_last .word 0 ; Last received ADC value
```

---

4-20
Example 4–2. Setting the TA and TB Registers (Continued)

```assembly
;**************************************************************
; Begin main code loop here
;**************************************************************
main   or   GIE,ST           ; Turn on INTS
   ldi   0x34,IE            ; Enable XINT/RINT/INT2
   b     main              ; Do it again!
;–––––––––––––––––––––––––––––––
DAC2   push  ST             ; DAC Interrupt service routine
   push  R3
   .if   RAMPEN
       ldi   @RAMP,R3
       addi   256,R3
       sti   R3,@RAMP
   .else
       ldi   @ADC_last,R3
   .endif
   andn  3,R3
   sti   R3,@S0_xdata       ; Output the new DAC value
   pop   R3
   pop   ST
   reti
;–––––––––––––––––––––––––––––––
ADC2   push  ST             ; ADC Interrupt service routine
   push  R3
   ldi   @S0_rdata,R3
   sti   R3,@ADC_last
   pop   R3
   pop   ST
   reti
;**************************************************************;
; The startup stub is used during initialization only;
; and can be safely overwritten by the stack or data;
;**************************************************************;
.entry  ST_STUB            ; Debugger starts here
ST_STUB  ldp   T0_ctrl       ; Use kernel data page and stack
   ldi   0,R0           ; Halt TIM0 & TIM1
   sti   R0,@T0_ctrl
   sti   R0,@T0_count
   ldi   1,R0
   sti   R0,@T0_prd
   ldi   0x2C1,R0       ; Restart both timers in pulse mode
   sti   R0,@T0_ctrl
;–––––––––––––––––––––
   ldi   @S0_xctrl_val,R0;
   sti   R0,@S0_xctrl    ; transmit control
   ldi   @S0_rctrl_val,R0;
   sti   R0,@S0_rctrl    ; receive control
   ldi   0,R0
   sti   R0,@S0_xdata    ; DXR data value
   ldi   @S0_gctrl_val,R0; Setup serial port
   sti   R0,@S0_gctrl    ; global control
```
Example 4–2. Setting the TA and TB Registers (Continued)

```assembly
; This section of code initializes the AIC
;
; AIC_INIT
LDI 0x10,IE      ; Enable only XINT interrupt
andn 0x34,IF      ;
ldi 0,R0          ;
sti R0,@S0_xdata ;
RPTS 0x040        ;
LDI 2,IOF         ; XF0=0 resets AIC
rpts 0x40         ;
LDI 6,IOF         ; XF0=1 runs AIC
;
ldi @C_REG,R0    ; Setup control register
call prog_AIC     ;
ldi 0xfffc,R0     ; Program the AIC to be real slow
call prog_AIC     ;
ldi 0xfffc|2,R0    ; Program the AIC to the final rate
ldi @B_REG,R0     ; (smallest divisor should be last)
call prog_AIC     ;
call prog_AIC     ;
call prog_AIC     ;
call prog_AIC     ;
ldi @A_REG,R0     ; bump up the Fs to final rate
ldi @S0_xdata,R1  ; Use original DXR data during 2 ndy
sti R1,@S0_xdata ;
idle                ;
ldi @S0_xdata,R1  ; Use original DXR data during 2 ndy
or 3,R1           ; Request 2 ndy XMIT
sti R1,@S0_xdata ;
idle                ;
sti R0,@S0_xdata ;
Send register value
idle                ;
andn 3,R1         ;
sti R1,@S0_xdata ; Leave with original safe value in DXR
;
ldi @S0_pdata,R0 ; Fix the receiver underrun by reading
rets main          ; the DRR before going to the main loop
;
; Install the XINT/RINT ISR handler directly into
; the vector RAM location it will be used for
;
.start "SP0VECTS",0x809FC5
.sect "SP0VECTS"
B DAC2 ; XINT0
B ADC2 ; RINT0
```
4.4 Host Software

The DSK software includes several source-code files that manipulate the parallel printer port and perform the necessary functions to initialize and communicate with the 'C31. The commands in each of the source-code files are summarized in the following subsections. The source files that are typically linked include:

- **driver.cpp** includes driver-level routines that control the host's parallel printer port interface.
- **target.cpp** includes the low-level routines that manipulate the data transmissions into packets that are recognized by the 'C31 communications kernel.
- **object.cpp** uses the target- and driver-level routines to initialize and download programs to the 'C31.
- **dsk_coff.cpp** includes DSK and COFF file loader and utilities.
- **errmsg.cpp** includes text strings associated with function returns.
- **symbols.cpp** includes symbol table support routines.
- **helpmsg.cpp** includes command-line help message.

The following subsections describe the routines contained in each of these files.

DSK software also includes an assembler and a debugger. These are described in Chapter 5, *Using the DSK Assembler*, and Chapter 7, *Using the DSK Debugger*. 
**getmem, putmem**  
*Host Software*

**Host communications target routines**

The communications kernel resident in the 'C31 assumes that data transfers to and from the host are organized into packets as shown in Figure 4–5 on page 4-8. The target.cpp file includes routines that manipulate data transmissions between the host and the 'C31 into this packet structure. These routines read and write blocks of data from the 'C31 memory, send commands to the 'C31, perform context save and restores, and provide debugging commands, such as run, single-step, and halt.

---

**getmem**  
*Get Memory*

**Syntax**  
`MSGS getmem (ulong addr, ulong length, ulong *data)`

**Description**  
The `getmem` routine reads a block of data from the 'C31 memory.

**Arguments**  
- `addr` Address of the data to be read
- `length` Size of memory block to read
- `data` Pointer to host memory address in which to place data read from the 'C31

**Return Value**  
- **NO_ERR**  Block read completed successfully
- **RECV_ERR**  Failed reception
- **XMIT_ERR**  Failed transmission

---

**putmem**  
*Put Memory*

**Syntax**  
`MSGS putmem (ulong addr, ulong length, ulong *data)`

**Description**  
The `putmem` routine writes a block of data into 'C31 memory.

**Arguments**  
- `addr` Starting address to write the data to
- `length` Size of memory block to write
- `data` Pointer to host memory address to read data from. The data is then placed into 'C31 memory.

**Return Value**  
- **NO_ERR**  Block write completed successfully
- **XMIT_ERR**  Failed transmission
**Host Software**  
SSTEP_CPU, RUN_CPU, HALT_CPU

---

### SSTEP_CPU

**Single-Step Command**

**Syntax**

`MSGS SSTEP_CPU (void)`

**Description**

The SSTEP_CPU routine single-steps one instruction by restoring the context of the CPU, executing one instruction, and then saving the CPU context. This command places the CPU in command mode.

**Arguments**

None

**Return Value**

- **NO_ERR** Command and data completed successfully
- **XMIT_ERR** Failed transmission
- **RECV_ERR** Failed reception

---

### RUN_CPU

**Run Command**

**Syntax**

`MSGS RUN_CPU (void)`

**Description**

The RUN_CPU routine executes instructions starting at the program counter obtained from the CPU context save area and ending at a breakpoint, if one has been set.

**Arguments**

None

**Return Value**

- **NO_ERR** Command and data completed successfully
- **XMIT_ERR** Failed transmission

---

### HALT_CPU

**Halt Command**

**Syntax**

`MSGS HALT_CPU (void)`

**Description**

The HALT_CPU routine halts the execution of instructions. This command places the CPU in command mode and saves the CPU context.

**Arguments**

None

**Return Value**

- **NO_ERR** Command completed successfully
- **RECV_ERR** Failed reception
**GET_DEBUG_CTX**

*Host Software*

---

**GET_DEBUG_CTX**

*Return CPU Context Save Address*

**Syntax**

MSGS GET_DEBUG_CTX (void)

**Description**

The GET_DEBUG_CTX routine retrieves the 'C31 context save location starting address. The context address value is placed in the global variable DEBUG_CTX.

**Arguments**

External unsigned long DEBUG_CTX.

**Return Value**

- **NO_ERR**  
  Command completed successfully
- **RECV_ERR**  
  Failed reception
- **XMIT_ERR**  
  Failed transmission
**Host communications driver routines**

To facilitate the data transfer from the host to the `C31, the DSK software includes several driver-level routines in the file driver.cpp. This file includes routines that manipulate the hardware interface circuitry of the host to reset, send, and receive data through unidirectional and bidirectional parallel printer ports.

### DSK_reset

**Reset**

**Syntax**

```c
MSGS DSK_reset (void)
```

**Description**

The `reset` routine resets the DSK by toggling the INIT signal.

**Arguments**

None

**Return Value**

- **NO_ERR**: Reset sequence completed
- **RESET_ERR**: Reset has failed

### input_rdy

**Input Ready**

**Syntax**

```c
char input_rdy (void)
```

**Description**

The `input_rdy` routine indicates that the DSK is ready to receive.

**Arguments**

None

**Return Value**

- **0**: DSK ready to receive data
- **1**: DSK not responding to host command

### recv_long_byte

**Receive Long Byte**

**Syntax**

```c
MSGS recv_long_byte (ulong * rcv_data)
```

**Description**

The `recv_long_byte` routine receives a 32-bit value in four 8-bit data transfers (to be used only in bidirectional parallel printer ports).

**Arguments**

- **rcv_data**: Address of the value to receive

**Return Value**

- **NO_ERR**: Successful reception
- **RECV_ERR**: Failed reception
recv_long, xmit_long, xmit_byte  Host Software

recv_long  \textit{Receive Long}

\textbf{Syntax} \quad \texttt{MSGS \ recv\_long\ (ulong \ *rcv\_data)}

\textbf{Description} \quad The \texttt{recv\_long} routine receives a 32-bit value in eight 4-bit data transfers (to be used in bidirectional and unidirectional parallel printer ports).

\textbf{Arguments} \quad \texttt{rcv\_data}  Address of the value to receive

\textbf{Return Value}  
\begin{itemize}
  \item \texttt{NO\_ERR}  Successful reception
  \item \texttt{RECV\_ERR}  Failed reception
\end{itemize}

xmit_long  \textit{Transmit Long}

\textbf{Syntax} \quad \texttt{MSGS \ xmit\_long\ (ulong \ snd\_data)}

\textbf{Description} \quad The \texttt{xmit\_long} routine transmits a 32-bit value in four 8-bit data transfers (to be used in bidirectional and unidirectional parallel printer ports).

\textbf{Arguments} \quad \texttt{snd\_data}  Value to transmit

\textbf{Return Value}  
\begin{itemize}
  \item \texttt{NO\_ERR}  Successful transmission
  \item \texttt{XMIT\_ERR}  Failed transmission
\end{itemize}

xmit_byte  \textit{Transmit Byte}

\textbf{Syntax} \quad \texttt{MSGS \ xmit\_byte\ (char \ snd\_data)}

\textbf{Description} \quad The \texttt{xmit\_byte} routine transmits an 8-bit value in a single data transfer (to be used in bidirectional and unidirectional parallel printer ports)

\textbf{Arguments} \quad \texttt{snd\_data}  Value to transmit

\textbf{Return Value}  
\begin{itemize}
  \item \texttt{NO\_ERR}  Successful transmission
  \item \texttt{XMIT\_ERR}  Failed transmission
\end{itemize}
Host communications object routines

Using the low-level driver routines, the DSK software provides several high-level routines that allow the loading of programs or data from dsk3a files or COFF (Common Object File Format), that move binary data from the host to the DSK, and that initialize the DSK system. These routines assume an active communications kernel resident on the 'C31 to send and receive packets of data. See Appendix A of the TMS320 Floating-Point Assembly Language Tools User’s Guide for a detailed description of the COFF format.

Load File

Syntax

Load_File (char *file, TASK task)

Description

The Load_File function performs several tasks depending on the enumerated TASK given to it. DSK and COFF file formats are distinguished by the extension of the file. The enumerated TASK list is defined in the file DSK_COFF.H.

An ASCII hexadecimal file format that contains the bootloader header information and raw data is also supported. Since the header information defines where and how long a section is, this file format can be used to either bootload or load files. This file format is easily converted to ROM files with a user-defined post processor.

TASK Task to perform
LOAD Loads a DSK or COFF file into the DSK target.
BOOT Boots a DSK or COFF file into the DSK target.
FILE2HEX Creates loadable/bootloadable ascii .HEX file.
BOOTHEX Bootloads FILE.HEX into the DSK.
LOADHEX Loads (using kernel) FILE.HEX into the DSK.
DSK2COFF Convert DSK file to COFF file.
SLOAD Loads symbols from the file.

Arguments

*file Pointer to the name of the file to load

Return Value

NO_ERR Successful transmission
OPEN_ERR Cannot open file
ACCESS_ERR File not found
INV_COFF_MGC COFF file not created for a TMS320C31
MAX_SECTN More than 64 sections
BAD_OPTN_HDR Incorrect optional COFF header
COM_ERR Communication failure
**Init_Communication**

**Initialize Communication**

**Syntax**

```
MSGS Init_Communication (int init_n_times)
```

**Description**

The `Init_Communication` function first attempts to communicate with the DSK assuming that a valid communications kernel already exists. If this fails, the DSK is reset and the kernel is bootloaded up to `init_n_times`. This function also queries an existing communications kernel to determine if the kernel is configured for bytewide- or nibble-mode readback.

After initializing communications with the DSK, the `Load_File` function then loads the desired application.

**Arguments**

- `init_n_times`  Number of times to attempt bootloading the communications kernel before failing. Typically, this value is set to a large value to allow you to connect cables and power to the DSK.

**Return Value**

- `NO_ERR`  The DSK communications link is valid.
- `INIT_ERR`  The communications link has failed.
This chapter explains how to use the DSK assembler and describes valid DSK source files.

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5.1 Creating DSK Assembler Source Files

To create a DSK assembler source file, you can use almost any ASCII program editor. Be careful using word processors; these files contain various formatting codes and special characters.

DSK assembly language source programs consist of source statements that can contain assembler directives, assembly language instructions, and comments. Source statement lines can be up to 80 characters per line.

The next several lines show examples of source statements:

```assembly
C_REG   .set ((10100b) << 2) + 3 ; Control word
.start
ldi  2h, IOF           ; Pull AIC into reset
ldi  0h, T4            ; Clear R4
ldp  SGCR0
sti  R4, @SGCR0        ; Reset serial port
ldi  @SINIT1, R7       ; Load initialization value 1 into R7
sti  R7, @SPCX0        ; Initialize FSX/DX/CLKX control reg.
sti  R7, @SPCR0        ; Initialize FSR/DR/CLKR control reg.
ldi  @SINIT0, R7       ; Load initialization value 0 into R7
sti  R7, @SGCR0        ; Enable RINT and 16-bit transfers
sti  R4, @DTX0         ; Transmit 0
sti  R4, @TGCR0        ; Reset timer 0
ldi  TIMERPER, R7
sti  R7, @TPR0         ; Store timer 0 period
```

Your source statement can contain four ordered fields. The general syntax for source statements is as follows:

```
[ label ] [:] mnemonic [ operand list ] [:; comment]
```

Follow these guidelines:

- All statements must begin with a label, a blank, an asterisk, or a semicolon.
- Labels are optional; if you use them, they must begin in column 1.
- One or more blanks must separate each field. Note that tab characters are equivalent to blanks.
- Comments are optional. Comments that begin in column 1 can begin with an asterisk or a semicolon (* or ;), but comments that begin in any other column must begin with a semicolon.
Using valid labels

Labels are optional for all assembly language instructions and for most (but not all) assembler directives. When you use them, a label must begin in column 1 of a source statement. A label can contain up to eight alphanumeric characters (A–Z, a–z, 0–9, and _ ). Labels are case-sensitive, and the first character cannot be a number. For example:

```
.start "text",0x809C00
.entry start
CTRL .set 0
IN .set 1
OUT .set 2
.WSHIFT .word -8
start ldp @stack ; Load data page
ldi @stack,SP ; Initialize the stack
ldf 0.0,R0
ldi 0x100,R0
lsh @WSHIFT,R0
BRD jump
ldf 0.0,R1
ldf 0.0,R2
ldf 1.0,R3
jump: ldf 1.0,R4
b start
stack .word $ + 1
.end
```

In the preceding example, the colon appended to the jump label is optional. The DSK assembler does not require a label terminator.

When you use a label, its value is the current value of the section program counter (the label points to the statement it's associated with). If, for example, you use the .int directive to initialize several words, a label would point to the first word. In the following example, the label Begin has the value 0x00809800.

```
0x00809800 directive Begin .int 0Ah,3,7
0x00809800 0x0000000a <int>
0x00809801 0x00000003 <int>
0x00809802 0x00000007 <int>
```

When a label appears on a line by itself, it points to the instruction on the next line:

```
0x0080981f nocode XMIT
0x0080981f 0x10760010 or 10h, IE
0x00809820 0x06000000 idle
```

When an opcode or directive references a label, the label is substituted with the address of the label's location in memory. The only exception to this is the .set directive, which assigns a value to a label. If you don't use a label, the first character position must contain a blank, a semicolon, or an asterisk.
Using the mnemonic field

The mnemonic field follows the label field. The mnemonic field cannot start in column 1, or it is interpreted as a label. The mnemonic field can contain one of the following opcodes:

- Machine-instruction mnemonic (such as ADDI, MPYF)
- Assembler directive (such as .data, .set, .entry)

If you have a label in the first column, a space, colon, or tab must separate the mnemonic field (opcode) from the label. For example:

```asm
;==================================================
.start    "AICTEST",0x809900
.sect     "AICTEST"
.set      0x2000
;============================================================
.C3xMMRS.ASM
A_REG    .word    (TA<<9)+(RA<<2)+0 ; 0x809902
B_REG    .word    (TB<<9)+(RB<<2)+2 ; 0x809903
C_REG    .word    10000011b         ; 0x809904  +/- 1.5 V
;
S0_gctrl_val    .word  0x0E970300
S0_xctrl_val    .word  0x00000111 ;
S0_rctrl_val    .word  0x00000111 ;
;
prog_AIC    push R1
    push IE
    ldi 0x10,IE
    andn 0x30,IF
    ldi @S0_xdata,R1
    sti R1,@S0_xdata
    idle
    ldi @S0_xdata,R1
    or 3,R1
    sti R1,@S0_xdata
    idle
    sti R0,@S0_xdata
    idle
    andn 3,R1
    sti R1,@S0_xdata
    pop IE
    pop R1
    rets
```

Refer to the TMS320C3x User’s Guide for syntax specifications on individual opcodes.

It is necessary to resolve all fields in an opcode. If an opcode field (such as the section name in a .sect opcode) is omitted, the assembler generates the error statement, “Invalid, Undefined, or Missing Operand”. 
Using the operand field

The operand field is a list of operands that follow the mnemonic field. An operand can be a constant (see Section 5.2, page 5-8), a symbol (see Section 5.4, page 5-11), or a combination of constants and symbols in an expression. You must separate operands with commas.

The assembler lets you specify whether to use a constant, or use a symbol as an immediate value, a direct address or an indirect address. The following rules apply to the operands of instructions.

- **No prefix — the operand is a well-defined immediate value.** The assembler expects a well-defined immediate value, such as a register symbol or a constant. For floating-point operations, use an extended register (R0–R7). For integer operations, use any register. For example:

  ```
  Label: ADDI  0x0, R4
  ```

  This instruction adds the integer value 0 to the extended-precision register R4.

- **@ prefix — the operand is direct address.** If you use the @ sign as a prefix, the assembler treats the operand as the contents of a 32-bit address, specified by @addr. The 16 MSBs of the address are specified by the DP register; the 16 LSBs are specified by the instruction word. For example:

  ```
  Label: LDP  0x0080
  ADDI @0x9800, R0
  ```

  The first line of this code sets the DP register to 0x0080. The second line uses the concatenated value of DP and 0x9800 to form an address of 0x0080 9800. The value stored at 0x0080 9800 to is then added the value stored in R0.

- *** prefix — the operand is a register indirect address.** If you use the * sign as a prefix, the assembler treats the operand as an indirect address; that is, it uses the operand as an address. For example:

  ```
  Label: ADDI  *AR3, R0
  ```

  This instruction adds the integer stored in the location pointed to by AR3 to the value stored in R0.

Table 5–1 lists the various forms that indirect operands may take. The displacement can be specified as a value from 0–255 or as one of the index registers (IR0 or IR1). It is not necessary to specify the displacement if it is 1, because the assembler assumes a default displacement of 1. For example, *++ARn is equivalent to *++ARn(1).
Table 5–1. Indirect Addressing

<table>
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<th>Operand</th>
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<td>Indirect with no displacement</td>
</tr>
<tr>
<td>*+ARn(disp)</td>
<td>Indirect with predisplacement or preindex add</td>
</tr>
<tr>
<td>*-ARn(disp)</td>
<td>Indirect with predisplacement or preindex subtract</td>
</tr>
<tr>
<td>*++ARn(disp)</td>
<td>Indirect with predisplacement or preindex add and modification</td>
</tr>
<tr>
<td>*--ARn(disp)</td>
<td>Indirect with predisplacement or preindex subtract and modification</td>
</tr>
<tr>
<td>*ARn++(disp)[%] †</td>
<td>Indirect with postdisplacement or postindex add and modification</td>
</tr>
<tr>
<td>*ARn--(disp)[%] †</td>
<td>Indirect with postdisplacement or postindex subtract and modification</td>
</tr>
<tr>
<td>*ARn++(IR0)B</td>
<td>Indirect with postindex (IR0) and bit-reversed modification</td>
</tr>
</tbody>
</table>

† Optional circular modification (specified by %)

For more information on indirect addressing and bit-reversed addressing, refer to the *TMS320C3x User’s Guide*. 
Commenting your source file

A comment can begin in any column and extends to the end of the source line. A comment can contain any ASCII character, including blanks. Comments are printed in the assembly source listing, but they do not affect the assembly.

You can comment your source file in one of two ways. The most common way is to place a semicolon anywhere on the line you want to comment. All text placed after the semicolon is ignored by the DSK assembler. For example:

```
* Memory map register locations
SGR0 .set 0x808040 ; Serial port 0 global control register
SPCX0 .set 0x808042 ; Serial port 0 FSX/DX/CLKX control register
SPCR0 .set 0x808043 ; Serial port 0 FSR/DR/CLKR control register
DTX0 .set 0x808048 ; Serial port 0 data transmit register
DRX0 .set 0x80804c ; Serial port 0 data receive register
TGCR0 .set 0x808020 ; Timer 0 global control register
TCNT0 .set 0x808024 ; Timer 0 counter register
TPR0 .set 0x808028 ; Timer 0 period register
```

The second way to comment your source file is to use an asterisk in column 1 of your code.

If the asterisk is not in column 1, the assembler assumes it is part of your code and can generate an error.

A source statement that contains only a comment is valid.
5.2 Constants

The assembler supports five types of constants:

- Binary integer constants
- Decimal integer constants
- Hexadecimal integer constants
- Floating-point constants
- Character constants

The assembler maintains each constant internally as a 32-bit quantity. Constants are not sign extended. For example, the constant 0FFh is equal to 00FF (base 16) or 255 (base 10); it does not equal –1.

**Binary integers**

A binary integer constant is a string of 0s and 1s followed by the suffix B (or b). Examples of valid binary constants include:

- `0101b` Constant equal to 5
- `10101B` Constant equal to 21
- `–0101b` Constant equal to –5

**Decimal integers**

A decimal integer constant is a string of decimal digits, ranging from –2 147 483 647 to 4 294 967 295. Examples of valid decimal constants include:

- `1000` Constant equal to 1 000\(_{10}\) or 3E8\(_{16}\)
- `–32768` Constant equal to –32 768\(_{10}\) or 8000\(_{16}\)
- `25` Constant equal to 25\(_{10}\) or 19\(_{16}\)

**Hexadecimal integers**

A hexadecimal integer constant is a string of up to eight hexadecimal digits followed by the suffix H (or h) or preceded by the prefix 0x. Hexadecimal digits include the decimal values 0–9 and the letters A–F or a–f. A hexadecimal constant must begin with a decimal value (0–9). Examples of valid hexadecimal constants include:

- `78H` Constant equal to 120\(_{10}\) or 0078\(_{16}\)
- `0x0f` Constant equal to 15\(_{10}\) or 000F\(_{16}\)
- `37ACH` Constant equal to 14 252\(_{10}\) or 37AC\(_{16}\)
### Floating-point constants

A floating-point constant is a string of decimal digits, followed by an optional decimal point, fractional portion, and exponent portion. Examples of floating-point numbers include:

- **1.75e–10** represented internally as 2202 629A₁₆
- **4** represented internally as 0200 0000₁₆
- **–3.5** represented internally as 01A0 0000₁₆
- **3.2e5** represented internally as 12E3 C000₁₆

A floating-point constant can be preceded with a + or – sign.

### Character constants

A character constant is a single character enclosed in single quotes. The characters are represented as 8-bit ASCII characters. Examples of valid character constants include:

- `'ab'` represented internally as 0000 0061₁₆
- `'C'` represented internally as 0000 0043₁₆

Note the difference between character *constants* and character *strings*. A character constant represents a simple integer value and is enclosed in single quotes; a string is a list of characters and is enclosed in double quotes.
5.3 Character Strings

A character string is a string of characters enclosed in double quotes. The maximum length of the string varies and is defined for each directive that requires a character string. Examples of valid character strings include:

- "sample program" defines a 14-character string, sample program
- "temp.asm" defines an 8-character string, temp.asm

Character strings are used for the following:

- Filenames as in .copy "filename"
- Section names as in .sect "section name"
- Operand of a .string directive
5.4 Symbols

Symbols are used as labels, constants, and substitution symbols. A symbol name is a string of up to eight alphanumeric characters (A–Z, a–z, 0–9, $, –, and +); symbols cannot contain embedded blanks. The first character in a symbol cannot be a number or special character. The symbols you define are case-sensitive; for example, the assembler recognizes ABC, Abc, and abc as three unique symbols.

Labels

Symbols that are used as labels become symbolic addresses that are associated with locations in the program. A label must be unique. Note that you should not use register names as labels.

Constants

Symbols can be set to constant values. By using constants, you can equate meaningful names with constant values. The .set directive enables you to set constants to symbolic names. Symbolic constants cannot be redefined. The following example shows how these directives can be used:

```
.text ; initialize PC
K .set 12 ; constant definition K=12
BIN .set 01010101b ; BIN = 055h
max_buf .set K*2 ; max_buf = K*2 = 24
LDI K, R0 ; loads 12
LDI –K, R0 ; loads –12
LDI K*2, R0 ; loads 24
LDI max_buf,R0 ; loads 24
LDI !BIN, R0 ; loads 0AAh
```

Predefined symbolic constants

The assembler has several predefined symbols, including the following:

- $, the dollar sign character, represents the current value of the section program counter (SPC).
- Register symbols, including

```
AR0–AR7   IF   PC   RS
BK       IOF   R0–R7   SP
DP       IR0   RC   ST
IE       IR1   RE
```
5.5 Expression Analyzer

The expression analyzer used in the DSK assembler includes ANSI C math library functions that aid in the generation of tables and constants. These functions eliminate the tedious work of calculating tables and constants before including them in the assembly process. The functions are shown in Table 5–2.

**Note:**

If you use any of these functions, a post-assembly warning is generated to remind you that these functions are not supported by the TMS320 floating-point code generation COFF tools. If you want to use these functions with the COFF toolset, then extract the resulting hexadecimal values from the DSK listing file.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>long abs(long);</td>
<td>Absolute value</td>
</tr>
<tr>
<td>long labs(long);</td>
<td>Absolute value</td>
</tr>
<tr>
<td>double fabs(double);</td>
<td>Floating-point absolute</td>
</tr>
<tr>
<td>double cos(double);</td>
<td>Cosine</td>
</tr>
<tr>
<td>double acos(double);</td>
<td>Arc cosine</td>
</tr>
<tr>
<td>double cosh(double);</td>
<td>Hyperbolic cosine</td>
</tr>
<tr>
<td>double sin(double);</td>
<td>Sine</td>
</tr>
<tr>
<td>double asin(double);</td>
<td>Arc sine</td>
</tr>
<tr>
<td>double sinh(double);</td>
<td>Hyperbolic sine</td>
</tr>
<tr>
<td>double tan(double);</td>
<td>Tangent</td>
</tr>
<tr>
<td>double atan(double);</td>
<td>Arc tangent</td>
</tr>
<tr>
<td>double tanh(double);</td>
<td>Hyperbolic tangent</td>
</tr>
<tr>
<td>long ceil(long);</td>
<td>Ceiling operator</td>
</tr>
<tr>
<td>double floor(double);</td>
<td>Floor operator</td>
</tr>
<tr>
<td>double exp(double);</td>
<td>Natural exponent (e) raised to the power of a value</td>
</tr>
<tr>
<td>double log(double);</td>
<td>Natural logarithm (ln)</td>
</tr>
</tbody>
</table>
Table 5–2. ANSI C Math Library Functions Supported by the DSK Assembler (Continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>double log10(double);</td>
<td>Logarithm (based–10)</td>
</tr>
<tr>
<td>double pow10(double);</td>
<td>10 raised to the power of a value</td>
</tr>
<tr>
<td>double sqrt(double);</td>
<td>Square root</td>
</tr>
<tr>
<td>double log2(double);</td>
<td>Logarithm (based–2)</td>
</tr>
<tr>
<td>double pow(double,double);</td>
<td>First value raised to the power of the second value</td>
</tr>
<tr>
<td>long br(long, long);</td>
<td>Align the first value to the next address located by raising the second value to the power of 2</td>
</tr>
<tr>
<td>long circ(long,long);</td>
<td>Align the first value to the next address located by raising the second value to the power of 2</td>
</tr>
</tbody>
</table>

You can generate a table of values using certain assembler directives. To generate a table of values use the .loop/.endloop directives and the math library functions listed in Table 5–2. For example, to create the twiddle table for an FFT, use the following directives:

```assembly
TWlength .set 16 ; Table size is 16
.brstart "TwiddleTable",2*TWlength ; Align to valid br–address
TWstart: ; create label OUTside loop
    .loop TWlength ; 16 pairs of complex numbers
        .float sin(($–TWStart)*2*pi/TWlength) ; sin(n*pi/N)
        .float cos(($–TWStart)*2*pi/TWlength) ; cos(n*pi/N)
    .endloop
```

Table 5–3 shows the operators recognized by the DSK assembler.
### Table 5–3. Operators Used in Expressions

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Addition</td>
<td>!=</td>
<td>Not equal</td>
</tr>
<tr>
<td>-</td>
<td>Subtraction</td>
<td>=</td>
<td>Equal to</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication</td>
<td>==</td>
<td>Equal to</td>
</tr>
<tr>
<td>/</td>
<td>Division</td>
<td>&amp;</td>
<td>Logical AND</td>
</tr>
<tr>
<td>%</td>
<td>Modulo Division</td>
<td></td>
<td>Logical OR</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
<td>^</td>
<td>Logical XOR</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater than or equal to</td>
<td>~</td>
<td>Bitwise negation (1s complement)</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
<td>!</td>
<td>Logical NOT. If expression = 0 then 1 is returned, else 0 is returned.</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal to</td>
<td>&lt;&lt;=</td>
<td>Shift left</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal</td>
<td>&gt;&gt;</td>
<td>Shift right</td>
</tr>
</tbody>
</table>
5.6 Assembling Your Program

Before you attempt to debug your programs, you must first assemble them. Here’s the command for invoking the assembler when preparing a program for debugging:

```
dsk3a filename [options]
```

`dsk3a` is the command that invokes the assembler.

`filename` is the assembly language source file. Filenames are not case-sensitive. If you do not specify an extension, the assembler assumes the default extension `.asm`.

`options` affect the way the assembler processes input files.

You can specify options and filenames in any order on the command line.

Table 5–4 lists the assembler options; the following subsections describe the options.

Table 5–4. Summary of Assembler Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exxx</td>
<td>Stops assembling after xxx error messages occur (5 is the default)</td>
</tr>
<tr>
<td>Q</td>
<td>Suppresses the banner and all progress information (quiet)</td>
</tr>
<tr>
<td>Wxxx</td>
<td>Stops assembling after xxx warning messages occur</td>
</tr>
</tbody>
</table>
5.7 Placing Code Sections in Memory Locations

The assembly source contains several sections that must be placed in 'C31 memory locations, because the DSK assembler includes several new directives that control the starting address of the sections. A linker is not needed.

In the following code example, an output section named Mysect is placed beginning at address 000x80 9800. The entry (execution start) point is then defined at the label START. Next, a simple code loop that increments R0 is placed into the current section.

```
.start "Mysect",0x809800 ; Mysect begins at 0x809800
.sect "Mysect" ; Assemble code into Mysect
.entry START ; Execution START point
START   LDI 0,R0 ; Initialize R0=0
       ADDI 1,R0 ; Increment R0
       B LOOP ; Do it again
```

To place two sections of code that leave a hole of unused memory, look at the following code. The first section, Mysect, which starts at location 0x0080 9800, is followed by a second section, jumpback, which starts at location 0x0080 9900.

```
.start "Mysect",0x809800 ; Mysect begins at 0x809800
.sect "Mysect" ; Assemble code into Mysect
.entry START ; Execution START point
START   LDI 0,R0 ; Initialize R0=0
       ADDI 1,R0 ; Increment R0
       B JUMP1
;;--------------------------------------------------------
.start "jumpback",0x809900 ; jumpback begins at 0x809900
.sect "jumpback" ; Assemble code into jumpback
JUMP1   ADDI 1,R0 ; Increment R0
       B JUMP2
;;--------------------------------------------------------
.sect "Mysect" ; Add more code to Mysect
JUMP2   ADDI 1,R0 ; Increment R0
       B LOOP ; Finish LOOP
```
To simulate a linker command file, such as the one used in the TMS320 code generation tools, you can use a single file to control the starting address of all sections and then use the `.include` directive to append all assembly source files. For example, consider the following build file where three source files are appended to each other using a common block statement for several `.start` directives.

```asm
;BUILDA.M
;
.start "text",0x809800 ; Initialize start address for each section
.start "data",0x809C00 ;
.start "sect1",0x809900 ;
.start "sect2",0x809A00 ;
.include "FILE1.ASM" ; Include source files
.include "FILE2.ASM"
.include "FILE3.ASM"
```
Assembler directives supply program data and control the assembly process. They allow you to do the following:

- Assemble code and data into specified sections
- Reserve space in memory for uninitialized variables
- Initialize memory
- Assemble conditional blocks

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Using the DSK Assembler Directives</td>
<td>6-2</td>
</tr>
<tr>
<td>6.2 Directives That Define Sections</td>
<td>6-5</td>
</tr>
<tr>
<td>6.3 Directives That Initialize Constants</td>
<td>6-8</td>
</tr>
<tr>
<td>6.4 Directives That Reference Other Files</td>
<td>6-9</td>
</tr>
<tr>
<td>6.5 Directives That Enable Conditional Assembly</td>
<td>6-10</td>
</tr>
<tr>
<td>6.6 Directives That Align the Section Program Counter</td>
<td>6-11</td>
</tr>
<tr>
<td>6.7 Directives That Define Symbols at Assembly Time</td>
<td>6-11</td>
</tr>
<tr>
<td>6.8 Miscellaneous Directives</td>
<td>6-12</td>
</tr>
<tr>
<td>6.9 Directives Reference</td>
<td>6-13</td>
</tr>
</tbody>
</table>
6.1 Using the DSK Assembler Directives

Table 6–1 summarizes the assembler directives. Note that all source statements that contain a directive may have a label and a comment. To improve readability, they are not shown as part of the directive syntax.

Table 6–1. Assembler Directives Summary

(a) Directives that define sections

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.data</td>
<td>Assemble source code into data memory</td>
<td>6-18</td>
</tr>
<tr>
<td>.sect &quot;section name&quot;</td>
<td>Assemble source code into a named (initialized) section</td>
<td>6-27</td>
</tr>
<tr>
<td>.text</td>
<td>Assemble source code into program memory</td>
<td>6-32</td>
</tr>
</tbody>
</table>

(b) Directives that initialize constants (data and memory)

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte value_1 [..., value_n]</td>
<td>Initialize one or more 8-bit integers</td>
<td>6-16</td>
</tr>
<tr>
<td>.fill size in words</td>
<td>Reserve size words in the current section; note that a label points to the beginning of the reserved space</td>
<td>6-29</td>
</tr>
<tr>
<td>.float expression</td>
<td>Initialize a 32-bit TMS320C3x floating-point constant</td>
<td>6-21</td>
</tr>
<tr>
<td>.float16 expression</td>
<td>Initialize a 16-bit TMS320C3x floating-point constant</td>
<td>6-21</td>
</tr>
<tr>
<td>.float8 expression</td>
<td>Initialize an 8-bit TMS320C3x floating-point constant</td>
<td>6-21</td>
</tr>
<tr>
<td>.ieee expression</td>
<td>Initialize one or more 32-bit, IEEE single-precision, floating-point constants</td>
<td>6-22</td>
</tr>
<tr>
<td>.int value_1 [..., value_n]</td>
<td>Initialize one or more 16-bit integers</td>
<td>6-16</td>
</tr>
<tr>
<td>.long value_1, ..., value_n</td>
<td>Initialize one or more 32-bit integers</td>
<td>6-16</td>
</tr>
<tr>
<td>.pfloat16</td>
<td>Initialize 16-bit TMS320C3x floating-point constants into a single word</td>
<td>6-21</td>
</tr>
<tr>
<td>.pfloat8</td>
<td>Initialize 8-bit TMS320C3x floating-point constants into a single word</td>
<td>6-21</td>
</tr>
<tr>
<td>.q.xx value_1 [..., value_n]</td>
<td>Initialize a 16-bit, signed 2’s-complement integer, whose decimal point is displaced xx places from the LSB</td>
<td>6-25</td>
</tr>
<tr>
<td>.space size in words</td>
<td>Reserve size words in the current section; note that a label points to the beginning of the reserved space</td>
<td>6-29</td>
</tr>
</tbody>
</table>
(b) Directives that initialize constants (data and memory) (Continued)

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.string &quot;string1&quot;, &quot;stringn&quot;</td>
<td>Initialize one or more text strings</td>
<td>6-31</td>
</tr>
<tr>
<td>.word value1, ..., valueN</td>
<td>Initialize one or more 32-bit integers</td>
<td>6-16</td>
</tr>
</tbody>
</table>

(c) Directives that reference other files

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.copy [&quot;filename&quot;]</td>
<td>Include source statements from another file</td>
<td>6-17</td>
</tr>
<tr>
<td>.include &quot;filename&quot;</td>
<td>Include source statements from another file</td>
<td>6-17</td>
</tr>
</tbody>
</table>

(d) Directives that enable conditional assembly

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.else</td>
<td>Optional conditional assembly</td>
<td>6-23</td>
</tr>
<tr>
<td>.endif</td>
<td>End conditional assembly</td>
<td>6-23</td>
</tr>
<tr>
<td>.if well-defined expression</td>
<td>Begin conditional assembly</td>
<td>6-23</td>
</tr>
<tr>
<td>.loop [well-defined expression]</td>
<td>Begin repeatable assembly of a code block; the loop count is determined by the well-defined expression.</td>
<td>6-24</td>
</tr>
<tr>
<td>.endloop</td>
<td>End .loop code block</td>
<td>6-24</td>
</tr>
</tbody>
</table>

(e) Directives that modify the section program counter (SPC)

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.align [size in bytes]</td>
<td>Align the SPC on a boundary specified by size in bytes, which must be a power of 2; default to byte boundary</td>
<td>6-14</td>
</tr>
<tr>
<td>.entry [address]</td>
<td>Initialize the starting address of the SPC when loading a file</td>
<td>6-20</td>
</tr>
</tbody>
</table>
Using the DSK Assembler Directives

(f) Directives that define symbols at assembly time

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.set value</td>
<td>Equate a value with a local symbol</td>
<td>6-28</td>
</tr>
<tr>
<td>.sdef value</td>
<td>Equate a value with a local symbol multiple times</td>
<td>6-26</td>
</tr>
</tbody>
</table>

(g) Miscellaneous Directives

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>.brstart &quot;section name&quot;, n</td>
<td>Align the named section to the next 2n address boundary.</td>
<td>6-15</td>
</tr>
<tr>
<td>.end</td>
<td>Program end</td>
<td>6-19</td>
</tr>
<tr>
<td>.start &quot;section name&quot;, address</td>
<td>Links the named section to start assembling at the location address.</td>
<td>6-30</td>
</tr>
</tbody>
</table>
6.2 Directives That Define Sections

These directives associate the various portions of an assembly language program with the appropriate sections:

- The `.data` directive identifies portions of code to place in data memory. Data memory usually contains initialized data.

- The `.sect` directive defines an initialized named section and associates subsequent code or data with that section. A section defined with `.sect` can contain code or data.

- The `.text` directive identifies portions of code in the `.text` section. The `.text` section usually contains executable code.

Example 6–1 shows how you can use sections directives to associate code and data with the proper sections. This is an output listing; column 1 shows, the SPC value and column 2 shows the memory contents, if affected by the previous line, or a comment. (Each section has a section program counter (SPC). The .start directive for a section determines that section’s initial SPC value. When you resume assembling into a section, its SPC resumes counting as if there had been no intervening code.

After the code in Example 6–1 is assembled, the sections contain:

- `.text` Bytes with the values 1, 2, 3, 4, 5, and 6
- `.data` Bytes with the values 9, 10, 11, and 12
- `mysect` Bytes with the values 21, 22, 23, 24

Note:

The `.text` and `.data` directives are short hand representations of `.sect` statements for that section name.

`.text` is equivalent to `.sect "text"
`data` is equivalent to `.sect "data"
Example 6–1. Sections Directives

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00809800</td>
<td>directive</td>
<td>.start &quot;text&quot;, 0x809800</td>
</tr>
<tr>
<td>0x00809800</td>
<td>directive</td>
<td>.start &quot;data&quot;, 0x809900</td>
</tr>
<tr>
<td>0x00809800</td>
<td>directive</td>
<td>.start &quot;mysect&quot;, 0x809a00</td>
</tr>
<tr>
<td>0x00809800</td>
<td>nocode</td>
<td>; Start assembling into .text</td>
</tr>
<tr>
<td>0x00809800</td>
<td>nocode</td>
<td>; Resume assembling into .data</td>
</tr>
<tr>
<td>0x00809804</td>
<td>directive</td>
<td>.sect &quot;mysect&quot;</td>
</tr>
<tr>
<td>0x00809900</td>
<td>directive</td>
<td>.byte 1,2</td>
</tr>
<tr>
<td>0x00809900</td>
<td>nocode</td>
<td>; Start assembling into .data</td>
</tr>
<tr>
<td>0x00809904</td>
<td>directive</td>
<td>.byte 5,6</td>
</tr>
<tr>
<td>0x00809905</td>
<td>nocode</td>
<td>; Resume assembling into .text</td>
</tr>
<tr>
<td>0x00809a00</td>
<td>directive</td>
<td>.byte 21,22</td>
</tr>
<tr>
<td>0x00809a01</td>
<td>directive</td>
<td>.byte 23,24</td>
</tr>
<tr>
<td>0x00809a02</td>
<td>nocode</td>
<td></td>
</tr>
<tr>
<td>0x00809a03</td>
<td>nocode</td>
<td></td>
</tr>
<tr>
<td>0x00809a04</td>
<td>nocode</td>
<td></td>
</tr>
</tbody>
</table>
### Example 6–1. Sections Directives (Continued)

<table>
<thead>
<tr>
<th>Symbol reference table</th>
<th>Type</th>
<th>Addressable</th>
</tr>
</thead>
<tbody>
<tr>
<td>ref Default-Start</td>
<td>0x00809800</td>
<td>1</td>
</tr>
<tr>
<td>ref 0x00000001</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ref .text 0x00809800</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ref .data 0x00809900</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ref mysect 0x00809a00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ref 0x00000001</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output section start</th>
<th>end</th>
<th>length</th>
</tr>
</thead>
<tbody>
<tr>
<td>sect Default_Start</td>
<td>0x00809800 0x00809800</td>
<td>0x00000000</td>
</tr>
<tr>
<td>sect .text 0x00809800</td>
<td>0x00809800 0x00809800</td>
<td>0x00000006</td>
</tr>
<tr>
<td>sect .data 0x00809900</td>
<td>0x00809904 0x00809904</td>
<td>0x00000004</td>
</tr>
<tr>
<td>sect mysect 0x00809a00</td>
<td>0x00809a04 0x00809a04</td>
<td>0x00000004</td>
</tr>
</tbody>
</table>

>>> PASS 2 Complete
>>> Errors: 0 Warnings: 0
>>> ENTRY 0x00809800
>>> Symbol reference table
>>> ref Default-Start 0x00809800 1 1
>>> ref 0x00000001 1 2
>>> ref .text 0x00809800 1 1
>>> ref .data 0x00809900 1 1
>>> ref mysect 0x00809a00 1 1
>>> ref 0x00000001 1 2
>>> Output section start end length
>>> sect Default_Start 0x00809800 0x00809800 0x00000000
>>> sect .text 0x00809800 0x00809800 0x00000006
>>> sect .data 0x00809900 0x00809904 0x00000004
>>> sect mysect 0x00809a00 0x00809a04 0x00000004
>>> END DSK
6.3 Directives That Initialize Constants

Several directives assemble values for the current section.

- The `.byte` directive places one or more 8-bit values into consecutive words in the current section. A byte in this case uses all 32 bits of the word placing 0s into the upper 24 bits.

- The `.fill` directive reserves a specified number of words in the current section with a value. The assembler advances the SPC and skips the reserved words. When you use a label with `.fill`, it points to the first word of the reserved block.

- The `.float` directive converts an expression value into a 32-bit TMS320C3x floating-point constant. This format has an 8-bit exponent and a 24-bit mantissa.

- The `.float16` directive converts an expression value into a 16-bit TMS320C3x floating-point constant. This format has an 8-bit exponent and an 8-bit mantissa. The format is identical to that used by the `.sfloat` directive of the TMS320C32. The upper 16 bits are not used and are filled with 0s.

- The `.float8` directive converts an expression value into an 8-bit TMS320C3x floating-point constant. This format has a 4-bit exponent and a 4-bit mantissa. This format can be used for a quick logarithm approximation. The upper 24 bits are not used and are filled with 0s.

- The `.ieee` directive calculates the 32-bit IEEE floating-point representation of a single precision floating-point value.

- The `.int` directive places one or more 16-bit values into consecutive words in the current section. The upper 16 bits are not used and are filled with 0s.

- The `.long` directive places one or more 32-bit values into consecutive bytes in the current section.

- The `.pfloat16` directive converts an expression value into a 16-bit floating-point constant. The values are packed into consecutive fields of memory.

- The `.pfloat8` directive converts an expression value into an 8-bit floating-point constant. The values are packed into consecutive fields of memory.

- The `.qxx` directive places one or more 16-bit, signed 2s-complement values into consecutive words in the current section. Note that the decimal point is displaced `xx` places from the LSB (least significant bits.)
The `.space` directive reserves a specified number of bits in the current section. The assembler advances the SPC and skips the reserved words. When you use a label with `.space`, it points to the first word of the reserved block.

The `.string` directive places 8-bit characters from one or more character strings into the current section.

The `.word` directive places one or more 32-bit values into consecutive bytes in the current section.

### 6.4 Directives That Reference Other Files

The `.copy` and `.include` directives tell the assembler to begin reading source statements from another file. When the assembler finishes reading the source statements in the copy/include file, it resumes reading source statements from the current file.
6.5 Directives That Enable Conditional Assembly

Conditional assembly directives enable you to instruct the assembler to assemble certain sections of code according to a true or false evaluation of an expression. Two sets of directives allow you to assemble conditional blocks of code:

- The `.if`.else`.endif` directives tell the assembler to assemble a block of code according to a true or false evaluation of an expression. Note that you cannot nest if statements.

  - `.if well-defined expression` marks the beginning of a conditional block and assembles code if the `.if well-defined expression` is true.

  - `.else` marks a block of code to be assembled if the `.if well-defined expression` is false.

  - `.endif` marks the end of a conditional block and terminates the block.

- The `.loop`.break`.endloop` directives tell the assembler to repeatedly assemble a block of code according to the evaluation of an expression.

  - `.loop well-defined expression` marks the beginning a repeatable block of code. The optional expression evaluates to the loop count.

  - `.endloop` marks the end of a repeatable block.
6.6 Directives That Align the Section Program Counter

These directives affect the section program counter (SPC).

- The **.align** directive aligns the SPC at a 1-byte to 32K-byte boundary. This ensures that the code following the directive begins on the byte value that you specify. If the SPC is already aligned at the selected boundary, it is not incremented.

- The **.entry** directive identifies the starting address of the section program counter. By default, the current address is used, or, you can specify an optional address.

6.7 Directives That Define Symbols at Assembly Time

Assembly-time symbol directives equate meaningful symbol names to constant values or strings.

- The **.set** directive equates meaningful symbol names to constant values or strings. The symbol is stored in the symbol table and cannot be redefined; for example:

  ```
  bval .set 0100h
  .byte bval
  b bval
  ```

- The **.sdef** directive equates meaningful symbol names to constant values or strings; the symbol name can be redefined.
6.8 Miscellaneous Directives

These directives enable miscellaneous functions or features:

- The `.brstart` directive aligns the named section to the next $2^n$ address boundary following the current section.

- The `.end` directive terminates assembly. It should be the last source statement of a program. This directive has the same effect as an end-of-file.

- The `.start` directive links the named section to start assembling at the location address. This effectively gives the DSK assembler the functionality of a linker.
## 6.9 Directives Reference

The remainder of this chapter is a reference. Generally, the directives are organized alphabetically, one directive per page; however, related directives (such as `.if/.else/.endif`) are presented together on one page. Here is an alphabetical table of contents for the directive reference:

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</tr>
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<td>6-16</td>
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<tr>
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<td>.ieee</td>
<td>6-22</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Directive</th>
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<tr>
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<tr>
<td>.int</td>
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<td>.long</td>
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<td>.sdef</td>
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<td>.sect</td>
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<tr>
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<td>6-28</td>
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<tr>
<td>.space</td>
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<tr>
<td>.start</td>
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<td>.string</td>
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</tr>
<tr>
<td>.text</td>
<td>6-32</td>
</tr>
<tr>
<td>.word</td>
<td>6-16</td>
</tr>
</tbody>
</table>
.align  Align to a 32-Word Boundary

Syntax

Description
The .align directive aligns the current section to a 32-word boundary, filling the hole with NOPs. If the hole is greater than 2 words, .align places a branch to the newly-aligned address. This directive is useful for placing critical code blocks on the boundaries that best use the cache resources of the 'C3x architecture.

Example
Here is an example of the .align directive.

```assembly
; Slightly modified FIR filter example from C3x Users Guide
;---------------------------------------------------------------
.start "ISR",0x809808 ; Create an output section which is
.sect "ISR" ; not on a 32-word boundary for demo
.align ;
FIRLENG .set 64 ; Size of FIR filter
Critical ldp @FIRCOEF ;
ldi @FIRCOEF,AR0 ; AR0=address of h(N–1)
ldi @FIRDATA,AR1 ; AR1=address of x(n–(N–1))
mpyf3 *AR0++(1),*AR1++(1)%,R1 ;
ldf 0.0,R2 ;
ldi FIRLENG-2,RC ; Be sure to unroll length by 2
rptb FIR ; Begin block repeat
mpyf3 *AR0++(1),*AR1++(1)%,R1 ;
FIR || addf3 R0,R1,R2 ;
  b $ ; Done, result is in R2
FIRCOEF .word 0x809900 ; Address for coefficient storage
FIRDATA .word 0x809A00 ; Address for input data storage
```
Align to Address Boundary  .brstart

Syntax

`brstart “section name”, n`

Description

The `brstart` directive aligns the `section name` to the next $2^n$ address boundary immediately following the current section. This directive aligns data buffers in order to use the 'C3x circular and bit-reversed addressing modes. Another method for creating a section whose start is bit-reversed, is to use the br() function within the .start directive’s address field.

Example

Here is an example of the .brstart directive.

```assembly
.word  $        ; The present address is
.brstart “Twiddle”, 128 ; Create a new section on a new 128 word boundary
.word  $        ; The new address is
```
Initialize a 32-bit Integer

Syntax

- `.byte` value\(_1\) \([,...,\text{ value}_n]\)
- `.int` value\(_1\) \([,...,\text{ value}_n]\)
- `.long` value\(_1\) \([,...,\text{ value}_n]\)
- `.word` value\(_1\) \([,...,\text{ value}_n]\)

Description

These directives place one or more values into the current section.

- The `.byte` directive places 8-bit values into consecutive words in the current section. The `value` must be an expression that evaluates to a number within –128 and 127. The upper 24 bits are 0.

- The `.int` directive places 16-bit values into consecutive words in the current section. The `value` must be an expression that evaluates to a number within the range of –32768 and 32767. The upper 16 bits are always 0.

- The `.long` and `.word` directives place 32-bit values into consecutive words in the current section. The `value` is an expression that the assembler evaluates and treats as a 32-bit signed number.

A `value` must be absolute. You can use as many values as fit on a single line (80 characters). If you use a label, it points to the first word that is initialized.

Example 1

Here is an example of these directives.

```
.word 'A', 'B', 'C', 1, 0x1234, 0320C31h
.int 111b, 1<<4
.long 0x87654321, 1<<31
.byte 0x20, 'A', 'B', 'C'
.hword 32765,1 -32768, -2, 2
```
Copy Source File: `.copy`, `.include`

Syntax

| `.copy "filename"` |
| `.include "filename"` |

Description

The `.copy` and `.include` directives tell the assembler to read source statements from a different file. The assembler:

1) Stops assembling statements in the current source file
2) Assembles the statements in the copied/included file
3) Resumes assembling statements in the main source file, starting with the statement that follows the `.copy` or `.include` directive

The `filename` is a required parameter that names a source file. The `filename` must be enclosed in double quotes and must follow operating system conventions. You can specify a full pathname (for example, `c:\dsktools\file1.asm`). If you do not specify a full pathname, the assembler searches for the file in the current directory.

The `.copy` and `.include` directives can be nested within a file that is copied or included. The assembler limits this type of nesting to eight levels; the host operating system may set additional restrictions.

Example

This example shows how the `.include` directive is used to tell the assembler to read and assemble source statements from other files, then to resume assembling into the current file.

Source file: (source.asm)

```asm
.space 10h ; Filename: source.asm
.include "byte.asm" ; Filename: source.asm
.space 20h ; Filename: source.asm
```

First copy file: (byte.asm)

```asm
.byte 'a', 0ah, 32 ; Filename: byte.asm
.include "word.asm" ; Filename: byte.asm
.byte 11,12,13 ; Filename: byte.asm
```

Second copy file: (word.asm)

```asm
.word oabcdh, 56 ; Filename: word.asm
```

Assembler Directives 6-17
.data  Assemble Into .data Section

Syntax

<table>
<thead>
<tr>
<th>.data</th>
</tr>
</thead>
</table>

Description

The .data directive tells the assembler to begin assembling source code into data memory. The .data section normally contains tables of data or preinitialized variables.

Note that the assembler assumes that .text is the default section. Therefore, at the beginning of an assembly, the assembler assembles code into the .text section unless you specify a section control directive.

Example

This example shows how to assemble code into the .data and .text sections.

```
.data

.start "data", 0x809900
.entry BEGIN
BEGIN ldi 0, R0 ; Initialize R0 and R1
   ldi 1, R1
   .data
value .int 0, 1, 2, 3, 4, 5 ; Integer values
```
The `.end` directive is an optional directive that terminates assembly. It should be the last source statement of a program. The assembler ignores any source statements that follow an `.end` directive.

Example

This example shows how the `.end` directive terminates assembly.

```
ldi 1,R1 ; Assemble this code
mpyi 5,R1 ;
.end    ; Stop assembler
subi 2,R1 ; does not assemble
```
**.entry**  Define Entry Point

**Syntax**

```
.entry [value]
```

**Description**

The **.entry** directive tells the assembler the address of the section program counter when a file is loaded. If you do not use the *value* parameter, the current program memory address, determined by the .text section, becomes the starting address. If you have more than one .entry directive in your file, then the last .entry directive encountered becomes the starting address of your code.

**Example**

Here is an example of the .entry directive.

```plaintext
.start "code",0x809800 ; Create a named section to assemble to
.sect "code"           ; use the new section
.entry BEGIN           ; Start program at BEGIN
BEGIN:               
  ldi 80h,AR0     ; Initialize ARx pointers to RAM0
  lsh 16,AR0      ;
  ldi AR0,AR1     ;
  ldi 0,R3        ; R3 is used as loop counter

LAB0:    ldi +AR0(0),R0 ; Both labels resolve to the same address
LAB1:   ldi +AR1(1),R1 ; Colon ':' is recognized as a WS character
          ; R0 contains the opcode at BEGIN
          ; R1 contains the opcode at BEGIN+1
          ;----------------------------------;

count:  addi 1,R3    ; Add 1 to count
          ;----------------------------------;
  b count    ; Wait in count loop forever
```
Initialize TMS320C3x Floating-Point Value .float, .float16, .float8, .pfloat16, .pfloat8

Syntax

```
.float value1 [,..., value_n]
.float16 value1 [,..., value_n]
.float8 value1 [,..., value_n]
.pfloat16 value1 [,..., value_n]
.pfloat8 value1 [,..., value_n]
```

Description

These directives convert one or more values into TMS320C3x floating-point constants.

- The `.float` directive converts a `value` into a 32-bit TMS320C3x floating-point constant. This format has an 8-bit exponent and a 24-bit mantissa.

- The `.float16` directive converts a `value` into a 16-bit TMS320C3x floating-point constant. This format has an 8-bit exponent and an 8-bit mantissa.

- The `.float8` directive converts a `value` into an 8-bit TMS320C3x floating-point constant. This format has a 4-bit exponent and a 4-bit mantissa. When properly scaled, this format can be used for quick logarithm approximations.

- The `.pfloat16` directive converts a `value` into a 16-bit floating-point constant. The values are packed into consecutive fields of memory.

- The `.pfloat8` directive converts a `value` into an 8-bit floating-point constant. The values are packed into consecutive fields of memory.

The `value` is a required parameter; it is an expression that is evaluated and placed in the constant. The value must be absolute.

Note that the 'C31 expects floating-point numbers to have the 32-bit format.

Example

Here is an example of these directives.

```
PI .set 3.1415926 ;.set remembers PI is float
.float -10/3, -0.1, 0, 0.1, PI, 2*PI ;Some easy to compare values
.float8 -10/3, -0.1, 0, 0.1, PI, 2*PI ;
.pfloat8 -10/3, -0.1, 0, 0.1, PI, 2*PI ;
.float16 -10/3, -0.1, 0, 0.1, PI, 2*PI ;
.pfloat16 -10/3, -0.1, 0, 0.1, PI, 2*PI ;
.ieee -10/3, -0.1, 0, 0.1, PI, 2*PI ;
```
**.ieee Initialize IEEE Format Floating-Point Value**

**Syntax**

```
.ieee expression
```

**Description**

The `.ieee` directive places the IEEE single-precision floating-point representation of a single floating-point constant into three bytes in the current section.

The `expression` is a required parameter; it is an expression that must evaluate to a floating-point constant. Each constant is converted to a floating-point value in IEEE single-precision 32-bit format.

**Example**

Here is an example of the `.ieee` directive.

```
.ieee -10/3, -0.1, 0, 0.1, PI, 2*PI ; Some values
```
Assemble Conditional Block .if, .else, .endif

Syntax

```plaintext
.if well-defined expression
.else
.endif
```

Description

Three directives provide conditional assembly:

- The `.if` directive marks the beginning of a conditional block. The `expression` is a required parameter.
  - If the expression evaluates to `true` (nonzero), the assembler assembles the code that follows it (up to an `.else`, or an `.endif`).
  - If the expression evaluates to `false` (0), the assembler assembles code that follows an `.else` (if present), or an `.endif`.

- The `.else` directive identifies a block of code that the assembler assembles when the `.if` expression is false (0). This directive is optional in the conditional block; if an expression is false and there is no `.else` statement, the assembler continues with the code that follows the `.endif`.

- The `.endif` directive terminates a conditional block.

Nested `.if/.else/.endif` directives are not valid.

Example

Here is an example of conditional assembly:

```plaintext
TRUE .set 1
FALSE .set 0

.if TRUE  ;
nop      ; Assembles ‘nop’ since TRUE
.else     ;
B $      ; Never assembles
.endif   
```
**.loop/.break/.endloop**  
**Assemble Code Block Repeatedly**

| Syntax | `.loop` well-defined expression  
|        | `.endloop` |

<table>
<thead>
<tr>
<th>Description</th>
<th>Two directives enable you to repeatedly assemble a block of code:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The <strong>.loop</strong> directive begins a repeatable block of code. The optional expression evaluates to the loop count (the number of loops to be performed). If there is no expression, the loop count defaults to 246.</td>
</tr>
<tr>
<td></td>
<td>The <strong>.endloop</strong> directive terminates a repeatable block of code; it executes when the number of loops performed equals the loop count given by <strong>.loop</strong>.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example</th>
<th>This example shows the <strong>.loop</strong> directive.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>;=========================================</td>
</tr>
<tr>
<td></td>
<td>; Create an FFT Twiddle table</td>
</tr>
<tr>
<td></td>
<td>;=========================================</td>
</tr>
<tr>
<td></td>
<td>.start &quot;TABLES&quot;, 0x809A00</td>
</tr>
<tr>
<td></td>
<td>.sect &quot;TABLES&quot;</td>
</tr>
<tr>
<td></td>
<td>pi .set 3.1415926</td>
</tr>
<tr>
<td></td>
<td>N .set 4</td>
</tr>
<tr>
<td></td>
<td>;----------------------------------------</td>
</tr>
<tr>
<td></td>
<td>TR ; REAL twiddles</td>
</tr>
<tr>
<td></td>
<td>;----------------------------------------</td>
</tr>
<tr>
<td></td>
<td>.loop N/2</td>
</tr>
<tr>
<td></td>
<td>.float cos((–TR)*pi/N)</td>
</tr>
<tr>
<td></td>
<td>.endloop</td>
</tr>
<tr>
<td></td>
<td>;----------------------------------------</td>
</tr>
<tr>
<td></td>
<td>TI ; IMAG twiddles</td>
</tr>
<tr>
<td></td>
<td>;----------------------------------------</td>
</tr>
<tr>
<td></td>
<td>.loop N/2</td>
</tr>
<tr>
<td></td>
<td>.float –1*sin((–TI)*pi/N)</td>
</tr>
<tr>
<td></td>
<td>.endloop</td>
</tr>
</tbody>
</table>
Syntax

`.`qxx value1 [,..., value_n]`

Description

The `.qxx` directive generates signed, 2s-complement fractional integers and long integers whose decimal point is displaced `xx` places from the LSB.

Example

Here's an example of the `.qxx` directive. The value of `xx` can be either positive or negative.

```
.q0 3.1415926 ; All upper 32 bits are integers
.q1 3.1415926 ; One fractional bit (left shift 1
.q2 3.1415926 ; Two fractional bits (left shift 2)
.q16 3.1415926 ; Upper 16 are whole integers,
                 ; lower 16 are fractional
```
.sdef  Define Assembly-Time Constant

Syntax  

\[ \text{symbol .sdef value} \]

Description  
The .sdef directive functions in the same manner as the .set directive; however, .sdef can redefine the symbol name multiple times without generating an error. All instances of .sdef symbols are stripped from the symbol table at the end of pass 1 analysis. When used with the .if directive, .sdef can conditionally assemble included blocks of code. This is useful for turning on and off included library functions.

- The symbol must appear in the label field.
- The value must be a well-defined expression; that is, all symbols in the expression must be previously defined in the current source module.

Example  
This shows how symbols can be assigned with .sdef.

```
VarA .set 15 ;
VarB .sdef 0xAAAA ;
   .word VarA, VarB ;
VarB .sdef 0x5555 ;
   .word VarA, VarB ; Note the VarB value change
```
The `.sect` directive begins assembling source code into the named section. The `.sect` directive defines named sections that are used like default `.text` and `.data` sections.

The section name identifies the section. The section name is significant to 80 characters and must be enclosed in double quotes.

Here's an example of the `.sect` directive.

```assembly
.start  "Mysect_1",0x809800 ; Create two output sections
.start  "Mysect_2",0x809880 ; at different addresses

.sect  "Mysect_1"            ; Begin assembling into Mysect_1
    .word   $,1,1,1             ; $ gives present address
.sect  "Mysect_2"            ; Begin assembling into Mysect_2
    .word   $,2,2,2             
.sect  "Mysect_1"            ; Go back to assembling into Mysect_1
    .word   $,1,1,1             ;
```
.set  Define Assembly-Time Constant

Syntax

\[ \text{symbol .set value} \]

Description

The .set directive equates a constant value to a symbol. The symbol can then be used in place of the value in assembly source. This allows you to equate meaningful names with constants and other values.

- The symbol must appear in the label field.
- The value must be a well-defined expression; that is, all symbols in the expression must be previously defined in the current source module.

Example

This example shows how to assign symbols with .set.

\[
\begin{align*}
\text{TA} & \quad .\text{set} \quad 1 \\
\text{TB} & \quad .\text{set} \quad 5 \\
\text{ldi} & \quad *\text{AR0++(TA)},\text{R0} \\
\text{ldi} & \quad *\text{AR0++(TB)},\text{R0}
\end{align*}
\]
Reserve Space  .space, .fill

Syntax

| .space  | size in words |
| .fill   | size in words, value |

Description

Two directives reserve space in the current section.

- The .space directive reserves size number of words in the current section and fills them with 0s. The SPC is incremented to point to the word following the reserved space.

- The .fill directive reserves size number of words in the current section and fills them with value. The value must be an absolute value. The SPC is incremented to point to the word following the reserved space.

When you use a label with the .space or .fill directive, it points to the first word reserved.

Example

This example shows how the .space and .fill directives reserve memory.

```assembly
.space  12        ; Fill 12 locations with the value 0x0
.fill   3,0x5555  ; Fill three words with 0x5555
.start  "Mysect",0x809800 ; Initialize start of Mysect
.sect   "Mysect"

.text
.data
```
**Syntax**

```
.start "section name", address
```

**Description**

The `.start` directive links the `section name` to start at location `address`. This directive effectively gives the DSK assembler the same functionality as a linker command file when used only to create runtime executable modules. For the specified section to have a valid starting address, the `.start` statement for the section must precede the `.text`, `.data`, or `.sect` directive that defines the section name. Note that by using an include file with an imbedded `.if/.sdef/.endif`, the `.start` directive can effectively be used in place of the linker.

**Example**

Here is an example of the `.start` directive.

```
.entry START
.start "MAIN",0x809800 ; Create an output sections
.sect "MAIN" ; Begin assembling into MAIN
LOOP:    addi  1,R0            ; Top of loop
         addi  1,R1
START:   ldi    0,R0            ; Initialize R0,R1
         ldi    0,R1
         b LOOP              ; Go to top of loop
```
Syntax

```
.string "string\text{1}"[,...,"string\text{n}\text{}"]
```

Description

The `.string` directive places one or more 8-bit character strings into consecutive bytes of the current section.

The character string must be enclosed in double quotes. Each character in a string represents a separate value.

The `.string` directive places the 8-bit values into memory in a packed form in the order they are encountered. If a word is not filled, the remaining bits are filled with 0s.

Example

This example shows several 8-bit values placed into consecutive bytes in memory. The label `Str_3` has the value `0h`, which is the location of the first initialized byte.

```
Str_3: .string "ABCD"
    .string 51h, 52h, 53h, 54h
    .string "Hoston"
    .string 36+12
```
Assemble Into .text Section

Syntax

<table>
<thead>
<tr>
<th>.text</th>
</tr>
</thead>
</table>

Description

The `.text` directive tells the assembler to begin assembling into the `.text` section. The `.text` section usually contains executable code. The section program counter (SPC) is set to 0, if nothing has been assembled into the `.text` section. If code has already been assembled into the `.text` section, the SPC is restored to its previous value in the section.

Note that the assembler assumes that `.text` is the default section. Therefore, at the beginning of an assembly, the assembler assembles code into the `.text` section unless you specify one of the other sections directives (`.data`, `.entry`, or `.sect`).

Example

This example shows the assembly of code into the `.data` and `.text` sections.

```
.start       "text", 0x809800
.entry       START
START       ldi 0, R0 ; Initialize R0 and R1
             ldi 1, R1
.text
value       .int 0, 1, 2, 3, 4, 5 ; integer values
```
Using the DSK Debugger

This chapter tells you how to invoke the DSK debugger and use its function keys and commands.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Invoking the Debugger</td>
<td>7-2</td>
</tr>
<tr>
<td>7.2 Understanding the Debugger Windows</td>
<td>7-4</td>
</tr>
<tr>
<td>7.3 Using the Help Menu</td>
<td>7-8</td>
</tr>
<tr>
<td>7.4 Using Software Breakpoints</td>
<td>7-9</td>
</tr>
<tr>
<td>7.5 Debugger Commands</td>
<td>7-10</td>
</tr>
<tr>
<td>7.6 Quick Reference Guide</td>
<td>7-13</td>
</tr>
</tbody>
</table>
7.1 Invoking the Debugger

Here's the command for invoking the debugger:

```
dsk3d [options]
```

*dsk3d* is the command that invokes the debugger.
*options* supply the debugger with additional information.

Table 7–1 lists the debugger options; the following subsections describe some of the more commonly used options.

**Table 7–1. Summary of Debugger Options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>? or HELP</td>
<td>Displays a listing of the available options</td>
</tr>
<tr>
<td>AUTO</td>
<td>Automatically detects if the parallel port supports 8- or 4-bit mode</td>
</tr>
<tr>
<td>BW = 4, Nibble</td>
<td>Forces communication using the parallel port in standard 4-bit unidirectional mode</td>
</tr>
<tr>
<td>BW = 8, Byte</td>
<td>Forces communication using the parallel port in 8-bit bidirectional mode</td>
</tr>
<tr>
<td>LPTx, LPT = x</td>
<td>Selects a parallel printer port (LPT1 is default)</td>
</tr>
<tr>
<td>PORT = 0x378</td>
<td>Selects any port address</td>
</tr>
<tr>
<td>RESET</td>
<td>Resets (cold boots) the DSK</td>
</tr>
<tr>
<td>TEST</td>
<td>Searches automatically through LPT1, LPT2, and LPT3 for the presence of a DSK</td>
</tr>
<tr>
<td>T = xx</td>
<td>Adds extra <em>xx</em> I/O bus cycles to each transfer for long or noisy cables</td>
</tr>
<tr>
<td>WIN = 1</td>
<td>Enables Windows Time Slice management</td>
</tr>
<tr>
<td>WIN = 0</td>
<td>Disables Windows Time Slice management and enables set or clear interrupt (STI/CLI)</td>
</tr>
</tbody>
</table>

**Displaying a list of available options (? or Help option)**

You can display the contents of Table 7–1 on your screen by using the ? or Help option. For example, enter:

```
dsk3d ?
```
Selecting the parallel printer port (LPT = 3 or LPT# option)

The LPT option selects a parallel printer port from the host to communicate with the DSK.

<table>
<thead>
<tr>
<th>Parallel Printer Port</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPT1 or LPT = 1</td>
<td>Selects printer port hardware at I/O address 0x378.</td>
</tr>
<tr>
<td>LPT2 or LPT = 2</td>
<td>Selects printer port hardware at I/O address 0x278.</td>
</tr>
<tr>
<td>LPT3 or LPT = 3</td>
<td>Selects printer port hardware at I/O address 0x3BC.</td>
</tr>
</tbody>
</table>

Note:
Some EISA machines and IBM PS/2s use a different naming convention for the LPTx.

<table>
<thead>
<tr>
<th>AT Convention</th>
<th>EISA and PS/2</th>
<th>I/O Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPT1</td>
<td>LPT2</td>
<td>0x378</td>
</tr>
<tr>
<td>LPT2</td>
<td>LPT3</td>
<td>0x278</td>
</tr>
<tr>
<td>LPT3</td>
<td>LPT1</td>
<td>0x3BC</td>
</tr>
</tbody>
</table>

Select the parallel printer port at a particular address (PORT option)

The port option selects the parallel printer port at the given address. For example:

\[
\text{port} = 0x378
\]

selects the host’s parallel port mapped to the address 0x378.

Note:
Use this option with extreme care since any base address can be used.

Automatically search for a printer port (TEST option)

Use the test option to systematically search for a parallel port that has a DSK connected. The search loops through LPT1, LPT2, and LPT3.

Note:
If you have a printer port or other peripheral connected to your PC, turn it off before using the test option.
7.2 Understanding the Debugger Windows

**DISASSEMBLY window**

The DISASSEMBLY window shows the reverse assembly of memory contents. As shown in Figure 7–1, this window displays several lines of code. Each line shows the instruction address, instruction opcode, label, and instruction mnemonic. The highlighted line corresponds to the next instruction to be executed.

**Figure 7–1. DISASSEMBLY Window**

<table>
<thead>
<tr>
<th>Instruction address</th>
<th>Instruction opcode</th>
<th>Label</th>
<th>Instruction mnemonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>809c03</td>
<td>507000080 start</td>
<td></td>
<td>LDIU 00080h,DP</td>
</tr>
<tr>
<td>809c04</td>
<td>08349c2c</td>
<td>LDI @09c2cH,SP</td>
<td></td>
</tr>
<tr>
<td>809c05</td>
<td>07608000</td>
<td></td>
<td>LDF 0.0000000e+00,R0</td>
</tr>
<tr>
<td>809c06</td>
<td>c610c1c0</td>
<td>LDI *AR0,R0</td>
<td></td>
</tr>
<tr>
<td>809c07</td>
<td>c610c1c0</td>
<td>LDI *AR0,R0</td>
<td></td>
</tr>
<tr>
<td>809c08</td>
<td>08600100</td>
<td>LDI 256,R0</td>
<td></td>
</tr>
<tr>
<td>809c09</td>
<td>09a09c00</td>
<td>LSH @09c00H,R0</td>
<td></td>
</tr>
<tr>
<td>809c0a</td>
<td>61809c0e</td>
<td>BRD jump</td>
<td></td>
</tr>
<tr>
<td>809c0b</td>
<td>07618000</td>
<td>LDF 0.0000000e+00,R1</td>
<td></td>
</tr>
<tr>
<td>809c0c</td>
<td>07628000</td>
<td>LDF 0.0000000e+00,R2</td>
<td></td>
</tr>
<tr>
<td>809c0d</td>
<td>07630000</td>
<td>LDF 1.0000000e+00,R3</td>
<td></td>
</tr>
<tr>
<td>809c0e</td>
<td>07640000 jump</td>
<td>LDF 1.0000000e+00,R4</td>
<td></td>
</tr>
<tr>
<td>809c0f</td>
<td>087b0003 loop</td>
<td>LDI 3,RC</td>
<td></td>
</tr>
<tr>
<td>809c10</td>
<td>64809c1a</td>
<td>RPTB block</td>
<td></td>
</tr>
<tr>
<td>809c11</td>
<td>02640001</td>
<td>ADDI 1,R4</td>
<td></td>
</tr>
</tbody>
</table>

To select the DISASSEMBLY window, press **ALT D**. While in the DISASSEMBLY window, you can use the cursor to select a line and then use a function key to set or clear a breakpoint. Refer to Table 7–13 for more information about function keys.
CPU REGISTER window

The CPU REGISTER window displays the content of all CPU registers as shown in Figure 7–2. The register’s contents are normally displayed in hexadecimal format. You can press F3 to display the extended-precision registers in floating-point decimal format. You can press F2 to display the extended-precision registers in 40-bit hexadecimal format.

Figure 7–2. CPU REGISTER Window

To modify the contents of a register, activate the CPU REGISTER window by pressing ALT C. You can type over the highlighted data and press ENTER to accept the changes when you are satisfied with them. Use the following keys to select the data you want to edit:

→ ↑ ↓ ← PAGE UP PAGE DOWN TAB
Memory Window

The MEMORY window shows the contents of a range of memory as shown in Figure 7–3. The MEMORY window has two parts:

- **Addresses.** The first column of numbers identifies the addresses of the first column of display data. No matter how many columns of data you display, only one address column is displayed. Each address in this column identifies the address of the data immediately to its right.

- **Data.** The remaining columns display values at the listed addresses.

For example, the MEMORY window below has four columns of data, so each new address is incremented by 4. Although the window shows four columns of data, there is still only one column of addresses; address 0x0080 9800 contains 0x0000 0007, address 0x0080 9801 contains 0xFFFF FFFC, address 0x0080 9804 (the first value in the second row) contains 0x0080 982C, address 0x0080 9805 contains 0x0080 9839, etc.

Figure 7–3. MEMORY Window

To modify the contents of the MEMORY window, press \( \text{ALT} + \text{M} \) to activate the window and then type over the data. To select a cell, you can use the following keys:

- \( \text{ALT} \)
- \( \text{TAB} \)
- \( \text{PAGE UP} \)
- \( \text{PAGE DOWN} \)
COMMAND window

The COMMAND window provides an area for entering commands, echoing commands, and displaying command output errors and messages. The COMMAND window has two parts:

- **Command line.** This is the area where you enter commands. When you want to enter a command, just type — no matter which window is active.

- **Display area.** This area echoes the commands that you enter, shows any output from your commands, and displays debugger error messages.

Figure 7–4 shows the window command line and display area.

**Figure 7–4. COMMAND Window**

You can use the ↑ and ↓ keys to select a previously entered command from the buffer (a > is used to indicate the buffer). The editing command keys are shown in Table 7–2.

**Table 7–2. Editing Command Keys**

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move through the command</td>
<td>←     →</td>
</tr>
<tr>
<td>Toggle the insert and type over mode</td>
<td>INS</td>
</tr>
<tr>
<td>Delete the character at the cursor</td>
<td>DEL</td>
</tr>
<tr>
<td>Move to the beginning of the line</td>
<td>HOME</td>
</tr>
<tr>
<td>Move to the end of the line</td>
<td>END</td>
</tr>
<tr>
<td>Clear the command</td>
<td>ESC</td>
</tr>
<tr>
<td>Select a command from the buffer</td>
<td>↑     ↓</td>
</tr>
</tbody>
</table>
7.3 Using the Help Menu

You can press the F1 or H key to bring up the Help Window Display shown in Figure 7–5. Choose from the menu selections listed below to find additional information.

Figure 7–5. Monitor Information Screen

<table>
<thead>
<tr>
<th>KEYBOARD COMMANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1  Help Screen</td>
</tr>
<tr>
<td>F2  40-bit hex display</td>
</tr>
<tr>
<td>F3  FLOAT display</td>
</tr>
<tr>
<td>F4  Source/DASM debug toggle</td>
</tr>
<tr>
<td>F5  Run</td>
</tr>
<tr>
<td>F6  Display breakpoints</td>
</tr>
<tr>
<td>F7  Clear all breakpoints</td>
</tr>
<tr>
<td>F8  Singlestep</td>
</tr>
<tr>
<td>F9  Toggle DASM window size</td>
</tr>
<tr>
<td>F10 Step over function</td>
</tr>
</tbody>
</table>

ALT+D Selects Disassembly Window
ALT+M Selects Memory Window

Move Up/Dn/Pup/Pdn — H–Xtra help — S–save help to file

To move through the help window, you can use:

- PGUP to move ahead a page
- PGDN to move back a page
- HOME to return to the first page of the help menu
- END to go to the last page of the help menu
- S to save help text to a file
- ESC to exit the help menu and return to the debugger
- H to enter a second help level. The second help level is more hardware-oriented and deals less with debugger-specific commands.
7.4 Using Software Breakpoints

This section describes how to set and clear software breakpoints and how to obtain a listing of all the breakpoints that are set.

While debugging, you may want to halt execution temporarily so that you can examine the contents of selected variables, registers, and memory locations before continuing with program execution. You can do this by setting software breakpoints in the assembly language code. A software breakpoint halts any program execution, whether you’re running or single-stepping through code.

**Setting a software breakpoint**

When you set a software breakpoint, the debugger highlights the breakpointed line in a bolder or brighter font. The highlighted statement appears in the DISASSEMBLY window.

After execution is halted by a breakpoint, you can continue program execution by reissuing any of the run or single-step commands.

You can set a software breakpoint by entering the SB command.

**sb addr** If you know the address where you’d like to set a software breakpoint, you can use the SB command. This command is useful because it doesn’t require you to search through code to find the desired line. When you enter the SB command, you enter an absolute address (addr). (Once you have entered the address, you are asked to choose the line number you want the breakpoint set on.) Note that you cannot set multiple breakpoints at the same statement.

**Clearing a software breakpoint**

**cb addr** If you’d like to clear a breakpoint, you can use the CB command. You can use the CB command to clear a specific address by entering an absolute address (addr) after the command. You can clear all breakpoints by entering the CB command without an address.

**Finding the software breakpoints that are set**

**db** Sometimes, you may need to know where software breakpoints are set. The DB command provides an easy way to get a complete listing of all the software breakpoints that are currently set in your program.
7.5 Debugger Commands

The following tables provide a summary of the debugger function keys and commands.

Table 7–3. Command-Line Editing

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move the cursor to the beginning of the command line</td>
<td>HOME</td>
</tr>
<tr>
<td>Move the cursor to the end of the command line</td>
<td>END</td>
</tr>
<tr>
<td>Delete the character to the left of the cursor</td>
<td>DEL.</td>
</tr>
<tr>
<td>Delete the character to the right of the cursor</td>
<td>SHIFT END</td>
</tr>
<tr>
<td>Move the cursor to the left</td>
<td>→</td>
</tr>
<tr>
<td>Move the cursor to the right</td>
<td>→</td>
</tr>
</tbody>
</table>

Table 7–4. Command-Line Buffer Manipulation

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall the last command typed</td>
<td>↑ or PAGE UP</td>
</tr>
<tr>
<td>Recall the first command in the command-line buffer</td>
<td>PAGE DOWN or ↓</td>
</tr>
<tr>
<td>Reexecute the last command typed</td>
<td>TAB</td>
</tr>
</tbody>
</table>

Table 7–5. Running Programs

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step through the instructions one at a time (single-step)</td>
<td>SS</td>
</tr>
<tr>
<td>Execute n instructions</td>
<td>XN n</td>
</tr>
<tr>
<td>Single-step through the instructions until you reach address addr</td>
<td>XG addr</td>
</tr>
<tr>
<td>Execute the program until a breakpoint is encountered</td>
<td>RUN</td>
</tr>
<tr>
<td>Execute the program and ignore breakpoints (run-free)</td>
<td>RUNF</td>
</tr>
</tbody>
</table>
### Table 7–6. Displaying and Changing Data

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display the contents of memory starting at address <code>addr</code> in the MEMORY window</td>
<td>MEM <code>addr</code></td>
</tr>
<tr>
<td>Modify memory at address <code>addr</code></td>
<td>MM <code>addr</code></td>
</tr>
<tr>
<td>Fill <code>leng</code> locations of memory starting at address <code>addr</code> with value <code>val</code>. If <code>val</code> is expressed in a floating-point format (with a decimal point), it will be converted into a TMS320 floating-point format.</td>
<td>MM <code>addr</code> <code>leng</code> <code>val</code></td>
</tr>
<tr>
<td>Display assembly language code starting at address <code>addr</code> in the DISASSEMBLY window</td>
<td>DASM <code>addr</code></td>
</tr>
<tr>
<td>Display extended-precision registers in 40-bit hexadecimal format in the register window</td>
<td>REG40</td>
</tr>
<tr>
<td>Display extended-precision registers in floating-point decimal format in the register window</td>
<td>FLOAT</td>
</tr>
<tr>
<td>Modify <code>reg</code> register in the CPU REGISTER window with the value from expression. For example PC = 0x809800 R0 = 1.34</td>
<td><code>reg = expression</code></td>
</tr>
</tbody>
</table>

### Table 7–7. Managing Breakpoints

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set a breakpoint at address <code>addr</code></td>
<td>SB <code>addr</code></td>
</tr>
<tr>
<td>Clear a breakpoint at address <code>addr</code></td>
<td>CB <code>addr</code></td>
</tr>
<tr>
<td>Clear all the breakpoints</td>
<td>CB</td>
</tr>
<tr>
<td>Display a list of all the breakpoints that are set</td>
<td>DB</td>
</tr>
</tbody>
</table>

### Table 7–8. Loading Programs

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load an object file</td>
<td>LOAD <code>filename</code></td>
</tr>
<tr>
<td>Load symbols</td>
<td>SLOAD <code>filename</code></td>
</tr>
<tr>
<td>Load binary only</td>
<td>BLOAD <code>filename</code></td>
</tr>
<tr>
<td>Clear symbols</td>
<td>SCLEAR</td>
</tr>
</tbody>
</table>
### Debugger Commands

#### Table 7–9. Performing System Tasks

<table>
<thead>
<tr>
<th>To do this</th>
<th>Use this command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset the DSK</td>
<td>RESET</td>
</tr>
<tr>
<td>Quit or exit the debugger</td>
<td>QUIT or EXIT</td>
</tr>
<tr>
<td>Enter the DOS shell and optionally execute the ex-</td>
<td>DOS (expression to Run)</td>
</tr>
<tr>
<td>pression. Enter EXIT to return to debugger</td>
<td></td>
</tr>
<tr>
<td>Enter the DOS shell and execute the editor to edit</td>
<td>EDIT filename</td>
</tr>
<tr>
<td>filename. (If no filename is given, the name of the</td>
<td></td>
</tr>
<tr>
<td>presently loaded file is used).</td>
<td></td>
</tr>
<tr>
<td>Enter the DOS shell and execute the DSK assembler</td>
<td>dsk3a filename.asm</td>
</tr>
<tr>
<td>to assemble file</td>
<td></td>
</tr>
</tbody>
</table>
7.6 Quick Reference Guide

The following tables provide a quick-reference guide of the function key definitions.

Table 7–10. Function Key Shortcuts for DISASSEMBLY Window Active

<table>
<thead>
<tr>
<th>Function Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Help screen</td>
</tr>
<tr>
<td>F2</td>
<td>Set breakpoint at cursor</td>
</tr>
<tr>
<td>F3</td>
<td>Clear breakpoint at cursor</td>
</tr>
<tr>
<td>F4</td>
<td>Run to cursor</td>
</tr>
<tr>
<td>F5</td>
<td>Run</td>
</tr>
<tr>
<td>F6</td>
<td>Display breakpoints</td>
</tr>
<tr>
<td>F7</td>
<td>Clears all breakpoints</td>
</tr>
<tr>
<td>F8</td>
<td>Single-steps your program</td>
</tr>
<tr>
<td>F9</td>
<td>Grow window</td>
</tr>
<tr>
<td>F10</td>
<td>Step over</td>
</tr>
<tr>
<td>SHIFT F9</td>
<td>Selects the DISASSEMBLY window</td>
</tr>
<tr>
<td>ESC or ENTER</td>
<td>Escape</td>
</tr>
</tbody>
</table>

Table 7–11. Function Key Shortcuts for CPU Window Active

<table>
<thead>
<tr>
<th>Function Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Help screen</td>
</tr>
<tr>
<td>ESC</td>
<td>Exit CPU window</td>
</tr>
<tr>
<td>HOME</td>
<td>Move to top</td>
</tr>
<tr>
<td>END</td>
<td>Move to bottom</td>
</tr>
<tr>
<td>↑ or ↓</td>
<td>Move cell vertical</td>
</tr>
<tr>
<td>TAB</td>
<td>Move cell horizontal</td>
</tr>
</tbody>
</table>
### Table 7–12. Function Key Shortcuts for MEMORY Window Active

<table>
<thead>
<tr>
<th>Function Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Help screen</td>
</tr>
<tr>
<td>F9</td>
<td>Toggle window size</td>
</tr>
<tr>
<td>ESC</td>
<td>Exit memory window</td>
</tr>
<tr>
<td>HOME</td>
<td>Move to top</td>
</tr>
<tr>
<td>END</td>
<td>Move to bottom</td>
</tr>
<tr>
<td>PAGE UP</td>
<td>Move by page up/down</td>
</tr>
<tr>
<td>↓ or ↑</td>
<td>Move cell vertical</td>
</tr>
<tr>
<td>TAB</td>
<td>Move cell horizontal</td>
</tr>
</tbody>
</table>

### Table 7–13. Function Key Shortcuts for COMMAND Window Active

<table>
<thead>
<tr>
<th>Function Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Displays a list of commands</td>
</tr>
<tr>
<td>F2</td>
<td>Displays extended-precision registers in 40-bit hexadecimal format</td>
</tr>
<tr>
<td>F3</td>
<td>Displays extended-precision registers in floating-point decimal format</td>
</tr>
<tr>
<td>F4</td>
<td>Toggles between displaying the source file and the memory disassembly.</td>
</tr>
<tr>
<td>F5</td>
<td>Executes your program to the next breakpoint</td>
</tr>
<tr>
<td>F6</td>
<td>Displays all breakpoints</td>
</tr>
<tr>
<td>F7</td>
<td>Clears all breakpoints</td>
</tr>
<tr>
<td>F8</td>
<td>Single-steps your program</td>
</tr>
<tr>
<td>F9</td>
<td>Toggles the DISASSEMBLY window size</td>
</tr>
<tr>
<td>F10</td>
<td>Single-steps your program and steps past calls</td>
</tr>
<tr>
<td>ALT D</td>
<td>Selects the DISASSEMBLY window</td>
</tr>
<tr>
<td>ALT M</td>
<td>Selects the MEMORY window</td>
</tr>
<tr>
<td>ALT C</td>
<td>Selects the CPU REGISTER window</td>
</tr>
<tr>
<td>ESC</td>
<td>Exits the active window</td>
</tr>
</tbody>
</table>
Communications Kernel Source Code

This appendix contains the source code for the TMS320C3x DSK communications kernel.
Communications Kernel Source Code

```
; TMS320C3x DSK COMMUNICATIONS AND DEBUG MONITOR KERNAL
; Texas Instruments Incorporated
; (C) 1995,1996
;
.start "vectors",0x809FC1
.start "kernel",vectors-0xAB ; Use size report from DSK3A
.start "sstack",0x809F00 ; output to pack to end of RAM
.entry START

;=================================

; COMMUNICATION MONITOR START
;
;
; STACK SPACE
;
; ----------

; A section of unoccupied free memory of STACKSIZE size words just
; below the kernel is used on startup for initialization and stack
; space. If more (or less) stack space is required, a new stack
; pointer value can be initialized within the users applications code
; to any location, or by re-assembling this code with a new STACKSIZE
;
; When initialization is complete, the startup stub can be safely
; overwritten since it is no longer needed. In this case the startup
; stub is placed after the stack. Another 'safe' location would be
; a section of memory which is used for I/O or uninitialized data.
;
; This section of code also initializes the timers which are used by
; the PAL to create the PWM signal which drives the LED. The rate
; at which the LED changes color is F0-F1 where F0 and F0 are the two
; timer output frequencies. (See the Users Guide)

;=================================

;sect   "sstack"
stack:  .word   stack-1         ; start of kernel stack
MMRBASE .word   0x00808000      ;
PRD0   .word   0x0000A000      ;
PRD1   .word   0x0000A060      ;
TSTART .word   0x000003C3      ;
START  ldp     @START          ; Set up stack and other params
       ldi     @stack,SP       ;
       ldi     @MMRBASE,AR0    ; Init timers for slow PWM modulation
       ldi     3,R0            ; HALT timers
       sti    R0,*/+AR0(0x20)  ;
       sti    R0,*/+AR0(0x30)  ;
       sti    R0,*/+AR0(0x24)  ; Init count registers
       sti    R0,*/+AR0(0x34)  ;
       ldi     @PRD0,R0        ; Init periods
       sti    R0,*/+AR0(0x28)  ;
       ldi     @PRD1,R0        ;
       sti    R0,*/+AR0(0x38)  ;
       ldi     @TSTART,R0     ; Start timers
       sti    R0,*/+AR0(0x20)  ;
       sti    R0,*/+AR0(0x30)  ;
       b     spin0
```
The debugger commands are assembled into the lowest available kernel memory. If an application were to overgrow this section the debugger functions would be corrupted, but the application would continue to run so long as the debugger functions were not used.

These functions restore the CPU registers from the context save area before returning to the code pointed to by the program counter value. The only difference is that XSTEP purposely sets the interrupt flag used for single stepping before returning to the users code.

The tail end of this function is written such that a pending interrupt will not be serviced until one opcode has been fetched from the return address and executed (there may be other dummy fetches). This 'pending' interrupt then causes the processor to return back to the context save routine, effectively singlestepping the CPU.

S0_xdata .set 0x808048 ; SP 0 Data transmit
S0_rdata .set 0x80804C ; SP 0 Data receive
.sect "kernel"
.word 0x00320C31 ; Prepend a few easily recognizable markers
.word 0x00320C31 ;
XSTEP or 0x40,IF ; set XINT1 (safe INT for C31/C32 debug!)
XRUNF or 0xC4,IE ; set EXINT1 (safe INT for C31/C32 debug!)

st i IE,@_freerun ; Freerun !=0 indicates DSK is not halted
1di @CPUCTXT,AR0 ; Use parallel opcodes for squeeze
1di AR0,AR1 ;
addi 1,AR1 ;
1di 2,IR0 ;

1di @S0_rdata,R0 ; Clear under/overrun conditions before exit
1df *AR0++(IR0),R0 ; load floats (exponents)
1df *AR1++(IR0),R1 ;
1df *AR0++(IR0),R2 ;
1df *AR1++(IR0),R3 ;
1df *AR0++(IR0),R4 ;
1df *AR1++(IR0),R5 ;
1df *AR0++(IR0),R6 ;
1df *AR1++(IR0),R7 ;

1di *AR0++(IR0),R0 ; load longs (mantissa)
1di *AR1++(IR0),R1 ;
1di *AR0++(IR0),R2 ;
1di *AR1++(IR0),R3 ;
1di *AR0++(IR0),R4 ;
1di *AR1++(IR0),R5 ;
Communications Kernel Source Code

ldi *AR0++(IR0), R6  ;
|| ldi *AR1++(IR0), R7  ;
;; load ARx
ldi _AR0, AR0      ;
ldi _AR1, AR1      ;
ldi _AR2, AR2      ;
ldi _AR3, AR3      ;
ldi _AR4, AR4      ;
ldi _AR5, AR5      ;
ldi _AR6, AR6      ;
ldi _AR7, AR7      ;
ldi _IR0, IR0      ;
ldi _IR1, IR1  ;

; CPU interrupt flags
ldi _IF, IF
ldi _IOF, IOF ; IO flags
ldi _RS, RS ; Repeat start
ldi _RE, RE ; Repeat end
ldi _RC, RC ; Repeat counter
ldi _BK, BK ; Block size
ldi _SP, SP ; get user SP

ldi _PC, R5 ; return to PC from TOS return
andn 0x4, IF ; Clear/Poll INT2 before SSTEP or RUNF
tstb 4, IF ;
bnz $-3 ;
ldiu _ST, ST ; restore Status
or _IE, IE
BUD R5 ;
or 2000h, ST ; turn on INT’s
ldiu _R5, R5 ;
ldiu _DP, DP ; restore DP

;========================================================================;
; XHALT                                                                  ;
; When called this function restores the temporary use registers used    ;
; for quick returns from the XWRITE/XREAD before falling into a full     ;
; context save, followed by waiting for a new command.                    ;
;========================================================================;
XHALT pop AR1 ; restore original registers before save
pop AR0 ;
pop IR1 ;
pop R0 ;
pop DP ;
pop ST ; User PC now at TOS

A-4
SSTEP push DP              ; temp storage of user DP
    ldp  @_ST            ; DP for kernal
    sti  ST,@_ST         ; store ST
    sti  IR0,@_IR0       ; IR0 used as temp, later for indexed store
    pop   IR0            ; save user DP
    sti  IR0,@_DP        ;
    pop   IR0            ; save user PC
    sti  IR0,@_PC        ;
    sti  SP,@_SP         ; save user SP
    sti  BK,@_BK         ; Block size
    sti  IE,@_IE         ; Internal int enable
    sti  IF,@_IF         ; CPU interrupt flags
    sti  IOF,@_IOF       ; IO flags
    sti  RS,@_RS         ; Repeat start
    sti  RE,@_RE         ; Repeat end
    sti  RC,@_RC         ; Repeat counter
    sti  IR0,@_IR0       ; Keep everything <- IR0 Saved previously
    sti  IR1,@_IR1       ;
    ;-----------------------
    sti  AR0,@_AR0       ; Use parallel opcodes for squeeze
    sti  AR1,@_AR1       ;
    ldi  @CPUCTX,AR0     ;
    ldi  AR0,AR1         ;
    addi  1,AR1          ;
    ldi  2,IR0           ;
    ;-----------------------
    stf   R0,*AR0++(IR0)  ; Store floats
    ||  stf   R1,*AR1++(IR0) ;
    |  stf   R2,*AR0++(IR0) ;
    ||  stf   R3,*AR1++(IR0) ;
    |  stf   R4,*AR0++(IR0) ;
    ||  stf   R5,*AR1++(IR0) ;
    |  stf   R6,*AR0++(IR0) ;
    ||  stf   R7,*AR1++(IR0) ;
    ;-----------------------
    sti   R0,*AR0++(IR0)  ; Store longs
    ||  sti   R1,*AR1++(IR0) ;
    |  sti   R2,*AR0++(IR0) ;
    ||  sti   R3,*AR1++(IR0) ;
    |  sti   R4,*AR0++(IR0) ;
    ||  sti   R5,*AR1++(IR0) ;
    |  sti   R6,*AR0++(IR0) ;
    ||  sti   R7,*AR1++(IR0) ;
; AR2, AR3, AR4, AR5, AR6, AR7 already saved

ldi 0, R0           ; Freerun = 0 indicates HALT (spin0)
sti R0, @_FREERUN   
TRAP_AK call W_HOST  ; Send ACKNOWLEDGE (zero) to host
; b     spin0           ; <- Branch is removed (spin0 is inline)

; The spin0 code loop is used by the kernel as a known program loop ;
; when a process is halted. While in the spin loop, commands can be ;
; processed. This code loop is primarily used while debugging or ;
; during startup as a known useable code loop.                      ;

spin0 or 4,IE            ; Enable DSK31 HPI interrupt
and 4,IE                ; Shut down all interrupts except host
b    spin0               

S0xdata .word 0
GIE   .set 0x2000
; REGISTER CONTEXT STORAGE
; This block of memory holds the register values when a process is stopped. Essentially the registers displayed in the debugger are the contents of this memory block.
;================================================================================;
context

_F0        .word   0       ; R0
_F1        .word   0       ; R1
_F2        .word   0       ; R2
_F3        .word   0       ; R3
_F4        .word   0       ; R4
_F5        .word   0       ; R5
_F6        .word   0       ; R6
_F7        .word   0       ; R7
_R0        .word   0       ; F0
_R1        .word   0       ; F1
_R2        .word   0       ; F2
_R3        .word   0       ; F3
_R4        .word   0       ; F4
_R5        .word   0       ; F5
_R6        .word   0       ; F6
_R7        .word   0       ; F7
_AR0       .word   0       ; AR0
_AR1       .word   0       ; AR1
_AR2       .word   0       ; AR2
_AR3       .word   0       ; AR3
_AR4       .word   0       ; AR4
_AR5       .word   0       ; AR5
_AR6       .word   0       ; AR6
_AR7       .word   0       ; AR7
_D          .word   0       ; Data page
_IR0       .word   0       ; Index register 0
_IR1       .word   0       ; Index register 1
_BK        .word   0       ; Block size
_SP        .word   stack-1 ; Stack pointer (initial DSK3D value)
_ST        .word   0       ; Status
_IE        .word   0       ; Internal int enable
_IF        .word   0       ; CPU interrupt flags
_IOF       .word   0       ; I/O flags
_RS        .word   0       ; Repeat start
_RE        .word   0       ; Repeat end
_RC        .word   0       ; Repeat counter
_PC        .word   0       ; program counter
_FREERUN   .word   0       ; 1 = DSK is free running, 0 = DSK is HALT’ed
CPUCTXT    .word   context ;
; KERNEL COMMANDS
;
; These commands are the primary functions required by the kernel
; to perform host based communications. They have been packed into
; the available memory in such a way as to minimize the kernel's size.
; The non-debugger functions have also been placed after the debugger;
; commands making it easier to simply allow the application to
; 'overwrite' the debugger commands.
;
;====================================================================
; INTx is the starting point for all host generated commands.
; A host generated command is received when INT2 goes active (driven
; low) indicating HPSTB has gone low and that the host would like to
; transfer a piece of data or command.
;====================================================================

INTx ; maxspeed
push   ST       ; Push ISR variables
push   DP
push   R0       ; NOTE: A HALT command pops these
push   IR1      ; values followed by a full save
push   AR0
push   AR1
ldp    @JUMP    ; Get address of command from JUMP table
ldi    @S0_xdata,R0 ; Put a zero in the DXR making startup
sti    R0,@S0xdata  ; from a stalled port safe for the AIC
ldi    0,R0      ; which cannot accept 'garbage' which
sti    R0,@S0_xdata ; would reprogram it.
tstb   4,IF      ; Get here by driving INT2 low
bz      SR2       ; Make sure INT2 is active
call   R_HOST    ; R0==command
ldi    R0,AR1
addi   @JUMP,AR1
b       AR1       ; execute command

;********************************************************************
; COMN is used by both the XWRIT and XREAD functions to receive the
; block transfer length, address and address increment value.
;********************************************************************

COMN    call    R_HOST
ldi    R0,AR1    ; data packet length
call   R_HOST
ldi    R0,AR0    ; source address
call   R_HOST
ldi    R0,IR1    ; source index
subi    1,AR1
rets
The XCTXT command returns the address of the context save area to the host. Subsequently, the host can use this address to ‘get’ and put the CPU registers to modify the execution of the processor.

```assembly
XCTXT ldi @CPUCTXT,R0 ; Transmit location of context to CPU
    call W_HOST;
    b       SR2
```

SR2 is the short ‘common’ return sequence used by most commands.

```assembly
SR2     ldi     07F00h,AR0      ; Dummy non-HPI read releases READY
        ldi     *AR0,AR0        ; restore ISR variables
        pop     AR1             
        pop     AR0             
        pop     IR1             
        pop     R0              
        pop     DP              
        ; andn    0x4,IF          
        ; or      4,IE            
        pop     ST              
        reti                    ; return to original code
```

The TMS320C31 receives an interrupt it first fetches an address from the primary vector table (located in the bootloader ROM). This 32 bit value is then used as an address where the new execution begins.

```assembly
INT0    b       $               ; 0x809FC1  0x001
INT1    b       $               ; 0x809FC2  0x002
INT2    b       INTx            ; 0x809FC3  0x004 <- HPI
INT3    b       $               ; 0x809FC4  0x008
XINT0   b       $               ; 0x809FC5  0x010
RINT0   b       $               ; 0x809FC6  0x020
XINT1   b       SSTEP           ; 0x809FC7  0x040 <- SSTEP
RINT1   b       SSTEP; TRAPFIX  ; 0x809FC8  0x080 <- ETRAP 0x74000008
TINT0   b       $               ; 0x809FC9  0x100
TINT1   b       $               ; 0x809FCA  0x200
DINT    b       $               ; 0x809FCB  0x400
```
Communications Kernel Source Code

;====================================================================;
; HOST HPI communications routines packed into himem                 
;                                                                    
;  NOTE: These routines can be called from a high level language     
;  compiler using the C31s TRAP commands, by directly linking their  
;  resolved addresses or by using the jump table.                    
;====================================================================;
;  W_HOST performs an interlocked Host Port write of the contents   
;  of R0 to the host using the HPSTB/HPACK protocol. When called the 
;  host PC should be waiting for this function to send data.         
;====================================================================;
W_HOST  push    AR0             ; Used for HPI address
push    AR1             ; Used for loop counter
push    ST              ; Keep flags
push    DP              ; Might not be on same page
ldp     WSCOUNT         ;
ldi     0xF000,AR0      ; HPI address sign extends to 0xFFF000
ldi     @WSCOUNT,AR1    ;
WH      sti     R0,*AR0++(16)   ; Store lsbs to HPI
lsh     @WSHIFT,R0      ; shift to next lsbs
db      AR1,WH          ; loop until done
pop     DP              ;
; b       COMNHST         ;
COMNHST pop     ST              ; Next 4 opcodes common to W_HOST/R_HOST
pop     AR1             ;
pop     AR0             ;
rets                    ;
;====================================================================;
;  R_HOST performs an interlocked Host Port read from the printer    
;  port interface and places the result into R0.                    
;====================================================================;
R_HOST  push    AR0             ; HPI Address
push    AR1             ; loop counter
push    ST              ;
push    R1              ; temp register
ldi     0xF000,AR0      ; HPI address sign extends to 0xFFF000
ldi     3,AR1           ; bytes-1 to receive
RH      lsh     -8,R0           ; shift result right one byte
ldi     *AR0++,R1       ; Load byte
lsh     24,R1           ; shift to upper byte
or      R1,R0           ; or w/result
db      AR1,RH          ; loop until done
pop     R1              ; restore
;
; b       COMNHST         ; <- Branch can be saved
COMNHST pop     ST              ;
;
inputs

;====================================================================;
;  XWRIT is a host port command designed to transfer a block of      
;  data from the host to the C31’s memory.                          
;====================================================================;
XWRIT   call    COMN            ;
XW1     call    R_HOST          ;
sti     R0,*AR0++(IR1)        ;
db      AR1,XW1             ;
b       SR2                 ;

A-10
; XREAD is a host port command designed to transfer a block of data from C31 memory to the host.
;=====================================================================
XREAD   call    COMN            
XR1     ldi     *AR0++(IR1),R0  
call    W_HOST          
db      AR1,XR1         
b       SR2             
;=====================================================================
; There are a few leftover traps that can be used by applications.
; The number of TRAPs coincides with the amount of available unused memory before the JUMP table is encountered and was adjusted by hand by looking at the assembler listing.
;=====================================================================
TRAP00  b       $               ;          Leftover TRAPs which can be used by applications
TRAP01  b       $               ;          used by applications
;=====================================================================
; A JUMP table can also be used to access the DSK3 routines from other applications that require host communications. In this case, the contents of the location specified can be used in a register or branch.
;=====================================================================
        .start “JMPTBL”,0x809FF4
        .sect  “JMPTBL”
JUMP    .word   JUMP             ;0x809FF4 Jump table base address
        .word   XWRIT        ;1  ;0x809FF5 for DSK3 routines
        .word   XREAD        ;2  ;0x809FF6
        .word   XCTXT        ;3  ;0x809FF7
        .word   XRUNF        ;4  ;0x809FF8
        .word   XSTEP        ;5  ;0x809FF9
        .word   XHALT        ;6  ;0x809FFA
        .word   W_HOST       ;7  ;0x809FFB
        .word   R_HOST       ;8  ;0x809FFC
        .word   spin0        ;10 ;0x809FFD  Use for spare command
;=====================================================================
; The last two locations of internal memory hold the two parameters which define the printer ports bus return width. Depending on the values, either 8 bit bi-directional or 4 bit nibble returns can be implemented. These values control the loop count and shift value needed to place the correct bits on the proper return buffer inputs.
;
DO NOT OVERWRITE THESE VALUES unless you are performing buswidth verification or setup. For more details, see the communications initialization routines within the host side code.
;=====================================================================
WSCOUNT .word   7               ;0x809FFE These locations hold the W_HOST
WSHIFT  .word   -4              ;0x809FFF buswidth parameters (Nibble/Byte)
.end
Figure B–1 shows the dimensions of the DSK circuit board, and the rest of the appendix contains a brief description of the hardware in the TMS320C3x DSP Starter Kit, the schematic diagrams and design notes for host interface control.
Figure B–1. TMS320C3x DSP Starter Kit (DSK) Circuit Board Dimensions
B.1 Hardware Component Overview

This section describes the basic functions of the DSK components:

- **Expansion connectors** — The four 32-pin headers allow you to develop add-on cards that can directly interface to all of the 'C31 signals.

- **Jumper block header** — An 11-pin jumper block connects the 'C31 serial port to the TLC32040 AIC. Removal of the jumpers disconnects the AIC from the 'C31 serial port, so that a daughtercard can use the serial port signals.

- **Host interface logic** — The host interface logic consists of a programmable array logic (PAL) 22V10Z and two high-speed octal bus transceivers with tri-state outputs (74ACT245). These devices interface the 'C31 with the host parallel printer port. This interface logic supports 8-bit bidirectional or 4-bit unidirectional data modes of the PC host.

- **Oscillator** — The on-board 50Mhz oscillator drives the 'C31 clock input. The 'C31 internal clock value is divided by 1 (same frequency).

- **Parallel printer port connector** — The DB25 25-pin connector connects directly to the host parallel printer port.

- **RCA jacks** — The RCA jacks supply analog input or output and are routed to the I/O pins of the AIC.

- **Resettable fuses** — The polyswitch resettable fuses interrupt the flow of excessive current. The fuses reset after they cool down and the faulty condition is corrected. The fuses require no manual resetting or replacement.

- **TLC32040 AIC** — The analog interface circuit provides the 'C31 access to the analog world. The AIC samples analog data and converts it into a digital stream for 'C31 analysis. The 'C31 operates on this digital data and returns the "transformed" digital data to the AIC for conversion into an analog signal.

- **TMS320C31** — The main processor is a 32-bit, floating-point digital signal processor. You develop application code and load it to the on-chip memory of the 'C31. This code can be executed, single-stepped, and viewed in the debugger.
Voltage Regulators - The DSK uses a 7–12 Vdc or 6–9 Vac wall mount power supply. The 7–12 Vdc supply voltage is full-wave rectified and then regulated up to 5 volts by the LM7805. It is also converted to –5 volts by the capacitive switching circuit LT1054, and then regulated by the LM7905. The 6–9 Vac supply is full-wave rectified and then regulated by the LM7805 and LM7905 to +5V and −5V, respectively. The +5V and −5V supplies are used to power all of the DSK on-board circuitry. The TLC32040 AIC requires a negative poser supply of −5 volts.

XDS Emulator Port — An 11-pin header that connects the XDS510 emulator to the 'C31. The emulator allows you to upgrade to the full-featured XDS debugger to debug your application code while using the DSK as the XDS target board.

B.2 Schematics

The schematic diagrams included here show all of the internal and external connections in the DSK circuitry.
The power consumption of the TMS320C31 DSK was considerably lowered by the use of a CMOS TIBPAL22V10Z. When clocked at 25MHz (H1 rate) the TIBPAL22V10Z typically consumes 40mA (80mA max) as compared to 200mA for bipolar PAL devices. If lower consumption is needed the TMS320C31 can be programmed to use the LOPOWER or IDLE2 when full speed execution is not required. LOPOWER essentially runs the DSP at 1/16 of full speed and IDLE2 shuts the the clock completely off. This results in 1/16 and practically zero power for these modes respectively for both the PAL and the DSP. However due to the 25nS propogation delay through the TIBPAL22V10Z a wait state is required for host and peripheral decodes.

Memory access times for the /SRAM decoded output are as follows:

TIBPAL22V10Z (CMOS) at 50MHz, H1 = 40ns:

\[ t_{\text{access}} = H1 \times (1 + WS) - T_{\text{pal}} - (T_{d(H1-L-A)} - T_{s(D)R}) \]
\[ t_{\text{access}} = H1 \times (1 + WS) - 25\text{ns} - 19\text{ns} \]

wait states ==> 0 1 2 3 4 ...
t-access read ==> -4 36 76 116 156 ...

IDLE2 wakeup is initiated by asserting the INT2 pin low. Since the clock is stopped during IDLE2, gating with synchronized signals cannot be used. A buffer is used with INT2 to avoid differences in the logic thresholds of the PAL22V10 and the C31 and to improve the rise and fall time of that signal.

**TRI-COLOR LED (POWER AND PWM)**

If a logic high is applied to PWM (default state), the outputs /UBOOT and /USERX become an XOR and /XOR of T0 and T1. The XOR gate in this case is being used to detect the phase angle between T0 and T1. Therefore if T0 and T1 are configured as outputs, such as when the debugger is started, the color can be controled by adjusting the timers.

**USING THE PWM AS A DAC:**

If the output is filtered to a DC level by a low pass filter the DC level can be controlled by setting the two timers to identical frequencies seperated by a constant phase angle (delay). Since both the XOR and /XOR are provided a differential signal is also available.
If $T_0 = T_1$ the output is a DC level proportional to the phase difference.

If $T_0 = T_1$ the output is a DC level proportional to the phase difference.

 USING THE PWM AS A TRIANGLE WAVE GENERATOR

If $T_0$ and $T_1$ are set to different frequencies a PWM modulated triangle wave at a frequency of $F_{0,t0} - F_{1,t1}$ is produced. Since the two XOR outputs are compliments a bridged output is created. This then allows the current in the LED to reverse resulting in an alternating color sequence of R–Y–G–Y–R–Y–G–Y...

If $T_0 \neq T_1$ the output is a continuous triangle wave.

If an H bridge drive circuit is used with these signals an AC motor can be driven with a DSP controlled frequency. By using an external PAL to provide additional references signals and phase detectors a 3-phase PWM driver can be easily constructed. In this case the external PAL would contain a counter whose output is decoded to provide one of the reference frequencies in three phases separated by $2\pi/3$ radians. By then using one of the DSP timers for the other reference a variable frequency 3 phase output can be constructed.

NOTE: The amplitude of the PWM triangle wave cannot be controlled from the timers alone. Either the DSP would have to continuously calculate the outputs as a DC reference or an external circuit would have to chop the output.

<table>
<thead>
<tr>
<th>STRB</th>
<th>A23</th>
<th>H1</th>
<th>VCC</th>
<th>Q0</th>
<th>Q1</th>
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<td>A22</td>
<td>5</td>
<td>25</td>
<td>-UW</td>
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<td>A21</td>
<td>6</td>
<td>24</td>
<td>-UX</td>
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<td>A20</td>
<td>7</td>
<td>23</td>
<td>-SRAM</td>
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<td>8</td>
<td>22</td>
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<td>9</td>
<td>21</td>
<td>-RDY</td>
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<td>20</td>
<td>-INT2</td>
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<td>TCK0</td>
<td>11</td>
<td>19</td>
<td>-UBOOT</td>
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<tr>
<td>R/W</td>
<td>TRI</td>
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<td></td>
<td>GND</td>
<td>HPS</td>
<td>HPA</td>
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</tr>
</tbody>
</table>
Host Interface Control Design Notes

NC CLK STRB A23 A22 A21 A20 NC DEMO T1 T0 RW TRI GND
NC HPIS USERR HPIA UBOOT INT2 READY NC SRAM USERX USERW Q1 Q0 VCC
global
-- ----------------------------------------------------
EQUATIONS
; READY.TRST = TRI
; INT2.TRST = TRI
; INT2 = HPIS
; HPIA = /(A23 * A22 * A21 * /STRB) + /TRI ; 245 enable and HPIA
Q0 := INT2 ; 1st tap
Q1 := Q0 ; 2nd tap for pulse gen
READY = /(Q0*/Q1) * (A23*A22*A21*A20*/STRB) ;
;
; A23 A22 A21 A20 /STRB
;
; SRAM = (/A23*/A22 */STRB)
; USERR = (/A23* A22*/A21 */STRB* RW)
; USERW = (/A23* A22*/A21 */STRB* /RW)
; USERX = (/DEMO*/ /A23* A22*/A21 */STRB) + (DEMO* ((T0*/T1)+(/T0*T1)))
; UBOOT = (/DEMO*/ /A23*/A22*/A21*/A20*/STRB) + (DEMO*/((T0*/T1)+(/T0*T1)))
-- ----------------------------------------------------
; The decoded address ranges are as follows
; NOTE: By using A23 as an enable, it is possible to use external
; zero wait state RAM. Essentially by ignoring decoded outputs
-- ----------------------------------------------------
; USER_BOOT 000000 0FFFFFF EPROM boot or uP mode operation
; 100000 7FFFFFF No decode
; SRAM 0xB00000 0xBFFFFF lws decoded external memory
; USER_R 0xC00000 0xDFFFFF > Read access
; USER_W 0xC00000 0xDFFFFF > Write access
; USER_X 0xC00000 0xDFFFFF > Read or Write access
; HPI(asynch) 0xE00000 0xEFFFFF DSP access to bus w/o host lock
; HPI(host locked) 0xF00000 0xFFFFFF Must pulse HPIS to advance DSP state
;
SIMULATION
TRACE_ON CLK HPIS STRB HPIA READY INT2 T0 T1 DW USERX UBOOT SRAM USERR USERW
;
; Simulate access outside decoded range
()

Note:
The simulation vectors are omitted for clarity and brevity.
absolute address: An address that is permanently assigned to a memory location.

assembler: A software program that creates a machine-language program from a source file that contains assembly language instructions, directives, and macro directives. The assembler substitutes absolute operation codes for symbolic operation codes, and absolute or relocatable addresses for symbolic addresses.

assignment statement: A statement that assigns a value to a variable.

autoexec.bat: A batch file that contains DOS commands for initializing your PC.

batch file: A file that contains DOS commands for the PC to execute.

block: A set of declarations and statements that are grouped together with braces.

breakpoint: A point within your program where execution because of a previous request from you.

byte: A sequence of eight adjacent bits operated upon as a unit.
**Glossary**

**C**

**code-display windows:** Windows that show code, text files, or code-specific information.

**command line:** The portion of the COMMAND window where you can enter commands.

**command-line cursor:** A block-shaped cursor that identifies the current character position on the command line.

**comment:** A source statement (or portion of a source statement) that is used to document or improve readability of a source file. Comments are not assembled.

**common object file format (COFF):** An object file that promotes modular programming by supporting the concept of sections.

**constant:** A numeric value that can be used as an operand.

**cursor:** An icon on the screen (such as a rectangle or a horizontal line) that is used as a pointing device. The cursor is usually under keyboard control.

**D**

**debugger:** A windows-oriented software interface that helps you to debug DSK programs running on a DSK board.

**directive:** Special-purpose commands that control the actions and functions of a software tool like an assembler (as opposed to assembly language instructions, which control the actions of a device).

**disassembly:** Assembly language code formed from the reverse-assembly of the contents of memory.

**DSP:** Digital signal processing.

entry point: The starting execution point in target memory.

expression: A constant, a symbol, or a series of constants and symbols separated by arithmetic operators.

external symbol: A symbol that is used in the current program module but defined in a different program module.

file header: A portion of a COFF object file that contains general information about the object file (such as the number of section headers, the type of system the object file can be downloaded to, the number of symbols in the symbol table, and the symbol table's starting address).

global: A kind of symbol that is either: 1) defined in the current module and accessed in another or 2) accessed in the current module but defined in another.

input section: A section from an object file that will be linked into an executable module.

label: A symbol that begins in column 1 of a source statement and corresponds to the address of that statement.

listing file: An output file created by the assembler that lists source statements, their line numbers, and any unresolved symbols or opcodes.

LSB: Least significant bit.

LSByte: Least significant byte.
member:  An element or variable of a structure, union, or enumeration.

memory map:  A map of target system memory space that is partitioned into functional blocks.

mnemonic:  An instruction name that the assembler translates into machine code.

MSB:  Most significant bit.

MSByte:  Most significant byte.

named section:  1) An initialized section that is defined with a .sect directive, or 2) an uninitialized section that is defined with a .usect directive.

object file:  A file that has been assembled and contains machine-language object code.

operand:  The arguments or parameters of an assembly language instruction, assembler directive, or macro directive.

options:  Command parameters that allow you to request additional or specific functions when you invoke a software tool.

PC:  Personal computer or program counter, depending on the context and how it’s used. In this book, installation instructions or in information relating to hardware and boards, PC means Personal Computer (as in IBM PC). In general debugger and program-related information, PC means Program Counter, which is the register that identifies the current statement in your program.

parallel port:  The parallel printer port interface is primarily used for connecting printers to the computer system, although the parallel port can also be used for other peripherals. In this case, the 'C3x DSK is connected to the parallel printer port.
**raw data:** Executable code or initialized data in an output section.

**section:** A relocatable block of code or data that ultimately occupies contiguous space in the memory map.

**serial port:** The serial port that the DSK uses for communicating with the analog interface circuit (AIC). The port address is selected, based on which communication port the AIC is attached to.

**single-step:** A form of program execution that allows you to see the effects of each statement. The program is executed statement by statement; the debugger pauses after each statement to update the data-display windows.

**source file:** A file that contains C code or assembly language code that will be assembled to form a temporary object file.

**symbol:** A string of alphanumeric characters that represents an address or a value.

**VGA:** Video Graphics Array. An industry standard for video cards.

**window:** A defined rectangular area of virtual space on the display.

**word:** A 32-bit addressable location in target memory.
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