

F2802x Firmware Development Package

USER'S GUIDE



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Table of Contents

Copyright	2
Revision Information	2
1 Introduction	5
2 Driver Library and Header File Quickstart	7
2.1 Device Support	7
2.2 Introduction	7
2.3 Understanding The Peripheral Bit-Field Structure Approach	10
2.4 Peripheral Example Projects	10
2.5 Steps for Incorporating the Driver Library and/or Header Files	20
2.6 Troubleshooting Tips and Frequently Asked Questions	25
2.7 F2802x bit field headers API to F2802x driver library API code suggestions	28
2.8 Packet Contents	30
2.9 Detailed Revision History	36
3 Piccolo F2802x Example Applications	41
3.1 ADC Start-Of-Conversion (SOC)	42
3.2 ADC Temperature Sensor	42
3.3 ADC Temperature Sensor Conversion	42
3.4 LaunchPad Demo	42
3.5 CPU Timer	43
3.6 ECAP Asymmetric PWM	43
3.7 ECAP Capture EPwm3	43
3.8 PWM Blanking Window	43
3.9 PWM Digital Compare Event Trip Zone	44
3.10 PWM Trip Zone Test with Comparator Inputs	45
3.11 PWM deadband generation	45
3.12 PWM Timer Interrupt	46
3.13 PWM Trip Zone	46
3.14 Action Qualifier Module Upcount mode	47
3.15 Action Qualifier Module - Using up/down count	47
3.16 External Interrupts	48
3.17 EPwm interrupt from Flash	48
3.18 GPIO Setup	49
3.19 GPIO Toggle	49
3.20 High Resolution PWM	50
3.21 High Resolution PWM SFO Duty Cycle Control	50
3.22 High Resolution PWM SFO Period Control	51
3.23 High Resolution PWM SFO Period (Up Count) Control	52
3.24 High Resolution PWM SFO Period (Up-Down Count) Control	53
3.25 High Resolution PWM Slider	54
3.26 LED BoosterPack Capacitive Touch Demo	55
3.27 LED BoosterPack PC GUI Demo	55
3.28 Device Halt Mode and Wakeup	55
3.29 Device Idle Mode and Wakeup	56
3.30 Standby Mode and Wakeup	56
3.31 Internal Oscillator Compensation	56
3.32 SCI Echoback	57
3.33 SCI FIFO Digital Loop Back	57
3.34 SCI Digital Loop Back with Interrupts	57

3.35	SPI Digital Loop Back	58
3.36	SPI Digital Loop Back with Interrupts	58
3.37	Software Prioritized Interrupts	59
3.38	LED Blink	59
3.39	Watchdog Interrupt	60
A	Interrupt Service Routine Priorities	61
A.1	Interrupt Hardware Priority Overview	61
A.2	F2802x Interrupt Priorities	62
A.3	Software Prioritization of Interrupts - The DSP28 Example	63
B	Internal Oscillator Compensation Functions	67
B.1	Introduction	67
B.2	Oscillator Compensation Functions Available in the Header Files and Peripheral Examples Package	69
	IMPORTANT NOTICE	72

1 Introduction

The Texas Instruments® F2802x Firmware Development Package is a collection of device header files, common source files, helper libraries and example applications for the 2802x line of devices in the Piccolo portfolio.

The package comes with a complete set of example projects that demonstrate the basics of getting started with a Piccolo device and working with its different peripheral modules.

Chapter 2 talks about how the software package is structured, how the header files are organized and used in the example applications. The peripheral bit-field structure approach is presented in detail along with step-by-step instructions on how to use it in your code. A complete revision history of the header files is provided at the end of the chapter.

Chapter 3 covers all the examples provided in the development package; what each example does, its setup and observation procedures and, in a few cases, the mathematics involved in setting up control values for peripherals.

The examples for Piccolo(2802x) can be found in the *F2802x\examples* directory. As users move past evaluation, and get started developing their own application, TI recommends they maintain a similar project directory structure to that used in the example projects.

The Appendix covers the following topics

1. **Appendix A** - describes the default hardware prioritizing of Interrupt Software Routines and how it can be over-ridden in software.
2. **Appendix B** - Each factory programmed device from TI has compensation routines in OTP memory for oscillator drift due to temperature fluctuations. These routines are described here.

2 Driver Library and Header File Quickstart

Device Support	7
Introduction	7
Understanding The Peripheral Bit-Field Structure Approach	10
Example Projects	10
Steps for Incorporating the Header Files and Sample Code	20
Troubleshooting Tips & Frequently Asked Questions	25
F2802x bit field headers API to F2802x driver library API code suggestions	28
Packet Contents	30
Detailed Revision History	36

2.1 Device Support

This software package supports 2802x devices. This includes the following: TMS320F28022, TMS320F28023, TMS320F28026, and TMS320F28027. Throughout this document, TMS320F28022, TMS320F28023, TMS320F28026, and TMS320F28027 are abbreviated as F28022, F28023, F28026, and F28027 respectively.

2.2 Introduction

The 2802x C/C++ peripheral header files, driver library, and example projects facilitate writing in C/C++ Code for the Texas Instruments TMS320x2802x devices. The code can be used as a learning tool or as the basis for a development platform depending on the current needs of the user.

1. Learning Tool

This download includes several example Code Composer StudioTM v 6.0+ ¹ projects for a 2802x development platform.

These examples demonstrate the steps required to initialize the device and utilize the on-chip peripherals. The provided examples can be copied and modified giving the user a platform to quickly experiment with different peripheral configurations.

These projects can also be migrated to other devices by simply changing the memory allocation in the linker command file.

2. Development Platform

The peripheral header files can easily be incorporated into a new or existing project to provide a platform for accessing the on-chip peripherals using C or C++ code. In addition, the user can pick and choose functions from the provided code samples as needed and discard the rest.

To get started this document provides the following information:

1. Overview of the bit-field structure approach used in the 2802x C/C++ peripheral header files.
2. Overview of the included peripheral example projects.
3. Steps for integrating the peripheral header files into a new or existing project.

¹Code Composer Studio is a trademark of Texas Instruments (www.ti.com).

4. Troubleshooting tips and frequently asked questions.
5. Migration tips for users moving from the 2802x header files to the 2802x header files.

Finally, this document does not provide a tutorial on writing C code, using Code Composer Studio, or the C28x Compiler and Assembler. It is assumed that the reader already has a 2802x hardware platform setup and connected to a host with Code Composer Studio installed. The user should have a basic understanding of how to use Code Composer Studio to download code through JTAG and perform basic debug operations.

2.2.1 Revision History(Summary)

1. **Version 3.02.00.00**

- This version contains header, source, and example file bug fixes.

2. **Version 3.01.00.00**

- This version adds LaunchPad examples.

3. **Version 3.00.00.00**

- This version contains header, source, and example file updates and bug fixes for C2000Ware Package. Some files have been relocated in this revision.

4. **Version 2.30**

- This version contains header, source, and example file bug fixes. Some files have been relocated in this revision.

5. **Version 2.22**

- This version contains header files and source file bug fixes. Also, cleans up CCS example warnings.

6. **Version 2.21**

- This version added a F28027 Flash Kernel Example.

7. **Version 2.20**

- This version contains header files, source files, and examples bug fixes and minor enhancements.

8. **Version 2.10**

- This version of the 2802x header files and examples contains bug fixes and minor enhancements.

2.2.2 Directory Structure

As installed, the 2802x C/C++ Header Files and Peripheral Examples is partitioned into a well-defined directory structure(see figure 2.1).

Table 2.1 describes the contents of the main directories used by 2802x header files and peripheral examples:

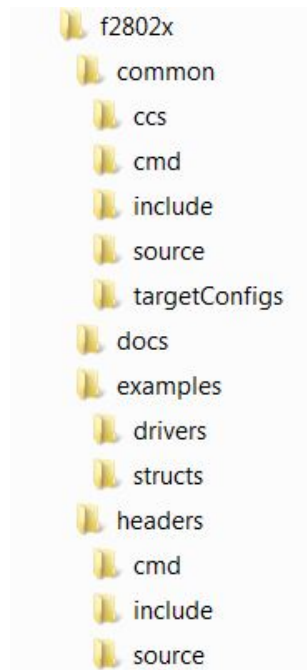


Figure 2.1: F2802x Main Directory Structure

Directory	Description
<base>	Base install directory
<base>docs	Documentation including the revision history from the previous release.
<base>headers	Files required to incorporate the peripheral header files into a project. The header files use the bit-field structure approach described in Section 2.3. Integrating the header files into a new or existing project is described in Section 2.5.
<base>examples\drivers	Example Code Composer Studio v6 projects. These example projects illustrate how to configure many of the on-chip peripherals using the driver libraries. An overview of the examples is given in Section 2.4.
<base>examples\structs	Example Code Composer Studio v6 projects. These example projects illustrate how to configure many of the on-chip peripherals using the bit structured headers. An overview of the examples is given in Section 2.4.
<base>common	Drivers and common source files shared across example projects to illustrate how to perform tasks using header file approach. Use of these files is optional, but may be useful in new projects. A list of these files is in Section 2.8.

Table 2.1: DSP2802x Main Directory Structure

Under the F2802x\headers and F2802x\common directories the source files are further broken down into sub-directories each indicating the type of file. Table 2.2 lists the sub-directories and describes the types of files found within each:

Sub-Directory	Description
headers\cmd	Linker command files that allocate the bit-field structures described in Section 2.3.
headers\source	Source files required to incorporate the header files into a new or existing project.
headers\include	Header files for each of the on-chip peripherals.
common\ccs	Driver library (.lib) and project files for the driver library that is used by the peripheral examples.
common\cmd	Example memory command files that allocate memory on the devices.
common\include	Driver and common .h files that are used by the peripheral examples.
common\source	Driver and common .c files that are used by the peripheral examples.
common\targetConfigs	Target Configuration file for this device.

Table 2.2: F2802x Sub-Directory Structure

2.3 Understanding The Peripheral Bit-Field Structure Approach

The following application note includes useful information regarding the bit-field peripheral structure approach used by the header files and examples. This method is compared to traditional #define macros and topics of code efficiency and special case registers are also addressed. The information in this application note is important to understand the impact using bit fields can have on your application code.

Programming TMS320x28xx and 28xxx Peripherals in C/C++ (SPRAA85)

2.4 Peripheral Example Projects

This section describes how to get started with and configure the peripheral examples included in the 2802x Driver Library, Header Files, and Peripheral Examples software package.

2.4.1 Getting Started in Code Composer Studio v6.0+

To get started, follow these steps to load the 32-bit CPU-Timer example. Other examples are set-up in a similar manner.

1. **Have a hardware platform connected to a host with Code Composer Studio installed**

NOTE: As supplied, the 2802x example projects are built for the 28027 device. If you are using another 2802x device, the memory definition in the linker command file (.cmd) will need to be changed and the project rebuilt.

2. **Open the example project** Each example has its own project directory which is “imported”/opened in Code Composer Studio v6. To open the 2802x CPU-Timer example project directory, follow the following steps:

- In Code Composer Studio v 6.x: Project->Import Existing CCS/CCE Eclipse Project.
- Next to "Select Root Directory", browse to the CPU Timer example directory: i.e. f2802x\examples\structs\cpu_timer. Remember to unselect the "Copy projects into workspace" box. Select the Finish button. This will import/open the project in the CCStudio v6 C/C++ Perspective project window.

3. **Edit F2802x_Device.h** Edit the F2802x_Device.h file and make sure the appropriate device is selected. By default the 28027 is selected.

```
//
// F2802x_Device.h
//

//
// Defines
//
#define    TARGET    1

//
// User To Select Target Device:
//
#define    DSP28_28022PT    0
#define    DSP28_28022DA    0

#define    DSP28_28023PT    0
#define    DSP28_28023DA    0

#define    DSP28_28026PT    0
#define    DSP28_28026DA    0

#define    DSP28_28027PT    TARGET
#define    DSP28_28027DA    0
```

4. **Edit F2802x_Examples.h** Edit F2802x_Examples.h and specify the clock rate, the PLL control register value (PLLCR and DIVSEL). These values will be used by the examples to initialize the PLLCR register and DIVSEL bits.

The default values will result in a 50MHz SYSCLKOUT frequency.

```
//
// common\include\F2802x_Examples.h
//

//
// Specify the PLL control register (PLLCR) and divide
// select (DIVSEL) value.
//

// #define DSP28_DIVSEL    0 // Enable /4 for SYSCLKOUT
// #define DSP28_DIVSEL    1 // Disable /4 for SYSCLKOUT
#define DSP28_DIVSEL    2 // Enable /2 for SYSCLKOUT
// #define DSP28_DIVSEL    3 // Enable /1 for SYSCLKOUT

//
// Uncomment for 50 Mhz devices [50 Mhz = (10MHz * 10)/2]
```

```
//
#define DSP28_PLLCR    10

// #define DSP28_PLLCR    9

//
// Uncomment for 40 MHz devices [40 MHz = (10MHz * 8)/2]
//
// #define DSP28_PLLCR    8
// #define DSP28_PLLCR    7
// #define DSP28_PLLCR    6
// #define DSP28_PLLCR    5
// #define DSP28_PLLCR    4
// #define DSP28_PLLCR    3
// #define DSP28_PLLCR    2
// #define DSP28_PLLCR    1
// #define DSP28_PLLCR    0           // PLL is bypassed in this mode
//
```

In F2802x_Examples.h, also specify the SYSCLKOUT rate. This value is used to scale a delay loop used by the examples. The default value is for a 50 MHz SYSCLKOUT.

```
//
// common\include\F2802x_Examples.h
//
...
#define CPU_RATE    12.500L    // for a 80MHz CPU clock speed (SYSCLKOUT)
// #define CPU_RATE    16.667L    // for a 60MHz CPU clock speed (SYSCLKOUT)
// #define CPU_RATE    20.000L    // for a 50MHz CPU clock speed (SYSCLKOUT)
// #define CPU_RATE    25.000L    // for a 40MHz CPU clock speed (SYSCLKOUT)
...
```

5. **Review the comments at the top of the main source file: Example_2802xCpuTimer.c** A brief description of the example and any assumptions that are made and any external hardware requirements are listed in the comments at the top of the main source file of each example. In some cases you may be required to make external connections for the example to work properly.

6. **Perform any hardware setup required by the example** Perform any hardware setup indicated by the comments in the main source. The CPU-Timer example only requires that the hardware be setup for “Boot to SARAM” mode. Other examples may require additional hardware configuration such as connecting pins together or pulling a pin high or low. Table 2.3 shows a listing of the boot mode pin settings for your reference. Table 2.4 and Table 2.5 list the EMU boot modes (when emulator is connected) and the Get Mode boot mode options (mode is programmed into OTP) respectively. Refer to the documentation for your hardware platform for information on configuring the boot mode pins. For more information on the 2802x boot modes refer to the device specific *Boot ROM* chapter in the *Technical Reference Manual*.
When the emulator is connected for debugging: TRSTn = 1, and therefore the device is in EMU boot mode. In this situation, the user must write the key value of 0x55AA to EMU_KEY at address 0x0D00 and desired EMU boot mode value to EMU_BMODE at 0x0D01 via the debugger window according to Table 2.4.

When the emulator is not connected for debugging: SCI or Parallel I/O boot mode can be selected directly via the GPIO pins, or OTP_KEY at address 0x3D7BFB and OTP_BMODE at address 0x3D7BFE can be programmed for the desired boot mode per Table 2.5.

GPIO37 TDO	GPIO34 CMP2OUT	TRSTn	Mode
X	X	1	EMU Mode
0	0	0	Parallel I/O
0	1	0	SCI
1	0	0	Wait
1	1	0	"Get Mode"

Table 2.3: 2802x Boot Mode Settings

EMU_KEY 0x0D00	EMU_BMODE 0x0D01	Boot Mode Selected
!= 0x55AA	x	Wait
0x55AA	0x0000	Parallel I/O
	0x0001	SCI
	0x0002	Wait
	0x0003	Get Mode
	0x0004	SPI
	0x0005	I2C
	0x0006	OTP
	0x000A	Boot to RAM
	0x000B	Boot to FLASH
	Other	Wait

Table 2.4: 2802x EMU Boot Modes (Emulator Connected)

7. Build and Load the code

Once any hardware configuration has been completed, in Code Composer Studio v6, go to *Target->Debug Active Project*.

This will open the "Debug Perspective" in CCSv6, build the project, load the .out file into the 28x device, reset the part, and execute code to the start of the main function. By default, in Code Composer Studio v6, every time Debug Active Project is selected, the code is automatically built and the .out file loaded into the 28x device.

8. Run the example, add variables to the watch window or examine the memory contents

At the top of the code in the comments section, there should be a list of "Watch variables". To add these to the watch window, highlight them and right-click. Then select *Add Watch expression*. Now variables of interest are added to the watch window.

9. Experiment, modify, re-build the example

If you wish to modify the examples it is suggested that you make a copy of the entire header file packet to modify or at least create a backup of the original files first. New examples provided by TI will assume that the base files are as supplied.

Sections 2.4.2 and 2.4.3 describe the structure and flow of the examples in more detail.

10. When done, delete the project from the Code Composer Studio v6 workspace

Go to *View->C/C++ Projects* to open up your project view. To remove/delete the project from the workspace, right click on the project's name and select delete. Make sure the *Do not delete* contents button is selected, then select Yes. This does not delete the project itself. It merely removes the project from the workspace until you wish to open/import it again.

The examples use the header files in the F2802x\headers directory and shared source in the F2802x\common directory. Only example files specific to a particular example are located within the example directory.

OTP_KEY 0x3D7BFB	OTP_BMODE 0x3D7BFE	Boot Mode Selected
!= 0x55AA	x	Get Mode - Flash
0x55AA	0x0001	Get Mode - SCI
	0x000B	Get Mode - Flash
	0x0004	Get Mode - SPI
	0x0005	Get Mode - I2C
	0x0006	Get Mode - OTP
	Other	Get Mode - Flash

Table 2.5: 2802x GET Boot Modes (Emulator Disconnected)

NOTE: Most of the example code included uses the driver library, but shows the equivalent bit field approach in the comments. This is done to help the user learn how to use the peripheral and device. In addition, the example projects have the compiler optimizer turned off to aid in debugging. The user can change the compiler settings to turn on the optimizer if desired.

2.4.2 Example Program Structure

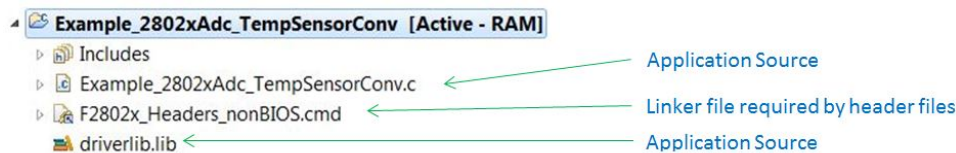


Figure 2.2: Example Program Structure

Each of the example programs has a very similar structure. This structure includes unique source code, shared driver library, and linker command files.

```
//
// examples\cpu_timer\Example_2802xCpuTimer.c
//
#include "DSP28x_Project.h" // Device Headerfile and Examples Include File
```

■ DSP28x_Project.h

This header file includes F2802x_Device.h and F2802x_Examples.h. Because the name is device-generic, example/custom projects can be easily ported between different device header files. This file is found in the <base>common\include directory.

■ F2802x_Device.h

This header file is required to use the header files. This file includes all of the required peripheral specific header files and includes device specific macros and typedef statements. This file can also be used to include all of the driver library header files by simply defining INCLUDE_ALL before this file is included (or in the case that DSP28x_Project.h is used, before that file is included). This file is found in the <base>headers\include directory.

■ F2802x_Examples.h

This header file defines parameters that are used by the example code. This file is not required to use just the F2802x peripheral header files but is required by some of the common source files. This file is found in the <base>common\include directory.

2.4.2.1 Source Code

Each of the example projects consists of source code that is unique to the example as well as source code that is common or shared across examples.

■ F2802x_GlobalVariableDefs.c

Any project that uses the F2802x peripheral header files must include this source file IF THEY ARE NOT USING THE DRIVER LIBRARY. In this file are the declarations for the peripheral register structure variables and data section assignments. This file is found in the <base>headers\source directory.

■ Example specific source code

Files that are specific to a particular example have the prefix Example_2802x in their filename. For example Example_2802xCpuTimer.c is specific to the CPU Timer example and not used for any other example. Example specific files are located in the <base>\examples\<example> directory.

■ driverlib.lib

This file contains the objects for all of the driver library functions. This file must be linked into the project if the project uses the driver library.

2.4.2.2 Linker Command Files

Each example uses two linker command files. These files specify the memory where the linker will place code and data sections. One linker file is used for assigning compiler generated sections to the memory blocks on the device while the other is used to assign the data sections of the peripheral register structures used by the F2802x peripheral header files.

■ Memory block linker allocation

The linker files shown in Table 2.6 are used to assign sections to memory blocks on the device. These linker files are located in the <base>\common\cmd directory. Each example will use one of the following files depending on the memory used by the example.

Memory Linker Command File Examples	Location	Description
28022_RAM_Ink.cmd	F2802x\common\cmd	28022 SARAM memory linker command file.
28023_RAM_Ink.cmd	F2802x\common\cmd	28023 SARAM memory linker command file.
28026_RAM_Ink.cmd	F2802x\common\cmd	28026 SARAM memory linker command file.
28027_RAM_Ink.cmd	F2802x\common\cmd	28027 SARAM memory linker command file.
F2802x_generic_ram.cmd	F2802x\common\cmd	Generic SARAM memory linker command file.
F28022.cmd	F2802x\common\cmd	F28022 memory linker command file. Includes all Flash, OTP and CSM password protected memory locations.
F28023.cmd	F2802x\common\cmd	F28023 memory linker command file.
F28026.cmd	F2802x\common\cmd	F28026 memory linker command file.
F28027.cmd	F2802x\common\cmd	F28027 memory linker command file.
F2802x_generic_flash.cmd	F2802x\common\cmd	Generic flash memory linker command file.

Table 2.6: Included Memory Linker Command Files

■ Header file structure data section allocation

Any project that uses the header file peripheral structures must include a linker command file that assigns the peripheral register structure data sections to the proper memory location. These files are described in Table 2.7.

Header File Linker Command File	Location	Description
F2802x_Headers_BIOS.cmd	F2802x\headers\cmd	Linker .cmd file to assign the header file variables in a BIOS project. This file must be included in any BIOS project that uses the header files. Refer to section 2.5.2.
F2802x_Headers_nonBIOS.cmd	F2802x\headers\cmd	Linker .cmd file to assign the header file variables in a non-BIOS project. This file must be included in any non-BIOS project that uses the header files. Refer to section 2.5.2.

Table 2.7: F2802x Peripheral Header Linker Command File

2.4.3 Example Program Flow

All of the example programs follow a similar recommended flow for setting up a 2802x device.



Figure 2.3: Flow for Example Programs

2.4.4 Included Examples

See Chapter 3 for a complete listing and description of available examples

2.4.5 Executing the Examples From Flash

Most of the F2802x examples execute from SARAM in “boot to SARAM” mode. One example, F2802x\examples\flash_f28027, executes from flash memory in “boot to flash” mode. This example is the PWM timer interrupt example with the following changes made to execute out of flash:

1. **Change the linker command file to link the code to flash**

Remove 28027_RAM_Ink.cmd from the project and link one of the flash based linker files (ex: F28027.cmd). These files are located in the <base>\common\cmd directory.

2. **Link the F2802x\common\source\F2802x_CSMPasswords.asm to the project**

This file contains the passwords that will be programmed into the Code Security Module (CSM) password locations. Leaving the passwords set to 0xFFFF during development is recommended as the device can easily be unlocked. For more information on the CSM refer to the appropriate *System Control and Interrupts* chapter of the *Technical Reference Manual*.

3. **Modify the source code to copy all functions that must be executed out of SARAM from their load address in flash to their run address in SARAM**

In particular, the flash wait state initialization routine must be executed out of SARAM. In the F2802x, functions that are to be executed from SARAM have been assigned to the ramfuncs section by compiler CODE_SECTION #pragma statements as shown in the example below.

```
//  
// common\source\F2802x_SysCtrl.c  
//  
#pragma CODE_SECTION(InitFlash, "ramfuncs");
```

The ramfuncs section is then assigned to a load address in flash and a run address in SARAM by the memory linker command file as shown below:

```
//  
// common\include\F28027.cmd  
//  
SECTIONS  
{  
    ramfuncs      : LOAD = FLASHA,  
                   RUN  = RAML0,  
                   LOAD_START(_RamfuncsLoadStart),  
                   LOAD_END(_RamfuncsLoadEnd),  
                   RUN_START(_RamfuncsRunStart),  
                   LOAD_SIZE(_RamfuncsLoadSize),  
                   PAGE = 0  
}
```

The linker will create symbols for the block “ramfuncs”. These are described in the Table [2.8](#).

Address	Symbol
Load start address	RamfuncsLoadStart
Load end address	RamfuncsLoadEnd
Run start address	RamfuncsRunStart
Load Size	RamfuncsLoadSize

Table 2.8: Linker Symbol assignment

These symbols can then be used to copy the functions from the Flash to SARAM using the C library standard `memcpy()` function.

To perform this copy from flash to SARAM using the included example `memcpy` function:

- (a) Include **string.h** at the top of the file.

NOTE: IF RUNNING FROM FLASH, PLEASE COPY OVER THE SECTION “ramfuncs” FROM FLASH TO RAM PRIOR TO CALLING `InitSysCtrl()` or `InitAdc()`. THIS PREVENTS THE MCU FROM THROWING AN EXCEPTION WHEN A CALL TO `DELAY_US()` IS MADE.

- (b) Add the following variable declaration to your source code to tell the compiler that these variables exist. The linker command file will assign the address of each of these variables as specified in the linker command file as shown in step 3. For the F2802x example code this has already been done in `F2802x_GlobalPrototypes.h`.

```
//
// common\include\F2802x_GlobalPrototypes.h
//
extern Uint16 RamfuncsLoadStart;
extern Uint16 RamfuncsLoadEnd;
extern Uint16 RamfuncsRunStart;
extern Uint16 RamfuncsLoadSize;
```

- (c) Modify the code to call the example `memcpy` function for each section that needs to be copied from flash to SARAM.

```
//
// examples\Flash source file
//
memcpy(&RamfuncsRunStart, &RamfuncsLoadStart, (Uint32)&RamfuncsLoadSize);
```

4. Modify the code to call the flash initialization routine

This function will initialize the wait states for the flash and enable the Flash Pipeline mode.

```
//
// F2802x peripheral example .c file
//
InitFlash();
```

5. **Set the required jumpers for “boot to Flash” mode** The required jumper settings for each boot mode are shown in Table 2.3, Table 2.4, and Table 2.5.

6. Program the device with the built code

In Code Composer Studio v6, when code is loaded into the device during debug, it automatically programs to flash memory.

This can also be done using SDFlash available from Spectrum Digital’s website ([Spectrum Digital](#)).

These tools will be updated to support new devices as they become available. Please check for updates.

2.5 Steps for Incorporating the Driver Library and/or Header Files

Follow these steps to incorporate the driver library into your own projects.

2.5.1 Before you begin

Before you include the driver library or header files into your own project, it is recommended that you perform the following:

1. **Load and step through an example project**

Load and step through an example project to get familiar with the driver library. This is described in Section [2.4](#).

2. **Create a copy of the example files you want to use**

F2802x\examples: 2802x fixed-point compiled example projects that use the driver files. Create a copy of any of the example directories in this folder and work on the copied folder to ensure the original is still there for reference purposes.

2.5.2 Including the F2802x Driver Library and Header Files

Including the F2802x driver library in your project will allow you to use the drivers for every peripheral on the device, substantially decreasing the learning curve of this device. This guide also shows how to include the header files in a project, but their use is discouraged in end application software.

To incorporate the drivers and or headers in a new or existing project perform the following steps:

1. **Include the necessary driver header files**

The F2802x_Device.h include file by default only includes the necessary files to make use of the peripheral bitfield structures. Include statements for all the driver header files may be conditionally compiled in by defining the variable INCLUDE_ALL.

```
//
// User's source file
//
#ifndef INCLUDE_ALL
#define INCLUDE_ALL
#endif

#include "F2802x_Device.h"
```

Another option is to #include "DSP28x_Project.h" in your source files, which in-turn includes "F2802x_Device.h" and "F2802x_Examples.h". Keep in mind that INCLUDE_ALL must still be defined in order for F2802x_Device.h to bring in the driver headers. Due to the device-generic nature of the file name, user code is easily ported between different device header files.

```
//
// User's source file
//
```

```
#ifndef INCLUDE_ALL
#define INCLUDE_ALL
#endif

#include "DSP28x_Project.h"
```

Finally if the user doesn't wish to include all of the driver headers in a particular source file they may include each needed file individually.

```
//
// User's source file
//
#include "common/include/adc.h"
#include "common/include/cpu.h"
#include "common/include/clk.h"
```

2. Edit F2802x_Device.h and select the target you are building for

In the below example, the file is configured to build for the 28027 device.

```
//
// headers\include\F2802x_Device.h
//
#define    TARGET    1

//
// User To Select Target Device:
//
#define    DSP28_28022PT    0
#define    DSP28_28022DA    0

#define    DSP28_28023PT    0
#define    DSP28_28023DA    0

#define    DSP28_28026PT    0
#define    DSP28_28026DA    0

#define    DSP28_28027PT    TARGET
#define    DSP28_28027DA    0
```

By default, the 28027 device is selected.

3. If you are not using the driver library, add the source file F2802x_GlobalVariableDefs.c to the project. If you are using the driver library, the driver library includes the objects from this source file.

This file is found in the f2802x\headers\source directory and includes:

- Declarations for the variables that are used to access the peripheral registers.
- Data section #pragma assignments that are used by the linker to place the variables in the proper locations in memory.

4. Add the appropriate F2802x header linker command file to the project.

As described in Section 2.4, when using the F2802x header file approach, the data sections of the peripheral register structures are assigned to the memory locations of the peripheral registers by the linker.

To perform this memory allocation in your project, one of the following linker command files located in f2802x\headers\cmd must be included in your project:

- For non-DSP/BIOS² projects: *F2802x_Headers_nonBIOS.cmd*
- For DSP/BIOS projects: *F2802x_Headers_BIOS.cmd*

The method for adding the header linker file to the project depends on preference

Method #1:

- Right-click on the project in the project window of the C/C++ Projects perspective.
- Select Link Files to Project...
- Navigate to the f2802x\headers\cmd directory on your system and select the desired .cmd file.

Note: The limitation with Method #1 is that the path to <install directory>\headers\cmd\<cmd file>.cmd is fixed on your PC. If you move the installation directory to another location on your PC, the project will “break” because it still expects the .cmd file to be in the original location. Use Method #2 if you are using “linked variables” in your project to ensure your project/installation directory is portable across computers and different locations on the same PC. For more information, see: [Portable_Projects_in_CCSv6_for_C2000](#)

Method #2:

- Right-click on the project in the project window of the C/C++ Projects perspective.
- Select New->File.
- Click on the Advanced» button to expand the window.
- Check the Link to file in the file system check-box.
- Select the Variables... button. From the list, pick the linked variable associated with your installation directory. (e.g. INSTALLROOT_2802X). For more information on linked variables and the macros.ini file, see: [Portable_Projects_in_CCSv6_for_C2000](#)
- Click on the Extend... button. Navigate to the desired .cmd file and select OK.

5. **If you intend to use the driver library, add the library file to your project.** If you would like to use the driver library you will need to add it to the project in much the same way as you added a linker file in the previous step. The library file can be found in f2802x/common/ccs/Debug and is called driverlib.lib. **Note: Debug and Release configurations of the driver library are available in its associated CCS project (found in f2802x/common/ccs), but the two build configurations output their library file to the same location. By default C2000Ware includes the debug configuration, but if the library is rebuilt all of the example projects will use the driver library build configuration that was last built.**

6. **Add the directory path to the F2802x device support files to your project**
Code Composer Studio 6.x:

To specify the directory where the header files are located:

- Open the menu: Project->Properties.
- In the menu on the left, select “C/C++ Build”.
- In the “Tool Settings” tab, Select “C2000 Compiler -> Include Options:”
- In the “Add dir to #include search path (-include_path, -I)” window, select the “Add” icon in the top right corner.

²DSP/BIOS is a trademark of Texas Instruments

- Select the “File system...” button and navigate to the directory path of C2000Ware_version\device_support\f2802x\ on your system.

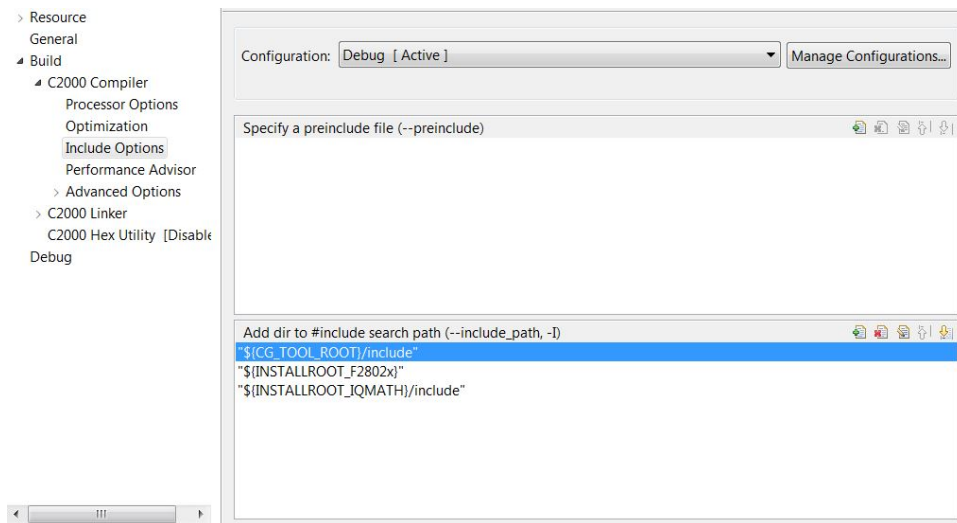


Figure 2.4: Adding device header file directories to the include search path

7. **Additional suggested build options** The following are additional compiler and linker options. The options can all be set via the Project-> Properties-> Tool Settings sub-menus.

■ C2000 Compiler

- **-ml Select Runtime Model Options and check -ml** Build for large memory model. This setting allows data sections to reside anywhere within the 4M-memory reach of the 28x devices.
- **-pdr Select Diagnostic Options and check -pdr** Issue non-serious warnings. The compiler uses a warning to indicate code that is valid but questionable. In many cases, these warnings issued by enabling -pdr can alert you to code that may cause problems later on.

■ C2000 Linker

- **-w Select Diagnostics and check -w** Warn about output sections. This option will alert you if any unassigned memory sections exist in your code. By default the linker will attempt to place any unassigned code or data section to an available memory location without alerting the user. This can cause problems, however, when the section is placed in an unexpected location.
- **-e Select Symbol Management and enter Program Entry Point -e** Defines a global symbol that specifies the primary entry point for the output module. For the F2802x examples, this is the symbol “code_start”. This symbol is defined in the f2802x\common\source\F2802x_CodeStartBranch.asm file. When you load the code in Code Composer Studio, the debugger will set the PC to the address of this symbol. If you do not define an entry point using the -e option, then the linker will use _c_int00 by default.

2.5.3 Including Common Example Code

Note: This section describes files which are no longer being maintained. We suggest you use the true driver library instead of these older sample source files.

Including the common source code in your project will allow you to leverage code that is already written for the device. To incorporate the shared source code into a new or existing project, perform the following steps:

1. #include “common\include\F2802x_Examples.h” (or “DSP28x_Project.h”) in your source files.

The “F2802x_Examples.h” include file will include common definitions and declarations used by the example code.

```
//  
// User's source file  
//  
#include "common\include\F2802x_Examples.h"
```

Another option is to #include “DSP28x_Project.h” in your source files, which in-turn includes “F2802x_Device.h” and “F2802x_Examples.h”. Due to the device-agnostic nature of the file name, user code is easily ported between different device header files.

```
//  
// User's source file  
//  
#include "DSP28x_Project.h"
```

2. Link a linker command file to your project.

The following memory linker .cmd files are provided as examples in the f2802x\common\cmd directory. For getting started the basic 28027_RAM_Ink.cmd file is suggested and used by most of the examples.

Memory Linker Command File Examples	Location	Description
28022_RAM_Ink.cmd	F2802x/common/cmd	28022 SARAM memory linker command file.
28023_RAM_Ink.cmd	F2802x/common/cmd	28023 SARAM memory linker command file.
28026_RAM_Ink.cmd	F2802x/common/cmd	28026 SARAM memory linker command file.
28027_RAM_Ink.cmd	F2802x/common/cmd	28027 SARAM memory linker command file.
F28022.cmd	F2802x/common/cmd	F28022 memory linker command file. Includes all Flash, OTP and CSM password protected memory locations.
F28023.cmd	F2802x/common/cmd	F28023 memory linker command file.
F28026.cmd	F2802x/common/cmd	F28026 memory linker command file.
F28027.cmd	F2802x/common/cmd	F28027 memory linker command file.

Table 2.9: Included Main Linker Command Files

3. **Set the CPU Frequency** In the `common\include\F2802x_Examples.h` file specify the proper CPU frequency. Some examples are included in the file.

```
//
// common\include\F2802x_Examples.h
//
...
#define CPU_RATE    20.000L    // for a 50MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    25.000L    // for a 40MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    33.333L    // for a 30MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    41.667L    // for a 24MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    50.000L    // for a 20MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    66.667L    // for a 15MHz CPU clock speed  (SYSCLKOUT)
// #define CPU_RATE    100.000L    // for a 10MHz CPU clock speed  (SYSCLKOUT)
...
```

4. **Link desired common source files to the project** The common source files are found in the `f2802x\common\source` directory.
5. **Include .c files for the PIE** Since all catalog 2802x applications make use of the PIE interrupt block, you will want to include the PIE support .c files to help with initializing the PIE. The shell ISR functions can be used directly or you can re-map your own function into the PIE vector table provided. A list of these files can be found in section [2.8.2.1](#)

2.6 Troubleshooting Tips and Frequently Asked Questions

■ In the examples, what do “EALLOW;” and “EDIS;” do?

EALLOW; is a macro defined in `F2802x_Device.h` for the assembly instruction EALLOW and likewise EDIS is a macro for the EDIS instruction. That is EALLOW; is the same as embedding the assembly instruction `asm(“ EALLOW”);`

Several control registers on the 28x devices are protected from spurious CPU writes by the EALLOW protection mechanism. The EALLOW bit in status register 1 indicates if the protection is enabled or disabled. While protected, all CPU writes to the register are ignored and only CPU reads, JTAG reads and JTAG writes are allowed. If this bit has been set by execution of the EALLOW instruction, then the CPU is allowed to freely write to the protected registers. After modifying the registers, they can once again be protected by executing the EDIS assembly instruction to clear the EALLOW bit.

The driver library defines new names for these two statements in order to make the code more readable. The new names are: “ENABLE_PROTECTED_REGISTER_WRITE_MODE;” and “DISABLE_PROTECTED_REGISTER_WRITE_MODE;”. The definitions for these new macros can be found in `cpu.h`.

For a complete list of protected registers, refer to *System Control and Interrupts* chapter of the *Technical Reference Manual*

■ Peripheral registers read back 0x0000 and/or cannot be written to

There are a few things to check:

- Peripheral registers cannot be modified or unless the clock to the specific peripheral is enabled. The function `InitPeripheralClocks()` in the `f2802x\common\source` directory shows an example of enabling the peripheral clocks.
- The driver library also includes functions to enable the clocks for a given peripheral. Take a look at `clk.c` in `f2802x\common\source`.

- Some peripherals are not present on all 2802x family derivatives. Refer to the device datasheet for information on which peripherals are available.
- The EALLOW bit protects some registers from spurious writes by the CPU. If your program seems unable to write to a register, then check to see if it is EALLOW protected. If it is, then enable access using the EALLOW assembly instruction. See *System Control and Interrupts* chapter in the *Technical Reference Manual* for a complete list of EALLOW protected registers.

■ **Memory block L0, L1 read back all 0x0000**

In this case most likely the code security module is locked and thus the protected memory locations are reading back all 0x0000. Refer to the *System Control and Interrupts* chapter in the *Technical Reference Manual* for information on the code security module.

■ **Code cannot write to L0 or L1 memory blocks**

In this case most likely the code security module is locked and thus the protected memory locations are reading back all 0x0000. Code that is executing from outside of the protected cannot read or write to protected memory while the CSM is locked. Refer to the *System Control and Interrupts* chapter in the *Technical Reference Manual* for information on the code security module

■ **A peripheral register reads back ok, but cannot be written to**

The EALLOW bit protects some registers from spurious writes by the CPU. If your program seems unable to write to a register, then check to see if it is EALLOW protected. If it is, then enable access using the EALLOW assembly instruction. See *System Control and Interrupts* chapter in the *Technical Reference Manual* for a complete list of EALLOW protected registers.

■ **I re-built one of the projects to run from Flash and now it doesn't work. What could be wrong?**

Make sure all initialized sections have been moved to flash such as .econst and .switch. If you are using SDFlash, make sure that all initialized sections, including .econst, are allocated to page 0 in the linker command file (.cmd). SDFlash will only program sections in the .out file that are allocated to page 0.

■ **Why do the examples populate the PIE vector table and then re-assign some of the function pointers to other ISRs?**

The examples share a common default ISR file. This file is used to populate the PIE vector table with pointers to default interrupt service routines. Any ISR used within the example is then remapped to a function within the same source file. This is done for the following reasons:

- The entire PIE vector table is enabled, even if the ISR is not used within the example. This can be very useful for debug purposes.
- The default ISR file is left unmodified for use with other examples or your own project as you see fit.
- It illustrates how the PIE table can be updated at a later time.

■ **When I build the examples, the linker outputs the following: warning: entry point other than _c_int00 specified. What does this mean?**

This warning is given when a symbol other than _c_int00 is defined as the code entry point of the project. For these examples, the symbol code_start is the first code that is executed after exiting the boot ROM code and thus is defined as the entry point via the -e linker option. This symbol is defined in the F2802x_CodeStartBranch.asm file. The entry point symbol is used by the debugger and by the hex utility. When you load the code, CCS will set the PC to the entry point symbol. By default, this is the _c_int00 symbol which marks the start of the C initialization routine. For the F2802x examples, the code_start symbol is used instead. Refer to the source code for more information.

■ **When I build many of the examples, the compiler outputs the following: remark: controlling expression is constant. What does this mean?**

Some of the examples run forever until the user stops execution by using a while(1) loop. The remark refers to the while loop using a constant and thus the loop will never be exited.

■ **When I build some of the examples, the compiler outputs the following: warning: statement is unreachable. What does this mean?**

Some of the examples run forever until the user stops execution by using a while(1) loop. If there is code after this while(1) loop then it will never be reached.

■ **I changed the build configuration of one of the projects from “Debug” to “Release” and now the project will not build. What could be wrong?**

When you switch to a new build configuration (Project->Active Build Configuration) the compiler and linker options changed for the project. The user must enter other options such as include search path and the library search path. Open the build options menu (Project-> Options) and enter the following information:

- C2000 Compiler, Include Options: Include search path
- C2000 Linker, File Search Path: Library search path
- C2000 Linker, File Search Path: Include libraries(i.e. rts2800_ml.lib)

Refer to section 2.5.3 for more details.

■ **In the flash example I loaded the symbols and ran to main. I then set a breakpoint but the breakpoint is never hit. What could be wrong?**

In the Flash example, the InitFlash function and several of the ISR functions are copied out of flash into SARAM. When you set a breakpoint in one of these functions, Code Composer will insert an ESTOP0 instruction into the SARAM location. When the ESTOP0 instruction is hit, program execution is halted. CCS will then remove the ESTOP0 and replace it with the original opcode. In the case of the flash program, when one of these functions is copied from Flash into SARAM, the ESTOP0 instruction is overwritten by code. This is why the breakpoint is never hit. To avoid this, set the breakpoint after the SARAM functions have been copied to SARAM.

2.6.1 Effects of read-modify-write instructions

When writing any code, whether it be C or assembly, keep in mind the effects of read-modify-write instructions.

The 28x DSP will write to registers or memory locations 16 or 32-bits at a time. Any instruction that seems to write to a single bit is actually reading the register, modifying the single bit, and then writing back the results. This is referred to as a read-modify-write instruction. For most registers this operation does not pose a problem. A notable exception is:

1. **Registers with multiple flag bits in which writing a 1 clears that flag**

For example, consider the PIEACK register. Bits within this register are cleared when writing a 1 to that bit. If more than one bit is set, performing a read-modify-write on the register may clear more bits than intended.

The below solution is incorrect. It will write a 1 to any bit set and thus clear all of them:

```
//
// User's source file
//
PieCtrl.PIEACK.bit.Ack1 = 1;    // INCORRECT! May clear more bits.
```

The correct solution is to write a mask value to the register in which only the intended bit will have a 1 written to it:

```
//  
// User's source file  
//  
#define PIEACK_GROUP1 0x0001  
...  
PieCtrl.PIEACK.all = PIEACK_GROUP1;    // CORRECT!
```

2. Registers with Volatile Bits

Some registers have volatile bits that can be set by external hardware.

Consider the PIEIFRx registers. An atomic read-modify-write instruction will read the 16-bit register, modify the value and then write it back. During the modify portion of the operation a bit in the PIEIFRx register could change due to an external hardware event and thus the value may get corrupted during the write.

The rule for registers of this nature is to never modify them during runtime. Let the CPU take the interrupt and clear the IFR flag.

2.7 F2802x bit field headers API to F2802x driver library API code suggestions

1. Initialize System Control

Headers:

```
InitSysCtrl();
```

Drivers:

```
//  
// Perform basic system initialization  
//  
WDog_disable(myWDog);  
CLK_enableAdcClock(myClk);  
(*Device_cal)();  
  
//  
// Select the internal oscillator 1 as the clock source  
//  
CLK_setOscSrc(myClk, CLK_OscSrc_Internal);  
  
//  
// Setup the PLL for x10 /2 which will yield 50Mhz = 10Mhz * 10 / 2  
//  
PLL_setup(myPll, PLL_Multiplier_10, PLL_DivideSelect_ClkIn_by_2);  
  
//  
// Disable the PIE and all interrupts  
//  
PIE_disable(myPie);  
PIE_disableAllInts(myPie);  
CPU_disableGlobalInts(myCpu);  
CPU_clearIntFlags(myCpu);
```

2. Initialize PIE

Headers:

```
DINT;
InitPieCtrl();
IER = 0x0000;
IFR = 0x0000;
InitPieVectTable();
```

Drivers:

```
PIE_setDebugIntVectorTable(myPie);
PIE_enable(myPie);
```

3. Register an Interrupt Handler

Headers:

```
EALLOW;
PieVectTable.ADCINT1 = &adc_isr;
EDIS;
```

Drivers:

```
PIE_registerPieIntHandler(myPie, PIE_GroupNumber_10, PIE_SubGroupNumber_1,
                          (intVec_t)&adc_isr);
```

4. Initialize the ADC

Headers:

```
InitAdc();
```

Drivers:

```
ADC_enableBandGap(myAdc);
ADC_enableRefBuffers(myAdc);
ADC_powerUp(myAdc);
ADC_enable(myAdc);
ADC_setVoltRefSrc(myAdc, ADC_VoltageRefSrc_Int);
```

5. Initialize GPIO

Headers:

```
InitEPwm1Gpio();
```

Drivers:

```
GPIO_setPullUp(myGpio, GPIO_Number_0, GPIO_PullUp_Disable);
GPIO_setPullUp(myGpio, GPIO_Number_1, GPIO_PullUp_Disable);
GPIO_setMode(myGpio, GPIO_Number_0, GPIO_0_Mode_EPWM1A);
GPIO_setMode(myGpio, GPIO_Number_1, GPIO_1_Mode_EPWM1B);
```

6. Acknowledge a PIE interrupt

Headers:

```
PieCtrlRegs.PIEACK.all = PIEACK_GROUP3;
```

Drivers:

```
PIE_clearInt(myPie, PIE_GroupNumber_3);
```

2.8 Packet Contents

This section lists all of the files included in the release.

2.8.1 Header File Support - f2802x\headers

The F2802x header files are located in the <base>\headers directory.

2.8.1.1 F2802x Header Files - Main Files

The files listed in Table 2.10 must be added to any project that uses the F2802x header files. Refer to section 2.5 for information on incorporating the header files into a new or existing project.

File	Location	Description
F2802x_Device.h	f2802x\headers\include	Main include file. Include this one file in any of your .c source files. This file in-turn includes all of the peripheral specific .h files listed below. In addition the file includes typedef statements and commonly used mask values. Refer to section 2.5.
F2802x_GlobalVariableDefs.c	f2802x\headers\source	Defines the variables that are used to access the peripheral structures and data section #pragma assignment statements. This file must be included in any project that uses the header files. If a project includes the driverlib.lib file F2802x_GlobalVariableDefs.c need not be included because it is already a part of the driver library. Refer to section 2.5.
F2802x_Headers_nonBIOS.cmd	f2802x\headers\cmd	Linker .cmd file to assign the header file variables in a non-BIOS project. This file must be included in any non-BIOS project that uses the header files. Refer to section 2.5.

Table 2.10: F2802x Header Files - Main Files

2.8.1.2 F2802x Header Files - Peripheral Bit-Field and Register Structure Definition Files

The files listed in Table 2.11 define the bit-fields and register structures for each of the peripherals on the 2802x devices. These files are automatically included in the project by including

F2802x_Device.h. Refer to section [2.4.2](#) for more information on incorporating the header files into a new or existing project.

File	Description
F2802x_Adc.h	ADC register structure and bit-field definitions.
F2802x_BootVars.h	External boot variable definitions.
F2802x_Comp.h	Comparator register structure and bit-field definitions.
F2802x_CpuTimers.h	CPU-Timer register structure and bit-field definitions.
F2802x_DevEmu.h	Emulation register definitions
F2802x_ECap.h	eCAP register structures and bit-field definitions.
F2802x_EPwm.h	ePWM register structures and bit-field definitions.
F2802x_EQep.h	eQEP register structures and bit-field definitions.
F2802x_Gpio.h	General Purpose I/O (GPIO) register structures and bit-field definitions.
F2802x_I2c.h	I2C register structure and bit-field definitions.
F2802x_NmiIntrupt.h	NMI interrupt register structure and bit-field definitions
F2802x_PieCtrl.h	PIE control register structure and bit-field definitions.
F2802x_PieVect.h	Structure definition for the entire PIE vector table.
F2802x_Sci.h	SCI register structure and bit-field definitions.
F2802x_Spi.h	SPI register structure and bit-field definitions.
F2802x_SysCtrl.h	System register definitions. Includes Watchdog, PLL, CSM, Flash/OTP, Clock registers.
F2802x_XIntrupt.h	External interrupt register structure and bit-field definitions.

Table 2.11: F2802x Header File Bit-Field Register Structure Definition Files(f2802x\headers\include)

2.8.1.3 Variable Names and Data Sections

This section is a summary of the variable names and data sections allocated by the f2802x\headers\source\F2802x_GlobalVariableDefs.c file as shown in Table [2.12](#). Note that all peripherals may not be available on a particular 2802x device. Refer to the device datasheet for the peripheral mix available on each 2802x family derivative.

Peripheral	Starting Address	Structure Variable Name
ADC	0x007100	AdcRegs
ADC Mirrored Result Registers	0x000B00	AdcMirror
Code Security Module	0x000AE0	CsmRegs
Code Security Module Password Locations	0x3F7FF8-0x3F7FFF	CsmPwl
COMP1	0x006400	Comp1Regs
COMP2	0x006420	Comp2Regs
CPU Timer 0	0x000C00	CpuTimer0Regs
CPU Timer 1	0x000C08	CpuTimer1Regs
CPU Timer 2	0x000C10	CpuTimer2Regs
Device and Emulation Registers	0x000880	DevEmuRegs
System Power Control Registers	0x00985	SysPwrCtrlRegs
ePWM1	0x006800	EPwm1Regs
ePWM2	0x006840	EPwm2Regs
ePWM3	0x006880	EPwm3Regs
eCAP1	0x006A00	ECap1Regs
External Interrupt Registers	0x007070	XIntruptRegs
Flash OTP Configuration Registers	0x000A80	FlashRegs
General Purpose I/O Data Registers	0x006fC0	GpioDataRegs
General Purpose Control Registers	0x006F80	GpioCtrlRegs
General Purpose Interrupt Registers	0x006fE0	GpioIntRegs
I2C	0x007900	I2caRegs
NMI Interrupt	0x7060	NmiIntruptRegs
PIE Control	0x000CE0	PieCtrlRegs
SCI-A	0x007050	SciaRegs
SPI-A	0x007040	SpiaRegs

Table 2.12: F2802x Variable Names and Data Sections

2.8.2 Common Example Code - f2802x\common

2.8.2.1 Peripheral Interrupt Expansion (PIE) Block Support

In addition to the register definitions defined in F2802x_PieCtrl.h, this packet provides the basic ISR structure for the PIE block. These files are shown in Table [2.13](#).

File	Location	Description
F2802x_DefaultIsr.c	f2802x\common\source	Shell interrupt service routines (ISRs) for the entire PIE vector table. You can choose to populate one of functions or re-map your own ISR to the PIE vector table. Note: This file is not used for DSP/BIOS projects.
F2802x_DefaultIsr.h	f2802x\common\include	Function prototype statements for the ISRs in F2802x_DefaultIsr.c. Note: This file is not used for DSP/BIOS projects.
F2802x_PieVect.c	f2802x\common\source	Creates an instance of the PIE vector table structure initialized with pointers to the ISR functions in F2802x_DefaultIsr.c. This instance can be copied to the PIE vector table in order to initialize it with the default ISR locations.

Table 2.13: Basic PIE Block Specific Support Files

In addition, the files in Table 2.14 are included for software prioritizing of interrupts. These files are used in place of those above when additional software prioritizing of the interrupts is required. Refer to the example and documentation in *f2802x\examples\sw_prioritized_interrupts* for more information.

File	Location	Description
F2802x_SWPrioritizedDefaultIsr.c	f2802x\common\source	Default shell interrupt service routines (ISRs). These are shell ISRs for all of the PIE interrupts. You can choose to populate one of functions or re-map your own interrupt service routine to the PIE vector table. Note: This file is not used for DSP/BIOS projects.
F2802x_SWPrioritizedIsrLevels.h	f2802x\common\include	Function prototype statements for the ISRs in F2802x_DefaultIsr.c. Note: This file is not used for DSP/BIOS projects.
F2802x_SWPrioritizedPieVect.c	f2802x\common\source	Creates an instance of the PIE vector table structure initialized with pointers to the default ISR functions that are included in F2802x_DefaultIsr.c. This instance can be copied to the PIE vector table in order to initialize it with the default ISR locations.

Table 2.14: Software Prioritized Interrupt PIE Block Specific Support Files

2.8.2.2 Peripheral Specific Files

Several peripheral specific initialization routines and support functions are included in the peripheral .c source files in the f2802x\common\source directory. These files are shown in [Table 2.15](#).

File	Description
F2802x_GlobalPrototypes.h	Function prototypes for the peripheral specific functions included in these files.
F2802x_Adc.c	ADC specific functions and macros.
F2802x_Comp.c	Comparator specific functions and macros
F2802x_CpuTimers.c	CPU-Timer specific functions and macros.
F2802x_ECap.c	eCAP module specific functions and macros.
F2802x_EPwm.c	ePWM module specific functions and macros.
F2802x_EPwm_defines.h	define macros that are used for the ePWM examples
F2802x_Gpio.c	General-purpose IO (GPIO) specific functions and macros.
F2802x_I2C.c	I2C specific functions and macros.
F2802x_I2c_defines.h	define macros that are used for the I2C examples
F2802x_PieCtrl.c	PIE control specific functions and macros.
F2802x_Sci.c	SCI specific functions and macros.
F2802x_Spi.c	SPI specific functions and macros.
F2802x_SysCtrl.c	System control (watchdog, clock, PLL etc) specific functions and macros.

Table 2.15: Included Peripheral Specific Files

NOTE: The specific routines are under development and may not all be available as of this release. They will be added and distributed as more examples are developed.

2.8.2.3 Utility Function Source Files

File	Description
F2802x_CodeStartBranch.asm	Branch to the start of code execution. This is used to re-direct code execution when booting to Flash, OTP or M0 SARAM memory. An option to disable the watchdog before the C init routine is included.
F2802x_DBGIER.asm	Assembly function to manipulate the DEBIER register from C.
F2802x_DisInt.asm	Disable interrupt and restore interrupt functions. These functions allow you to disable INTM and DBGM and then later restore their state.
F2802x_usDelay.asm	Assembly function to insert a delay time in microseconds. This function is cycle dependent and must be executed from zero wait-stated RAM to be accurate. Refer to f2802x\examples\adc_soc for an example of its use.
F2802x_CSMPasswords.asm	Include in a project to program the code security module passwords and reserved locations.

Table 2.16: Included Utility Function Source Files

2.8.2.4 Example Linker .cmd files

Example memory linker command files are located in the F2802x\common\cmd directory. For getting started the basic 28027_RAM_Ink.cmd file is suggested and used by many of the included examples.

The L0 SARAM block is mirrored on these devices. For simplicity these memory maps only include one instance of these memory blocks (Table 2.9).

2.8.2.5 Example Library .lib Files

Please refer to the *C28x IQMath Library - A Virtual Floating Point Engine (SPRC087)* for more information on IQMath and the most recent IQMath library.

2.9 Detailed Revision History

V3.03.00.00

- Migrated all examples to use compiler v20.2.I.LTS

V3.02.00.00

- Modified various driver library struct handles (GPIO_Obj to _GPIO_Obj_)
- Cleaned up SPI examples and set to use common init SPI in f2802x_spi.c
- adc.h - Corrected various enum definitions
- F2802x_sysctrl.c - Corrected order of switching to INTOSC2 in IntOsc2Sel()
- Flash.c - Fixed Flash_setup() OTP wait state value
- Added missing DAC and RAMP registers to F2802x_Comp.h
- Updated all examples and removed deprecated compiler options

V3.01.00.00

- Updated user documentation file names
- Added Launchpad example and LED Boost examples

V3.00.00.00

- Updated directories and naming for C2000Ware Package
- Cleaned up and reformatted source, header, and example code
- Libraries moved into C2000Ware libraries directory
- Added InstaSPIN devices to F2802x_Device.h
- SCI.h - Fixed even parity shift value
- F2802x_SWPrioritizedDefaultIsr.c - Corrected I2C interrupt group to 8
- User Guide - Added note to make sure examples aren't copied into workspace
- GPIO.h and GPIO.c - Corrected GPIO qualification configuration functions
- GPIO.h and GPIO.c - Corrected for GPIO_getPortData and GPIO_setPortData to handle 32bit changes

V2.30

- Moved F2802x_Device.h into F2802x_headers/include
- Moved DSP28x_Project.h into F2802x_common/include
- Corrected memory map for SARAM L0 in GEL files
- Fixed watchdog driver from erroneously overwriting bits
- Removed references to DSP2802x
- Corrected rsvd register in _I2C_OBJ_ in i2c.h
- Removed IQmath.lib and iqmathlib.h
- Cleaned up all examples comments and whitespace. Updated compiler version.
- Added PWMSYNCSEL bit to HRPCTL_BITS struct in F2802x_EPwm.h
- Corrected spelling typo in adc.h

V2.22

- Cleaned up example issues and CCS warnings
- Added 1ms delay to XtalOscSel function
- Updated ACQPS value and added SOC wait loops in ADC source

- Updated ADC examples with AdcOffsetSelfCal() function

V2.21

- F28027 Flash Kernel Example added

V2.20

- ADC acquisition window enumeration no longer contains invalid values
- Flash example now sets up flash wait states correctly
- PieVect Table is now volatile
- Added 2802x0 value line devices
- Added new internal and external oscillator functions
- Added comments to warn against calling some functions before memcpy to RAM
- Added HRPWM example using symmetrical mode PWM
- Added JTAGDEBUG register and JTAGDIS bit
- Cleaned up Memcopy documentation
- DSP28xxx_Examples.h - Fixed text match case issue
- Updated headers for comparator and DAC ramp modules
- HRPWM Example - Fixed Error in Function Prototype
- Ecap_apwm example now sets apwm period correctly
- Example_2802xSWPrioritizedInterrupts.c compile issue fixed
- 2802xSWPrioritizedInterrupts set to clear correct interrupt group
- GPIOsetup fixed issue trying to set up peripheral on incorrect GPIO
- DSP2802x_Adc.h - COMPHYSTCTL_BITS is no longer incorrectly defined as 17 bits
- Driverlib CLK_setLowSpdPreScaler now sets prescaler correctly
- F28020.cmd file - FLASHC corrected to length 0x1000
- function ConfigCpuTimer() - fixed error when setting CPU Timer period register
- Corrected F28027.cmd period issue
- Flash.c - EALLOW added to write to power mode register
- Added missing Ramp generator register definitions
- clk.h osc2src enum corrected
- TIMER_reload function corrected
- TIMER_setPreScaler() now sets correct bit fields
- cleaned up 2802x example comment typos and bugs
- Added missing NOP to SW Prioritized Interrupt example
- Fixed sci.c register name issue
- Fixed SCI_Echoback example issues
- IQmath.lib removed from the common folder
- Added comments to spi_echoback_interrupts example
- Removed delay_loop() from spia_loopback example

V2.10

- Minor bugs were fixed in example applications.

V2.00

- A driver library was added and major changes made to many of the examples and support files. This is a major release.

V1.29

- Additional cleanup of the CCS 4 projects in controlSUITE, and GEL files have been updated.

V1.28

- Improvements and additions to the CCS 4 projects in controlSUITE.

V1.27

- Improvements to the CCS 4 projects in controlSUITE.

V1.26

- This version includes minor corrections to the header files and examples.

V1.25

- This version includes minor corrections to the header files and examples. The most notable change is that gel files and cmd linker files for the 280200 devices now include 1K additional L0 RAM.

V1.21b

- This version update only updates the V1.21 Quick Start Readme to adjust wording for the controlSUITE software package. No changes to the header file and peripheral example code were made.

V1.21

- This version includes minor corrections and comment fixes to the header files and examples.

V1.20

- This version includes corrections and comment fixes to the header files and examples. It adds examples pertaining to the ADC temperature sensor and compensation of the oscillator frequency over temperature, and it also fixes an error in the SFO_TI_Build_V6.lib library in the new SFO_TI_Build_V6b.lib library.

V1.10

- This version is the second release of the F2802x header files and examples. Minor changes were made to the drivers and a header file to driver migration guide is included in the documentation.

V1.00

- This version is the first release (packaged with development tools and customer trainings) of the F2802x header files and examples.

3 Piccolo F2802x Example Applications

These example applications show the user how to make use of various peripherals present on the Piccolo device. They are intended for demonstration purposes only and a good starting point for building new applications.

Notes

- All examples require the F2802x header files
- All examples set up the PLL in x10/2 mode which gives a system clock of 50MHz. This is the default setting assuming the input clock is derived from the 10MHz internal clock.
- Some examples like those related to HRPWM require the use of an external scope to see the results, while other examples may require external connections between headers on the baseboard (e.g. adc_soc). Each example will describe the setup procedure that is required to properly execute it.
- As supplied, almost all projects are supplied with both RAM and Flash build configurations. The 2802x Boot Mode table is shown below.
 - While an emulator is connected to your device, the TRSTn pin = 1, which sets the device into EMU_BOOT boot mode. In this mode, the peripheral boot modes are shown in the table below.
 - Write EMU_KEY to 0xD00 and EMU_BMODE to 0xD01 via the debugger with the values from the table
 - Build/Load project, reset the device, and run the example

Boot Mode	EMU_KEY (0xD00)	EMU_BMODE (0xD01)
Wait	!=0x55AA	X
I/O	0x55AA	0x0000
SCI	0x55AA	0x0001
Wait	0x55AA	0x0002
Get_Mode	0x55AA	0x0003
SPI	0x55AA	0x0004
I2C	0x55AA	0x0005
OTP	0x55AA	0x0006
SARAM	0x55AA	0x000A (Boot to SARAM)
Flash	0x55AA	0x000B
Wait	0x55AA	Other

Table 3.1: Boot Modes for Piccolo 2802x

We have provided scripts to automate setting up watch variables and associated graphs called 'SetupDebugEnv.js' in several example folders. Once you have established a connection to the target device in debug mode go to View->Scripting Console. Within the console click the Open Command file icon in the far right corner of the console window and select the javascript file.

All of these examples reside in the `f2802x\examples` subdirectory of the C2000Ware package.

3.1 ADC Start-Of-Conversion (SOC)

Interrupts are enabled and the ePWM1 is setup to generate a periodic ADC SOC - ADCINT1. Two channels are converted, ADCINA4 and ADCINA2.

Watch Variables:

- Voltage1[10] - Last 10 ADCRESULT0 values
- Voltage2[10] - Last 10 ADCRESULT1 values
- ConversionCount - Current result number 0-9
- LoopCount - Idle loop counter

3.2 ADC Temperature Sensor

Interrupts are enabled and the ePWM1 is set up to generate a periodic ADC SOC interrupt - ADCINT1. One channel is converted - ADCINA5, which is internally connected to the temperature sensor.

Watch Variables:

- TempSensorVoltage[10] Last 10 ADCRESULT0 values
- ConversionCount Current result number 0-9
- LoopCount Idle loop counter

3.3 ADC Temperature Sensor Conversion

This program shows how to convert a raw ADC temperature sensor reading into deg. C or deg. K.

Watch Variables:

- temp
- degC
- degK

3.4 LaunchPad Demo

This program is the demo program that comes pre-loaded on the LaunchPad development kit. The program starts by flashing the 4 bit binary display. When the user pushes S3 (GPIO12) the demo then stops flashing the display and samples the device's internal temperature sensor to establish a reference. After this, the board displays a value of 0x08 and displays any increase or decrease in temperature as a delta on the display. So for instance if the temperature was initially 20C and now it is 22C, the value on the display would be $22C - 20C + 8 = 10 = 0x0A = 0b1010$. Additionally, the reference temperature may be reset to the current value by pressing and holding S3.

Watch Variables:

- referenceTemp
- currentTemp

3.5 CPU Timer

This example configures CPU Timer0, 1, & 2 and increments a counter each time the timer asserts an interrupt.

Watch Variables:

- timer0IntCount
- timer1IntCount
- timer2IntCount

3.6 ECAP Asymmetric PWM

This program sets up the eCAP pins in the APWM mode. This program runs at 50 MHz or 40 MHz SYSCLKOUT assuming a 10 MHz OSCCLK depending on the max frequency allowed by a particular device.

eCAP1 will come out on the GPIO5 pin. This pin is configured to vary between 3 Hz and 6 Hz (at 50 MHz SYSCLKOUT) or 2 Hz and 4 Hz (at 40 MHz SYSCLKOUT) using the shadow registers to load the next period/compare values.

Monitor eCAP1 pin on GPIO5 for PWM frequency

3.7 ECAP Capture EPwm3

This example configures EPWM3A for:

- Up count
- Period starts at 2 and goes up to 1000
- Toggle output on PRD

eCAP1 is configured to capture the time between rising and falling edge of the PWM3A output. Connect eCAP1 (GPIO5) to ePWM3A (GPIO4).

3.8 PWM Blanking Window

This example configures ePWM1 and ePWM2

2 Examples are included:

- ePWM1: DCAEVT1 forces EPWM1A high, a blanking window is used EPWM1B toggles on zero as a reference.

- ePWM2: DCAEVT1 forces EPWM2A high, no blanking window is used EPWM2B toggles on zero as a reference.

During the test, monitor ePWM1 or ePWM2 outputs on a scope. Create DCAEVT1 by pulling TZ1 low and TZ2 high to see the effect.

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1
- EPWM2A is on GPIO2
- EPWM2B is on GPIO3

EPWM1A is set to normally stay low. DCAEVT1 is true when TZ1 is low and TZ2 is high. When an event is true (DCAEVT1) EPWM1A is configured to be forced high. A blanking window is applied to keep the event from taking effect around the zero point. In other words, when the event is taken, EPWM1A will be forced high, but if there is no event, EPWM1A will remain low. EPWM1B is toggled at zero for a reference. Notice the blanking window keeps the event from forcing EPWM1A high around the zero point.

ePWM2 is configured the same as ePWM1 except no blanking window is applied.

View the EPWM1A/B, EPWM2A/B waveforms via an oscilloscope to see the effect of DCAEVT1

3.9 PWM Digital Compare Event Trip Zone

This example configures ePWM1 and ePWM2

2 Examples are included:

- ePWM1 has DCAEVT1 as a one shot trip source
- ePWM2 has DCAEVT2 as a cycle by cycle trip source
- ePWM3 reacts to DCAEVT2 and DCBEVT1 events

During the test, monitor ePWM1, ePWM2, or ePWM3 outputs on a scope pull TZ1 low and leave TZ2 high to create a DCAEVT1, DCAEVT2, DCBEVT1 and DCBEVT2.

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1
- EPWM2A is on GPIO2
- EPWM2B is on GPIO3
- EPWM3A is on GPIO4
- EPWM3B is on GPIO5

DCAEVT1, DCAEVT2, DCBEVT1 and DCBEVT2 are all defined as true when TZ1 is low and TZ2 is high

- ePWM1 will react to DCAEVT1 as a 1-shot trip.
The trip event will pull EPWM1A high.
The trip event will pull EPWM1B low.

- ePWM2 will react to DCAEVT2 as a cycle-by-cycle trip.
The trip event will pull EPWM2A high.
The trip event will pull EPWM2B low.
- ePWM3 will react to DCAEVT2 and DCBEVT1 events.
The DCAEVT2 event will pull EPWM3A high.
The DCBEVT1 event will pull EPWM3B low.

3.10 PWM Trip Zone Test with Comparator Inputs

This example configures ePWM1 and its associated trip zone.

Initially make voltage on pin COMP1A greater than COMP1B if using dual pin compare; else make internal DAC output lower than V on COMP1A.

During the test, monitor ePWM1 outputs on a scope. Increase the voltage on inverting side of comparator (either through COMP1B pin or internal DAC setting) to trigger a DCAEVT1, and DCBEVT1.

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1

DCAEVT1, DCBEVT1 are all defined as true when COMP1OUT is low.

ePWM1 will react to DCAEVT1 and DCBEVT1 as a 1 shot trip.

- DCAEVT1 will pull EPWM1A high.
- DCBEVT1 will pull EPWM1B low.

3.11 PWM deadband generation

This example configures ePWM1, ePWM2 and ePWM3 for:

- Count up/down
- Deadband

3 Examples are included:

- ePWM1: Active low PWMs
- ePWM2: Active low complementary PWMs
- ePWM3: Active high complementary PWMs

Each ePWM is configured to interrupt on the 3rd zero event/ When this happens, the deadband is modified such that $0 \leq DB \leq DB_MAX$. That is, the deadband will move up and down between 0 and the maximum value.

View the EPWM1A/B, EPWM2A/B and EPWM3A/B waveforms via an oscilloscope:

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1

- EPWM2A is on GPIO2
- EPWM2B is on GPIO3
- EPWM3A is on GPIO4
- EPWM3B is on GPIO5

3.12 PWM Timer Interrupt

This example configures the ePWM Timers and increments a counter each time an interrupt is taken.

As supplied:

- All ePWM's are initialized.
- All timers have the same period.
- The timers are started sync'ed.

An interrupt is taken on a zero event for each ePWM timer.

- ePWM1: takes an interrupt every event
- ePWM2: takes an interrupt every 2nd event
- ePWM3: takes an interrupt every 3rd event

Thus the Interrupt count for ePWM1 and ePWM4 should be equal. The interrupt count for ePWM2 should be about half that of ePWM1, and the interrupt count for ePWM3 should be about 1/3 that of ePWM1

Watch Variables:

- EPwm1TimerIntCount
- EPwm2TimerIntCount
- EPwm3TimerIntCount

3.13 PWM Trip Zone

This example configures ePWM1 and ePWM2

2 Examples are included:

- ePWM1 has TZ1 and TZ2 as one shot trip sources
- ePWM2 has TZ1 and TZ2 as cycle by cycle trip sources

Each ePWM is configured to interrupt on the 3rd zero event. When this happens, the deadband is modified such that $0 \leq DB \leq DB_MAX$. That is, the deadband will move up and down between 0 and the maximum value.

View the EPWM1A/B, EPWM2A/B waveforms via an oscilloscope to see the effect of TZ1 and TZ2
Initially tie TZ1 (GPIO12) and TZ2 (GPIO16) high.

During the test, monitor ePWM1 or ePWM2 outputs on a scope Pull TZ1 or TZ2 low to see the effect.

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1
- EPWM2A is on GPIO2
- EPWM2B is on GPIO3

ePWM1 will react as a 1 shot trip.

ePWM2 will react as a cycle by cycle trip and will be cleared if TZ1 and TZ2 are both pulled back high.

3.14 Action Qualifier Module Upcount mode

This example configures ePWM1, ePWM2, ePWM3 to produce a waveform with independent modulation on EPWMxA and EPWMxB.

The compare values CMPA and CMPB are modified within the ePWM's ISR.

The TB counter is in upmode for this example.

View the EPWM1A/B, EPWM2A/B and EPWM3A/B waveforms via an oscilloscope:

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1
- EPWM2A is on GPIO2
- EPWM2B is on GPIO3
- EPWM3A is on GPIO4
- EPWM3B is on GPIO5

3.15 Action Qualifier Module - Using up/down count

This example configures ePWM1, ePWM2, ePWM3 to produce a waveform with independent modulation on EPWMxA and EPWMxB.

The compare values CMPA and CMPB are modified within the ePWM's ISR.

The TB counter is in up/down count mode for this example.

View the EPWM1A/B, EPWM2A/B and EPWM3A/B waveforms via an oscilloscope:

- EPWM1A is on GPIO0
- EPWM1B is on GPIO1
- EPWM2A is on GPIO2
- EPWM2B is on GPIO3
- EPWM3A is on GPIO4
- EPWM3B is on GPIO5

3.16 External Interrupts

This program sets up GPIO0 as XINT1 and GPIO1 as XINT2. Two other GPIO signals are used to trigger the interrupt (GPIO28 triggers XINT1 and GPIO29 triggers XINT2). The user is required to externally connect these signals for the program to work properly.

XINT1 input is synched to SYSCLKOUT. XINT2 has a long qualification - 6 samples at $510 \times \text{SYSCLKOUT}$ each.

GPIO34 will go high outside of the interrupts and low within the interrupts. This signal can be monitored on a scope.

Each interrupt is fired in sequence - XINT1 first and then XINT2

Watch Variables:

- Xint1Count for the number of times through XINT1 interrupt
- Xint2Count for the number of times through XINT2 interrupt
- LoopCount for the number of times through the idle loop

3.17 EPwm interrupt from Flash

This example runs the EPwm interrupt example from flash.

1. Build the project
2. Flash the .out file into the device.
3. Set the hardware jumpers to boot to Flash
4. Use the included GEL file to load the project, symbols defined within the project and the variables into the watch window.

Steps that were taken to convert the EPwm example from RAM to Flash execution:

1. Change the linker cmd file to reflect the flash memory map.
2. Make sure any initialized sections are mapped to Flash. In SDFlash utility this can be checked by the View->Coff/Hex status utility. Any section marked as "load" should be allocated to Flash.
3. Make sure there is a branch instruction from the entry to Flash at 0x3F7FF6 to the beginning of code execution. This example uses the F2802x_CodeStartBranch.asm file to accomplish this.
4. Set boot mode Jumpers to "boot to Flash"
5. For best performance from the flash, modify the waitstates and enable the flash pipeline as shown in this example. Note: any code that manipulates the flash waitstate and pipeline control must be run from RAM. Thus these functions are located in their own memory section called ramfuncs.

EPwm1 Interrupt will run from RAM and puts the flash into sleep mode. EPwm2 Interrupt will run from RAM and puts the flash into standby mode. EPwm3 Interrupt will run from FLASH.

As supplied:

All timers have the same period. The timers are started sync'ed. An interrupt is taken on a zero event for each EPwm timer.

EPwm1: takes an interrupt every event. EPwm2: takes an interrupt every 2nd event. EPwm3: takes an interrupt every 3rd event.

Thus the Interrupt count for EPwm1, EPwm4-EPwm6 should be equal The interrupt count for EPwm2 should be about half that of EPwm1 and the interrupt count for EPwm3 should be about 1/3 that of EPwm1

Watch Variables:

- EPwm1TimerIntCount
- EPwm2TimerIntCount
- EPwm3TimerIntCount

Toggle GPIO34 while in the background loop.

3.18 GPIO Setup

Configures the 2802x GPIO into two different configurations This code is verbose to illustrate how the GPIO could be setup. In a real application, lines of code can be combined for improved code size and efficiency.

This example only sets-up the GPIO. Nothing is actually done with the pins after setup.

In general:

- All pullup resistors are enabled. For EPwms this may not be desired.
- Input qual for communication ports (eCAN, SPI, SCI, I2C) is asynchronous
- Input qual for Trip pins (TZ) is asynchronous
- Input qual for eCAP is synch to SYSCLKOUT
- Input qual for some I/O's and interrupts may have a sampling window

3.19 GPIO Toggle

Three different examples are included. Select the example (data, set/clear or toggle) to execute before compiling using the define statements found at the top of the code.

Warning:

- ALL OF THE I/O'S TOGGLE IN THIS PROGRAM. MAKE SURE THIS WILL NOT DAMAGE YOUR HARDWARE BEFORE RUNNING THIS EXAMPLE.

The pins can be observed using Oscilloscope.

3.20 High Resolution PWM

This example modifies the MEP control registers to show edge displacement due to the HRPWM control extension of the respective EPwm module. All EPwm1A,2A,3A,4A channels (GPIO0, GPIO2, GPIO4, GPIO6) will have fine edge movement due to HRPWM logic.

1. PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM1A toggle low/high with MEP control on rising edge
PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM1B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM2A toggle low/high with MEP control on rising edge
PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM2B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM3A toggle as high/low with MEP control on falling edge
PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM3B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM4A toggle as high/low with MEP control on falling edge
PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM4B toggle low/high with NO HRPWM control

Monitor ePWM1-ePWM4 pins on an oscilloscope.

- ePWM1A is on GPIO0
- ePWM1B is on GPIO1
- ePWM2A is on GPIO2
- ePWM2B is on GPIO3
- ePWM3A is on GPIO4
- ePWM3B is on GPIO5
- ePWM4A is on GPIO6
- ePWM4B is on GPIO7

3.21 High Resolution PWM SFO Duty Cycle Control

This example modifies the MEP control registers to show edge displacement due to the HRPWM control extension of the respective ePWM module.

This example calls the following TI's MEP Scale Factor Optimizer (SFO) software library V6 functions:

int SFO();

- updates MEP_ScaleFactor dynamically when HRPWM is in use
- updates HRMSTEP register (exists only in EPwm1Regs register space but valid for all channels) with MEP_ScaleFactor value
- returns 2 if error: MEP_ScaleFactor is greater than maximum value of 255 (Auto-conversion may not function properly under this condition)
- returns 1 when complete for the specified channel

- returns 0 if not complete for the specified channel

This example is intended to explain the HRPWM capabilities. The code can be optimized for code efficiency. Refer to TI's Digital power application examples and TI Digital Power Supply software libraries for details.

All ePWM1A-4A channels (GPIO0 through GPIO7) will have fine edge movement due to the HRPWM logic

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NOTE: For more information on using the SFO software library, see the 2802x High-Resolution Pulse Width Modulator (HRPWM) Reference Guide

=====

To load and run this example:

1. ****!!!IMPORTANT!!**** - in sfo_v6.h, set PWM_CH to the max number of HRPWM channels plus one. For example, for the F2802x, the maximum number of HRPWM channels is 4. $4+1=5$, so set define PWM_CH 5 in sfo_v6.h. (Default is 5)
2. In this file, set define AUTOCONVERT to 1 to enable MEP step auto-conversion logic. Otherwise, to manually perform MEP calculations in software, clear to 0.
3. Run this example at maximum SYSCLKOUT (60 or 40 MHz)
4. Load the Example_2802xHRPWM_Duty_sfo_v6.gel and observe variables in the watch window
5. Activate Real time mode
6. Run the code
7. Watch ePWM1-4 waveforms on a Oscilloscope
8. In the watch window: Set the variable UpdateFine = 1 to observe the ePWMxA output with HRPWM capabilities (default) Observe the duty cycle of the waveform change in fine MEP steps
9. In the watch window: Change the variable UpdateFine to 0, to observe the ePWMxA output without HRPWM capabilities Observe the duty cycle of the waveform change in coarse SYSCLKOUT cycle steps.

3.22 High Resolution PWM SFO Period Control

This example modifies the MEP control registers to show edge displacement for high-resolution period/frequency on multiple synchronized ePWM channels in Up-Down count mode due to the HRPWM control extension of the respective ePWM module.

Notice that all period and compare register updates occur in an ISR which interrupts at ePWM1 TBCTR = 0. This ensures that period and compare register updates across all ePWM modules occur within the same period.

This example calls the following TI's MEP Scale Factor Optimizer (SFO) software library V6 functions:

```
int SFO();
```

- updates MEP_ScaleFactor dynamically when HRPWM is in use

- updates HRMSTEP register (exists only in EPwm1Regs register space) with MEP_ScaleFactor value
- returns 2 if error: MEP_ScaleFactor is greater than maximum value of 255 (Auto-conversion may not function properly under this condition)
- returns 1 when complete for the specified channel
- returns 0 if not complete for the specified channel

All ePWM1A-4A channels will be synchronized to each other (with ePWM1 sync'd to the SWF-SYNC) and have fine edge period movement due to the HRPWM logic.

This example can be used as a primitive building block for applications which require high resolution frequency control with synchronized ePWM modules (i.e. resonant converter applications)

=====

NOTE: For more information on using the SFO software library, see the 2802x High-Resolution Pulse Width Modulator (HRPWM) Reference Guide

=====

To load and run this example:

1. *****!!IMPORTANT!!**** - in sfo_v6.h, set PWM_CH to the max number of HRPWM channels plus one. For example, for the F2802x, the maximum number of HRPWM channels is 4. 4+1=5, so set define PWM_CH 5 in sfo_v6.h. (Default is 5)
2. Run this example at maximum SYSCLKOUT (60 MHz or 40 MHz)
3. Add "UpdateFine" and "UpdateCourse" variables to the watch window.
4. Activate Real time mode
5. Run the code
6. Watch ePWM A channel waveforms on a Oscilloscope
7. In the watch window: Set the variable UpdateFine = 1 to observe the ePWMxA output with HRPWM capabilities (default) Observe the period/frequency of the waveform changes in fine MEP steps
8. In the watch window: Change the variable UpdateFine to 0, to observe the ePWMxA output without HRPWM capabilities To change the period/frequency in coarse steps, uncomment the relevant code, re-build and re-run with UpdateCoarse = 1. Observe the period/frequency of the waveform changes in coarse SYSCLKOUT cycle steps.

3.23 High Resolution PWM SFO Period (Up Count) Control

This example modifies the MEP control registers to show edge displacement for high-resolution period with ePWM in Up count mode due to the HRPWM control extension of the respective ePWM module.

This example calls the following TI's MEP Scale Factor Optimizer (SFO) software library V6 functions:

int SFO();

- updates MEP_ScaleFactor dynamically when HRPWM is in use
- updates HRMSTEP register (exists only in EPwm1Regs register space) with MEP_ScaleFactor value

- returns 2 if error: MEP_ScaleFactor is greater than maximum value of 255 (Auto-conversion may not function properly under this condition)
- returns 1 when complete for the specified channel
- returns 0 if not complete for the specified channel

This example is intended to explain the HRPWM capabilities. The code can be optimized for code efficiency. Refer to TI's Digital power application examples and TI Digital Power Supply software libraries for details.

All ePWM1A-4A channels (GPIO0 through GPIO7) will have fine edge movement due to the HRPWM logic.

=====

NOTE: For more information on using the SFO software library, see the 2802x High-Resolution Pulse Width Modulator (HRPWM) Reference Guide

=====

To load and run this example:

1. *****!!IMPORTANT!!***** - in sfo_v6.h, set PWM_CH to the max number of HRPWM channels plus one. For example, for the F2802x, the maximum number of HRPWM channels is 4. 4+1=5, so set define PWM_CH 5 in sfo_v6.h. (Default is 5)
2. Run this example at maximum SYSCLKOUT (60 or 40 MHz)
3. Load the Example_2802xHRPWM_PrdUpDown_sfo_v6.gel and observe variables in the watch window
4. Activate Real time mode
5. Run the code
6. Watch ePWM1-4 waveforms on a Oscilloscope
7. In the watch window: Set the variable UpdateFine = 1 to observe the ePWMxA output with HRPWM capabilities (default) Observe the period/frequency of the waveform changes in fine MEP steps
8. In the watch window: Change the variable UpdateFine to 0, to observe the ePWMxA output without HRPWM capabilities Observe the period/frequency of the waveform changes in coarse SYSCLKOUT cycle steps.

3.24 High Resolution PWM SFO Period (Up-Down Count) Control

This example modifies the MEP control registers to show edge displacement for high-resolution period with ePWM in Up-Down count mode due to the HRPWM control extension of the respective ePWM module.

This example calls the following TI's MEP Scale Factor Optimizer (SFO) software library V6 functions:

```
int SFO();
```

- updates MEP_ScaleFactor dynamically when HRPWM is in use
- updates HRMSTEP register (exists only in EPwm1Regs register space) with MEP_ScaleFactor value

- returns 2 if error: MEP_ScaleFactor is greater than maximum value of 255 (Auto-conversion may not function properly under this condition)
- returns 1 when complete for the specified channel
- returns 0 if not complete for the specified channel

This example is intended to explain the HRPWM configuration for high resolution period/frequency. The code can be optimized for code efficiency. Refer to TI's Digital power application examples and TI Digital Power Supply software libraries for details.

ePWM1A (GPIO0) will have fine edge movement due to the HRPWM logic

```
=====
NOTE:  For more information on using the SFO software library, see the
2802x  High-Resolution Pulse Width Modulator (HRPWM) Reference Guide
=====
```

To load and run this example:

1. *****!!IMPORTANT!!**** - in sfo_v6.h, set PWM_CH to the max used HRPWM channel # plus one. For example, for the F2802x, the maximum number of HRPWM channels is 4. 4+1=5, so set define PWM_CH 5 in sfo_v6.h. (Default is 5)
 - Note for this specific example, you could set define PWM_CH 2 (because it only uses ePWM1), but to cover all examples, PWM_CH is currently set to the maximum possible for the device.
1. Load the code and add the following watch variables to the watch window:
 - UpdateFine
 - PeriodFine
 - EPwm1Regs.TBPRD
 - EPwm1Regs.TBPRDHR
2. Run this example at maximum SYSCLKOUT (60 or 40 MHz)
3. Activate Real time mode
4. Run the code
5. Watch ePWM1A waveform on a Oscilloscope
6. In the watch window: Set the variable UpdateFine = 1 to observe the ePWMxA output with HRPWM capabilities (default) Observe the period/frequency of the waveform changes in fine MEP steps
7. In the watch window: Change the variable UpdateFine to 0, to observe the ePWMxA output without HRPWM capabilities

3.25 High Resolution PWM Slider

This example modifies the MEP control registers to show edge displacement due to HRPWM control blocks of the respective EPwm module, EPwm1A, 2A, 3A, and 4A channels (GPIO0, GPIO2, GPIO4, and GPIO6) will have fine edge movement due to HRPWM logic. Load the Example_2802xHRPWM_slider.gel file. Select the HRPWM_eval from the GEL menu. A FineDuty slider graphics will show up in CCS. Load the program and run. Use the Slider to and observe the EPwm edge displacement for each slider step change. This explains the MEP control on the EPwmxA channels

1. PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM1A toggle low/high with MEP control on rising edge
PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM1B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM2A toggle low/high with MEP control on rising edge
PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM2B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM3A toggle as high/low with MEP control on falling edge
PWM Freq = $\text{SYSCLK}/(\text{period}=10)$, ePWM3B toggle low/high with NO HRPWM control
1. PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM4A toggle as high/low with MEP control on falling edge
PWM Freq = $\text{SYSCLK}/(\text{period}=20)$, ePWM4B toggle low/high with NO HRPWM control

3.26 LED BoosterPack Capacitive Touch Demo

This example allows the user to control the LED Boosterpack's color by spinning their finger on the capacitive touch boosterpack when plugged into the LED boosterpack.

For this example to work S4 on the C2000 LaunchPad should be in the down position, while S1 on the LED Boosterpack should be in the up position.

This example uses the same control techniques used in the other LED BoosterPack examples, but uses the MSP430 present on the LED BoosterPack as a sensor hub. The MSP430 interfaces with the Capacitive Touch BoosterPack directly and reports actions to the Piccolo device on the C2000 LaunchPad via an asynchronous serial interface.

After loading and running this example, press the center section of the capacitive touch Booster-Pack twice to turn on the LEDs. Moving ones finger around the outer sections of the touchpad will change the LED color. Touching the center section again will turn off the LEDs.

3.27 LED BoosterPack PC GUI Demo

This example allows the user to control the LED Boosterpack's color and intensity via a GUI application on a host PC.

For this example to work S4 on the C2000 LaunchPad should be in the up position, while S1 on the LED Boosterpack should be in the down position.

This example uses the same control techniques used in the other LED BoosterPack examples and uses a serial communications link to communicate with a PC Gui application to allow for control of the BoosterPack's LEDs.

After loading and running this example, open up the PC GUI application and connect to the XDS100's USB/Serial Port. Move the slides to turn on and off the LEDs and adjust the color.

3.28 Device Halt Mode and Wakeup

This example puts the device into HALT mode. If the lowest possible current consumption in HALT mode is desired, the JTAG connector must be removed from the device board while the device is in HALT mode.

The example then wakes up the device from HALT using GPIO0. GPIO0 wakes the device from HALT mode when a high-to-low signal is detected on the pin. This pin must be pulsed by an external agent for wakeup.

The wakeup process begins as soon as GPIO0 is held low for the time indicated in the device datasheet. After the device wakes up, GPIO1 can be observed to go high.

GPIO0 is configured as the LPM wakeup pin to trigger a WAKEINT interrupt upon detection of a low pulse. Initially, pull GPIO0 high externally. To wake device from halt mode, pull GPIO0 low for at least the crystal startup time + 2 OSCCLKS, then pull it high again.

To observe when device wakes from HALT mode, monitor GPIO1 with an oscilloscope (toggled in WAKEINT ISR)

3.29 Device Idle Mode and Wakeup

This example puts the device into IDLE mode.

The example then wakes up the device from IDLE using XINT1 which triggers on a falling edge from GPIO0. This pin must be pulled from high to low by an external agent for wakeup.

To observe the device wakeup from IDLE mode, monitor GPIO1 with an oscilloscope, which toggles in the XINT_1_ISR.

3.30 Standby Mode and Wakeup

This example puts the device into STANDBY mode. If the lowest possible current consumption in STANDBY mode is desired, the JTAG connector must be removed from the device board while the device is in STANDBY mode.

The example then wakes up the device from STANDBY using GPIO0. GPIO0 wakes the device from STANDBY mode when a low pulse (signal goes high->low->high) is detected on the pin. This pin must be pulsed by an external agent for wakeup.

As soon as GPIO0 goes high again after the pulse, the device should wake up, and GPIO1 can be observed to toggle.

3.31 Internal Oscillator Compensation

This program shows how to use the internal oscillator compensation functions in `osc.c` or `F2802x_OscComp.c`. The temperature sensor is sampled and the raw temp sensor value is passed to the oscillator compensation function, which uses this parameter to compensate for frequency drift of the internal oscillator over temperature.

Watch Variables:

- temp
- SysCtrlRegs.INTOSC1TRIM
- SysCtrlRegs.INTOSC2TRIM

3.32 SCI Echoback

This test receives and echo-backs data through the SCI-A port.

1. Configure hyperterminal: Use the included hyperterminal configuration file SCI_96.ht. To load this configuration in hyperterminal: file->open and then select the SCI_96.ht file.
2. Check the COM port. The configuration file is currently setup for COM1. If this is not correct, disconnect Call->Disconnect Open the File-Properties dialog and select the correct COM port.
3. Connect hyperterminal Call->Call and then start the 2802x SCI echoback program execution.
4. The program will print out a greeting and then ask you to enter a character which it will echo back to hyperterminal.

Watch Variables:

- LoopCount for the number of characters sent
- ErrorCount

3.33 SCI FIFO Digital Loop Back

This test uses the loopback test mode of the SCI module to send characters starting with 0x00 through 0xFF. The test will send a character and then check the receive buffer for a correct match.

Watch Variables:

- LoopCount - Number of characters sent
- ErrorCount - Number of errors detected
- SendChar - Character sent
- ReceivedChar - Character received

3.34 SCI Digital Loop Back with Interrupts

This program is a SCI example that uses the internal loopback of the peripheral. Both interrupts and the SCI FIFOs are used.

A stream of data is sent and then compared to the received stream.

The SCI-A sent data looks like this:

00 01

01 02

02 03

....

FE FF

FF 00

etc..

The pattern is repeated forever.

Watch Variables:

- sdataA - Data being sent
- rdataA - Data received
- rdata_pointA - Keep track of where we are in the datastream. This is used to check the incoming data

3.35 SPI Digital Loop Back

This program is a SPI example that uses the internal loopback of the peripheral. Interrupts are not used.

A stream of data is sent and then compared to the received stream.

The sent data looks like this: 0000 0001 0002 0003 0004 0005 0006 0007 FFFE FFFF

This pattern is repeated forever.

Watch Variables:

- sdata - sent data
- rdata - received data

3.36 SPI Digital Loop Back with Interrupts

This program is a SPI-A example that uses the internal loopback of the peripheral. Both interrupts and the SPI FIFOs are used.

A stream of data is sent and then compared to the received stream.

The sent data looks like this: 0000 0001

0001 0002

0002 0003

....

FFFE FFFF

FFFF 0000

etc..

This pattern is repeated forever.

Watch Variables:

- sdata[2] - Data to send
- rdata[2] - Received data
- rdata_point - Used to keep track of the last position in the receive stream for error checking.

3.37 Software Prioritized Interrupts

For most applications, the hardware prioritization of the the PIE module is sufficient. For applications that need custom prioritization, this example illustrates an example of how this can be done through software.

For more information on F2802x interrupt priorities, refer to the Software ISR Priorities section of the firmware examples guide document included with the F2802x/doc directory.

This program simulates interrupt conflicts by writing to the PIEIFR registers. This will simulate multiple interrupts coming into the PIE block at the same time.

The interrupt service routine routines are software prioritized by the table found in the F2802x_SWPrioritizedIsrLevels.h file.

1. Before compiling you must set the Global and Group interrupt priorities in the F2802x_SWPrioritizedIsrLevels.h file.
2. Set the define CASE directive at the top of the code in this file to determine which test case to run
3. Compile the code, load, and run
4. At the end of each test there is a hard coded breakpoint (ESTOP0). When code stops at the breakpoint, examine the ISRTrace buffer to see the order in which the ISR's completed. All PIE interrupts will add to the ISRTrace.
5. If desired, set a new set of Global and Group interrupt priorities and repeat the test to see the change.

Watch Variables:

- ISRTrace[50] - Trace of ISR's in the order they complete After each test, examine this buffer to determine if the ISR's completed in the order desired. The ISRTrace will consist of a list of hex values as shown:
 0x00wx <- PIE Group w interrupt x finished first
 0x00yz <- PIE Group y interrupt z finished next

3.38 LED Blink

This example configures CPU Timer0 for a 500 msec period, and toggles the GPIO0-4 LEDs once per interrupt. For testing purposes, this example also increments a counter each time the timer asserts an interrupt.

Watch Variables:

- interruptCount

Monitor the GPIO0-4 LEDs blink on (for 500 msec) and off (for 500 msec) on the 2802x control card.

3.39 Watchdog Interrupt

This program exercises the watchdog.

First the watchdog is connected to the WAKEINT interrupt of the PIE block. The code is then put into an infinite loop.

The user can select to feed the watchdog key register or not by commenting one line of code in the infinite loop.

If the watchdog key register is fed by the WDOG_clearCounter function then the WAKEINT interrupt is not taken. If the key register is not fed by the WDOG_clearCounter function then WAKEINT will be taken.

Watch Variables:

- LoopCount for the number of times through the infinite loop
- WakeCount for the number of times through WAKEINT

A Interrupt Service Routine Priorities

Interrupt Hardware Priority Overview	61
F2802x Interrupt Priorities	62
Software Prioritization of Interrupts - The DSP28 Example	63

A.1 Interrupt Hardware Priority Overview

With the PIE block enabled, the interrupts are prioritized in hardware by default as follows:

Global Priority (CPU Interrupt level):

CPU Interrupt	Hardware Priority
Reset	1(Highest)
INT1	5
INT2	6
INT3	7
INT4	8
INT5	9
INT6	10
INT7	11
...	...
INT12	16
INT13	17
INT14	18
DLOGINT	19(Lowest)
RTOSINT	20
reserved	2
NMI	3
ILLEGAL	-
USER1	-(Software Interrupts)
USER2	-
...	...

CPU Interrupts INT1 - INT14, DLOGINT and RTOSINT are maskable interrupts. These interrupts can be enabled or disabled by the CPU Interrupt enable register (IER).

Group Priority (PIE Level):

If the Peripheral Interrupt Expansion (PIE) block is enabled, then CPU interrupts INT1 to INT12 are connected to the PIE. This peripheral expands each of these 12 CPU interrupt into 8 interrupts. Thus the total possible number of available interrupts in the PIE is 96. Note, not all of the 96 are used on a 2802x device.

Each of the PIE groups has its own interrupt enable register (PIEIERx) to control which of the 8 interrupts (INTx.1 - INTx.8) are enabled and permitted to issue an interrupt.

CPU Interrupt	PIE Group	PIE Interrupts							
		Highest ————— Hardware Priority Within the Group ————— Lowest							
INT1	1	INT1.1	INT1.2	INT1.3	INT1.4	INT1.5	INT1.6	INT1.7	INT1.8
INT2	2	INT2.1	INT2.2	INT2.3	INT2.4	INT2.5	INT2.6	INT2.7	INT2.8
INT3	3	INT3.1	INT3.2	INT3.3	INT3.4	INT3.5	INT3.6	INT3.7	INT3.8
... etc ...									
... etc ...									
INT12	12	INT12.1	INT12.2	INT12.3	INT12.4	INT12.5	INT12.6	INT12.7	INT4.8

Table A.1: PIE Group Hardware Priority

A.2 F2802x Interrupt Priorities

The PIE block is organized such that the interrupts are in a logical order. Interrupts that typically require higher priority, are organized higher up in the table and will thus be serviced with a higher priority by default.

The interrupts in a 2802x system can be categorized as follows (ordered highest to lowest priority):

1. Non-Periodic, Fast Response

These are interrupts that can happen at any time and when they occur, they must be serviced as quickly as possible. Typically these interrupts monitor an external event.

On the 2802x, such interrupts are allocated to the first few interrupts within PIE Group 1 and PIE Group 2. This position gives them the highest priority within the PIE group. In addition, Group 1 is multiplexed into the CPU interrupt INT1. CPU INT1 has the highest hardware priority. PIE Group 2 is multiplexed into the CPU INT2 which is the 2nd highest hardware priority.

2. Periodic, Fast Response

These interrupts occur at a known period, and when they do occur, they must be serviced as quickly as possible to minimize latency. The A/D converter is one good example of this. The A/D sample must be processed with minimum latency.

On the 2802x, such interrupts are allocated to the group 1 in the PIE table. Group 1 is multiplexed into the CPU INT1. CPU INT1 has the highest hardware priority.

3. Periodic

These interrupts occur at a known period and must be serviced before the next interrupt. Some of the PWM interrupts are an example of this. Many of the registers are shadowed, so the user has the full period to update the register values.

In the 2802x PIE module, such interrupts are mapped to group 2 - group 5. These groups are multiplexed into CPU INT3 to INT5 (the ePWM and eCAP), which are the next lowest hardware priority.

4. Periodic, Buffered

These interrupts occur at periodic events, but are buffered and hence the processor need only service such interrupts when the buffers are ready to filled/emptied. All of the serial ports

(SCI/ SPI/ I2C/ CAN/ McBSP) either have FIFOs or multiple mailboxes such that the CPU has plenty of time to respond to the events without fear of losing data.

In the 2802x, such interrupts are mapped to INT6, INT8, and INT9, which are the next lowest hardware priority.

A.3 Software Prioritization of Interrupts - The DSP28 Example

The user will probably find that the PIE interrupts are organized where they should be for most applications. However, some software prioritization may still be required for some applications.

Recall that the basic software priority scheme on the C28x works as follows:

■ Global Priority

This priority can be managed by manipulating the CPU IER register. This register controls the 16 maskable CPU interrupts (INT1 - INT16).

■ Group Priority

This can be managed by manipulating the PIE block interrupt enable registers (PIEIERx). There is one PIEIERx per group and each control the 8-interrupts multiplexed within that group.

The DSP28 software prioritization of interrupt example demonstrates how to configure the Global priority (via IER) and group priority (via PIEIERx) within an ISR in order to change the interrupt service priority based on user assigned levels. The steps required to do this are:

1. Set the global priority

Modify the IER register to allow CPU interrupts with a higher user priority to be serviced.

2. Set the Group priority

Modify the appropriate PIEIERx register to allow group interrupts with a higher user set priority to be serviced.

3. Enable interrupts

The DSP28 software prioritized interrupts example provides a method using mask values that are configured during compile time to allow you to manage this easily.

To setup software prioritization for the DSP28 example, the user must first assign the desired global priority levels and group priority levels.

This is done in the F2802x_SWPrioritizedIsrLevels.h file as follows:

1. User assigns global priority levels

INT1PL - INT16PL

These values are used to assign a priority level to each of the 16 interrupts controlled by the CPU IER register. A value of 1 is the highest priority while a value of 16 is the lowest. More than one interrupt can be assigned the same priority level. In this case the default hardware priority would determine which would be serviced first. A priority of 0 is used to indicate that

the interrupt is not used.

2. *User assigns PIE group priority levels*

GxyPL (where x = PIE group number 1 - 12 and y = interrupt number 1 - 8)

These values are used to assign a priority level to each of the 8 interrupts within a PIE group. A value of 1 is the highest priority while a value of 8 is the lowest. More than one interrupt can be assigned the same priority level. In this case the default hardware priority would determine which would be serviced first. A priority of 0 is used to indicate that the interrupt is not used.

Once the user has defined the global and group priority levels, the compiler will generate mask values that can be used to change the IER and PIEIERx registers within each ISR. In this manner the interrupt software prioritization will be changed. The masks that are generated at compile time are:

■ **IER mask values**

MINT1 - MINT16

The user assigned INT1PL - INT16PL values are used at compile time to calculate an IER mask for each CPU interrupt. This mask value will be used within an ISR to allow CPU interrupts with a higher priority to interrupt the current ISR and thus be serviced at a higher priority level.

■ **PIEIERxy mask values**

MGxy (where x = PIE group number 1 - 12 and y = interrupt number 1 - 8)

The assigned group priority levels (GxyPL) are used at compile time to calculate PIEIERx masks for each PIE group. This mask value will be used within an ISR to allow interrupts within the same group that have a higher assigned priority to interrupt the current ISR and thus be serviced at a higher priority level.

A.3.1 Using the IER/PIEIER Mask Values

Within an interrupt service routine, the global and group priority can be changed by software to allow other interrupts to be serviced. The procedure for setting an interrupt priority using the mask values created in the F2802x_SWPrioritizedIsrLevels.h is the following:

1. **Set the global priority**

- Modify IER to allow CPU interrupts from the same PIE group as the current ISR.
- Modify IER to allow CPU interrupts with a higher user defined priority to be serviced.

2. **Set the group priority**

- Save the current PIEIERx value to a temporary register.
- The PIEIER register is then set to allow interrupts with a higher priority within a PIE group to be serviced.

3. **Enable interrupts**

- Enable all PIE interrupt groups by writing all 1's to the PIEACK register
- Enable global interrupts by clearing INTM

4. **Execute ISR.** Interrupts that were enabled in steps 1-3 (those with a higher software priority) will be allowed to interrupt the current ISR and thus be serviced first.

5. Restore the PIEIERx register**6. Exit****A.3.2 Example Code**

The sample C code below shows an EV-A Comparator 1 Interrupt service routine software prioritization written in C. This interrupt is connected to PIE group 2 interrupt 1.

```
//
// Connected to PIEIER2_1 (use MINT2 and MG21 masks):
//
#if (G21PL != 0)
interrupt void
EPWM1_TZINT_ISR(void)                                // EPWM1 Trip Zone
{
    //
    // Set interrupt priority
    //
    volatile Uint16 TempPIEIER = PieCtrlRegs.PIEIER2.all;
    IER |= M_INT2;
    IER &= MINT2;                                     // Set "global" priority
    PieCtrlRegs.PIEIER2.all &= MG21;                 // Set "group" priority
    PieCtrlRegs.PIEACK.all = 0xFFFF;                 // Enable PIE interrupts
    EINT;

    //
    // Insert ISR Code here
    // for now just insert a delay
    //
    for(i = 1; i <= 10; i++)
    {

    }

    //
    // Restore registers saved
    //
    DINT;
    PieCtrlRegs.PIEIER2.all = TempPIEIER;

    //
    // Add ISR to Trace
    //
    ISRTrace[ISRTraceIndex] = 0x0021;
    ISRTraceIndex++;
}
#endif

CMP1INT_ISR:
    ASP
```

```
ADDB    SP, #1
CLRC    OVM, PAGE0
MOVW    DP, #0x0033
MOV      AL, @36
MOV      *-SP[1], AL
OR       IER, #0x0002
AND      IER, #0x0002
AND      @36, #0x000E
MOV      @33, #0xFFFF
CLRC     INTM
```

User code goes here...

```
SETC     INTM
MOV      AL, *-SP[1]
MOV      @36, AL
SUBB     SP, #1
NASP
IRET
```

The interrupt latency is approx 22 cycles.

/*!

B Internal Oscillator Compensation Functions

Introduction	67
Oscillator Compensation Functions Available in the Header Files and Peripheral Examples Package	69

B.1 Introduction

To compensate the internal oscillator, the Texas Instruments factory takes measurements of the internal oscillator and temperature sensor. It then calculates a reference point for the temperature sensor and oscillator trim and calculates an oscillator trim slope. The trim slope can be used to adjust the oscillator fine trim as the temperature sensor reading moves away from that of the reference point.

The reference point for the internal oscillator consists of two pieces of data. The first is the temperature sensor reading at that point. The second is the oscillator trim values to get 10.0MHz at that temperature. This trim itself is composed of two parts: the fine trim and the coarse trim. Only the fine trim will be adjusted by the compensation procedure. The coarse trim remains the same no matter what temperature the device is at.

The oscillator compensation slope contains the information needed to adjust the oscillator fine trim from the reference fine trim as the temperature moves away from the reference temperature. This slope has the units of oscillator fine trim steps / ADC codes (temperature sensor output).

If X is considered to be the temperature sensor reading and Y is considered to be the oscillator fine trim, then the basic oscillator compensation equation is

$$Y_1 = m * (X_1 - X_0) + Y_0 \quad (\text{B.1})$$

where,

Y_1 is the oscillator fine trim at the current temperature

Y_0 is the oscillator fine trim at the reference temperature

X_1 is the temperature sensor reading at the current temperature

X_0 is the temperature sensor reading at the reference temperature

m is the oscillator compensation slope, which is $\frac{\text{change in oscillator fine trim}}{\text{change in temperature sensor reading}}$

This is equivalent to a line with equation $Y = mX + b$:

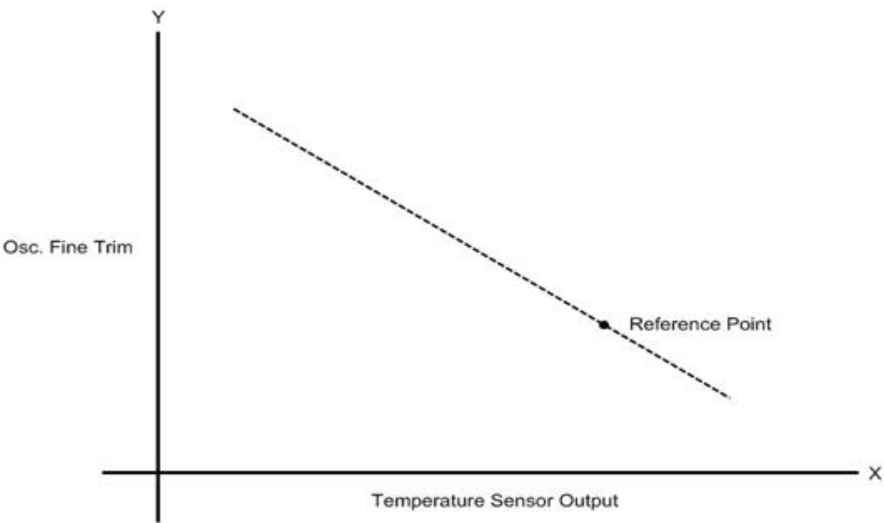


Figure B.1: Oscillator Reference

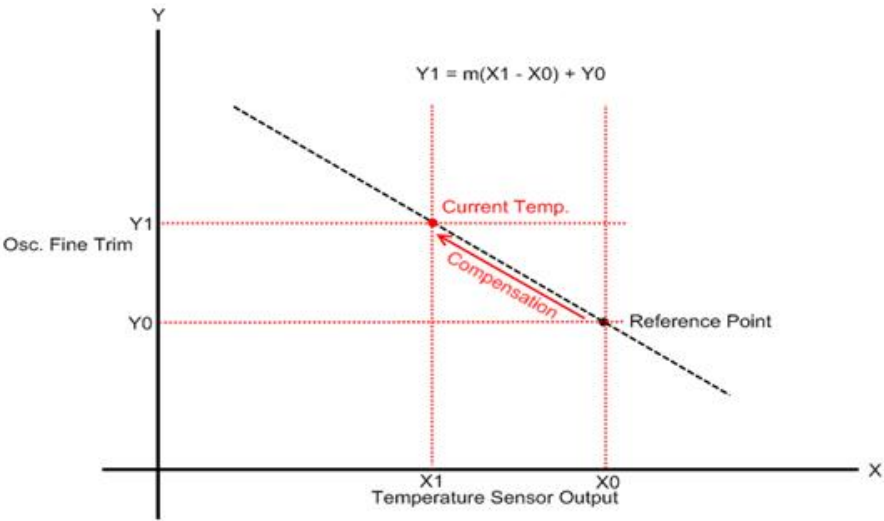


Figure B.2: Oscillator Fine Trim Compensation for change in Temperature

B.2 Oscillator Compensation Functions Available in the Header Files and Peripheral Examples Package

B.2.1 OTP Functions

The following functions in *F2802x_OscComp.c* are programmed in OTP and return variables stored in OTP used for oscillator compensation.

Similar functions following the new conventions of the driver library model can be found in *common/include/osc.h*. These functions are functionally identical but are named with an *OSC_* prefix. For instance instead of *getOsc1FineTrimOffset* the function is called *OSC_getFineTrimOffset1*.

Function Call: *getRefTempOffset()*

OTP address: 0x3D7EA2

Returns: Reference Temperature Offset

This is the temperature sensor reading of the reference point for oscillator compensation.

Function Call: *getOsc1FineTrimOffset()*

OTP address: 0x3D7E93

Returns: Oscillator 1 Fine Trim Offset

This is the fine trim of the reference point for oscillator 1. This is the fine trim required to get 10.0MHz when the temperature sensor reads the value of "High Temperature Offset".

Function Call: *getRefTempOffset()*

OTP address: 0x3D7EA2

Returns: Reference Temperature Offset

Function Call: *getOsc2FineTrimOffset ()*

OTP address: 0x3D7E9C

Returns: Oscillator 2 Fine Trim Offset

This is the fine trim of the reference point for oscillator 2. This is the fine trim required to get 10.0MHz when the temperature sensor reads the value of "High Temperature Offset".

Function Call: *getOsc1FineTrimSlope()*

OTP address: 0x3D7E90

Returns: Oscillator 1 Fine Trim Slope

This is the slope of the oscillator temperature characteristic determined by the factory for internal oscillator 1. Units are oscillator fine trim steps / ADC codes (temperature sensor output). This variable is stored as a Q0.15 fixed point number - e.g. if the slope = -0.04, then this value is stored as $-0.04 \times (215) = -1311$. Note that this will require us to use fixed point math to compensate the oscillator.

Function Call: *getOsc2FineTrimSlope()*

OTP address: 0x3D7E99

Returns: Oscillator 2 Fine Trim Slope

This is the slope of the oscillator temperature characteristic determined by the factory for internal oscillator 2. Units are oscillator fine trim steps / ADC codes (temperature sensor output). This

variable is stored as a Q0.15 fixed point number - e.g. if the slope = -0.04, then this value is stored as $-0.04 \times (215) = -1311$. Note that this will require us to use fixed point math to compensate the oscillator.

Function Call: `getOsc1CoarseTrim()`

OTP address: 0x3D7E96

Returns: Oscillator 1 Coarse Trim

This is the coarse trim to always use for oscillator 1 when doing oscillator compensation.

Function Call: `getOsc2CoarseTrim()`

OTP address: 0x3D7E9F

Returns: Oscillator 2 Coarse Trim

This is the coarse trim to always use for oscillator 2 when doing oscillator compensation.

B.2.2 Oscillator Compensation User Functions

The following functions use the ADC temperature sensor sample as a parameter and update the internal oscillator coarse and fine trim value while compensating for temperature. These functions can be called directly via user application code.

Function Call: `Osc1Comp(int16 sensorSample)`

This function uses the temperature sensor sample reading to perform internal oscillator 1 compensation with reference values stored in OTP.

Function Call: `Osc2Comp(int16 sensorSample)`

This function uses the temperature sensor sample reading to perform internal oscillator 2 compensation with reference values stored in OTP.

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