C55x Digital Signal Processors
Software Overview
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  – Example

• C55x DSP Library (DSPLIB)
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  – Structure
  – Programmer Reference Guide
  – Benchmarks
Chip Support Library (CSL)

C55x DSP Software Overview
The **C55x Chip Support Library (CSL)**:

- Facilitates software development on the following devices: C5504, C5505, C5514, C5515, C5517, C5535, and C5545
- Provides a collection of functions, macros, and symbols used to configure and control on-chip peripherals
- Is fully scalable and does not require the use of DSP/BIOS components to operate
- Contains examples that exercise the various peripherals on the C55x DSP and provides a foundation to build applications
**CSL Benefits**

- **Benefits of CSL:**
  - Peripherals ease of use
  - Shortened development time
  - Portability
  - Hardware abstraction
  - Level of standardization and compatibility among devices

- **Reference for customer driver development:**
  - All source code for CSL is open to customers.
  - Most of CSL is written in C.

- **CCS Compatible:** Examples are provided for CCSv6.
**CSL Structure: Package Contents**

- Release notes and guides.
- Peripheral drivers with source code:

<table>
<thead>
<tr>
<th>DAT</th>
<th>GPIO</th>
<th>I2S</th>
<th>McBSP</th>
<th>PLL</th>
<th>SAR</th>
<th>UHPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMA</td>
<td>GPT</td>
<td>INTC</td>
<td>McSPI</td>
<td>PM</td>
<td>SPI</td>
<td>USB</td>
</tr>
<tr>
<td>EMIF</td>
<td>I2C</td>
<td>LCD</td>
<td>MMC/SD</td>
<td>RTC</td>
<td>UART</td>
<td>WDT</td>
</tr>
</tbody>
</table>

- C55x CSL pre-built library and header files
- API documentation
- CCSv6 example code for the peripherals
- Programming Utility to burn user-specified binaries to memory:

<table>
<thead>
<tr>
<th>NAND Flash</th>
<th>SPI EEPROM</th>
<th>MMC</th>
<th>SPI Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOR Flash</td>
<td>IIC EEPROM</td>
<td>SD</td>
<td>McSPI Flash</td>
</tr>
</tbody>
</table>
These are the top-level directories in the C55XCSL package:

- TMS320C55XXCSL-LOWPWR-XX.XX.XX.XX
  - build
  - ccs_v6.x_examples
  - demos
  - doc
  - drivers
  - inc
  - src
  - webgen
  - Installation_Guide.pdf
  - Release_Notes.txt
  - SWManifest.pdf

The Installation Guide provides details on how to load/build/execute example code in CCS.
These examples can be imported into the CCS workspace, built, and executed on the C55x EVMs. The example folder also contains the programmer tool.

The build directory contains device-specific configuration files for CCS projects.
## CSL Directory Structure: Inc, Src

### inc

The inc directory contains the CSL include files.

### src

The src directory contains the CSL source code.
CSL Directory Structure: Drivers, Doc

The drivers directory contains an SD card driver and example.

The doc directory contains HTML-based documentation describing the various API calls and their arguments.
The demos folder contains associated TI Designs and application notes.
CSL Modules

- CSL consists of modules that are built and archived into a library file.
- Each peripheral is covered by a single module.
- Applications can be built utilizing either the function level or register level.
CSL Naming Conventions

The following conventions are used when naming CSL functions, macros, and data types.

<table>
<thead>
<tr>
<th>Object</th>
<th>Naming Convention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>PER_funcName()</td>
</tr>
<tr>
<td>Variable</td>
<td>PER_varName</td>
</tr>
<tr>
<td>Macro</td>
<td>PER_MACRO_NAME</td>
</tr>
<tr>
<td>Typedef</td>
<td>PER_Typename</td>
</tr>
<tr>
<td>Function Argument</td>
<td>funcArg</td>
</tr>
<tr>
<td>Structure Member</td>
<td>memberName</td>
</tr>
</tbody>
</table>

- All functions, macros, and data types start with PER_ (where PER is the peripheral module) in uppercase letters. At times CSL precedes the PER syntax.
- Function names use all lowercase letters. Uppercase letters are used only if the function name consists of two separate words. For example, PER_getConfig().
- Macro names use all uppercase letters; for example, DMA_INTERRUPT_DISABLE.
In order to better understand the usage of the CSL, let's unpack the `GPIO_output` example contained in the package.

**Step 1:** Include the header files of the module/peripheral, use `<csl_gpio.h>`.

```c
//required include files
#include "csl_gpio.h"
#include "csl_intc.h"
#include <stdio.h>
#include <csl_general.h>
#include "csl_sysctrl.h"

//parameters assoc with the test
#define CSL_TEST_FAILED (-1)
#define CSL_TEST_PASSED (0)

//structures to be used in the example
CSL_GpioObj gpioObj;
CSL_GpioObj *hGpio;
```

**Step 2:** Define the GPIO function prototypes.

```c
int gpio_output_pin_test(void);
int gpio_pin_config_test(void);
```
Step 3: Start defining the test in main(). The returned result from gpio_output_pin_test determines the test outcome.

```c
void main(void)
{
    printf("GPIO Output Pin Test!\n");

    result = gpio_output_pin_test();
    if(CSL_TEST_PASSED == result)
    {
        printf("GPIO Output Pin Test Passed!!\n");
    }
    else
    {
        printf("GPIO Output Pin Test Failed!!\n");
        PaSs_StAtE = 0x0000;
    }
}
```

Gpio_output_pin_test() Unpacked in the next slide

Check the returned value from gpio_output_pin_test() to determine the test result.
gpio_output_pin_test() unpacked

```
int gpio_output_pin_test(void)
{
    status = SYS_setEBSR(CSL_EBSR_FIELD_SP0MODE,
            CSL_EBSR_SP0MODE_2);
    if(CSL_SOK != status)
    {
        printf("SYS_setEBSR failed\n");
        return(CSL_TEST_FAILED);
    }

    hGpio = GPIO_open(&gpioObj, &status);
    if((NULL == hGpio) || (CSL_SOK != status))
    {
        printf("GPIO_open failed\n");
        return(CSL_TEST_FAILED);
    }
    else
    {
        printf("GPIO_open Successful\n");
    }
    GPIO_reset(hGpio);

    config.pinNum    = CSL_GPIO_PIN0;
    config.direction = CSL_GPIO_DIR_OUTPUT;
    config.trigger   = CSL_GPIO_TRIG_CLEAR_EDGE;
    status = GPTO_configBit(hGpio, &config);
    if(CSL_SOK != status)
    {
        printf("GPIO_configBit failed\n");
        return(CSL_TEST_FAILED);
    }

    return(CSL_TEST_PASSED);
}
```

**CSL Example Code**

Pin Muxing for GPIO Pins. Make Port 0 serial and enable an 8-pin parallel port. Set pins A15 to A20 as GPIO.

Open and reset the GPIO module.

Configure GPIO Pin 0 as an output pin.
gpio_output_pin_test() unpacked.

```c
status = GPIO_write(hGpio, CSL_GPIO_PIN0, writeVal);
if(CSL_SOK != status)
{
  printf("GPIO_write Failed\n");
  return(CSL_TEST_FAILED);
}
else
{
  printf("GPIO_write Successful\n");
}

status = GPIO_read(hGpio, CSL_GPIO_PIN0, &readVal);
if(CSL_SOK != status)
{
  printf("GPIO_read failed\n");
  return(CSL_TEST_FAILED);
}
else
{
  printf("GPIO_read Successful\n");
}
if(writeVal == readVal)
{
  printf("Data read is same as data written\n");
}
else
{
  printf("Data read is not same as data written \n");
  return(CSL_TEST_FAILED);
}

status = GPIO_close(hGpio);
if(CSL_SOK != status)
{
  printf("GPIO_close failed\n");
  return(CSL_TEST_FAILED);
}
return(CSL_TEST_PASSED);
```

Write a 1 to the output Pin 0.

Read Pin 0 and compare the read and written data to ensure that they are the same.

Close the GPIO module.
DSP Library (DSPLIB)

C55x DSP Software Overview
C55x DSPLIB: Introduction

- The **TMS320C55x DSP Library (DSPLIB)** from Texas Instruments is an optimized DSP Functions Library designed for use by C programmers on TMS320C55x devices.

- DSPLIB includes over 50 C-callable, assembly-optimized, general-purpose signal processing functions and mathematical functions.
  
  - Signal processing functions are typically used in computationally intensive real-time applications.
  
  - C55x is a fixed point processor. Most of the DSPLIB functions process 16-bit or 32-bit, fixed-point data. A few of the functions process floating-point data (Conversion from FP to Q15).

- Benchmark code and results are provided in the package.

- The package is tested against Matlab scripts.
C55x DSPLIB: DSP Routines

Below are some commonly used DSP routines contained within DSPLIB. These routines can be modified as needed to match the end application:

- Signal Processing: FFT, Filtering, FIR and IIR (complex and real), Convolution and Correlation, Adaptive Filters
- Standard Math: Log, Vector Add, subtract, Minimum, Maximum Reciprocal
- Trigonometry Functions: Sine, Arc tangent
- Linear Algebra: Matrix manipulation and transpose
- Utilities: Random number generation, Q15 to floating-point conversion (and back)
DSPLIB Directory Structure: Root, Src

These are the top-level directories in the DSPLIB package:

- `c55_dsplib_XX.XX.XX.XX`

- `55x_src`

The `55x_src` directory has the source code for all of the library functions. This source is written in assembly and optimized for the C55X architecture.
The build directory has the CCSv3 and CCSv5 main DSPLIB project that pulls in the files from the c55x_src. CCSv6 will be added in the future.

The examples directory has unit tests for ALL functions in the library. The examples provide a great platform to build applications utilizing DSPLIB.
The lib directory contains pre-built libraries as well as a collection of all source code.

The include directory has include files that are needed to call DSPLIB functions.
The twiddle directory contains routines with pre-calculated values used by FFT functions.

The doc directory includes the TMS320C55x DSP Library Programmer's Reference and the DSPLIB Software Manifest.
The **TMS320C55x DSP Library Programmer's Reference** contains descriptions and detailed usage for each of the DSPLIB functions. Below is an example on the `cfft` function:

<table>
<thead>
<tr>
<th><strong>cfft</strong></th>
<th><strong>Forward Complex FFT</strong></th>
</tr>
</thead>
</table>
| **Function** | void cfft (DATA *x, ushort nx, type);  
(defined in cfft.asm) |
| **Arguments** | |
| x [2*nx] | Pointer to input vector containing nx complex elements (2*nx real elements) in normal order. On output, vector contains the nx complex elements of the FFT(x) in bit-reversed order. Complex numbers are stored in interleaved Re-Im format. |
| nx | Number of complex elements in vector x. Must be between 8 and 1024. |
| type | FFT type selector. Types supported:  
- If type = SCALE, scaled version selected  
- If type = NOSCALE, non-scaled version selected |
| **Description** | Computes a complex nx-point FFT on vector x, which is in normal order. The original content of vector x is destroyed in the process. The nx complex elements of the result are stored in vector x in bit-reversed order. The twiddle table is in bit-reversed order. |
Benchmarks and Performance Estimation

The TMS320C55x DSP Library Programmer's Reference provides performance numbers (in cycles) for each FFT function. Below is an example of the benchmarks for the Forward Complex FFT (cfft) function:

<table>
<thead>
<tr>
<th>FFT Size</th>
<th>Cycles†</th>
<th>Code Size (in bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>208</td>
<td>493</td>
</tr>
<tr>
<td>16</td>
<td>358</td>
<td>493</td>
</tr>
<tr>
<td>32</td>
<td>624</td>
<td>493</td>
</tr>
<tr>
<td>64</td>
<td>1210</td>
<td>493</td>
</tr>
<tr>
<td>128</td>
<td>2518</td>
<td>493</td>
</tr>
<tr>
<td>256</td>
<td>5422</td>
<td>493</td>
</tr>
<tr>
<td>512</td>
<td>11848</td>
<td>493</td>
</tr>
<tr>
<td>1024</td>
<td>25954</td>
<td>493</td>
</tr>
</tbody>
</table>

† Assumes all data is in on-chip dual-access RAM and that there is no bus conflict due to twiddle table reads and instruction fetches (provided linker command file reflects those conditions).

The Instructions to Benchmark C55x DSP Library application note describes the process of implementing C55x benchmarks.
For More Information

- C55x Product Folder: http://www.ti.com/c55x
- C55x Chip Support Library (CSL): http://www.ti.com/tool/sprc133
- C55x DSP Library (DSPLIB): http://www.ti.com/tool/sprc100
- C55x Tools w/ programmer, boot image creator, board support package, gel file, schematics, BOM, etc:
  - C5515 EVM Support Page: http://support.spectrumdigital.com/boards/evm5515
  - C5517 EVM Support Page: http://support.spectrumdigital.com/boards/evm5517
  - C5535 eZdsp Support Page: http://support.spectrumdigital.com/boards/ezdsp5535
- Code Composer Studio (CCS) http://www.ti.com/tool/ccstudio
- C55x Training Series: http://training.ti.com/c55x-training-series
- For questions regarding topics covered in this training, visit the C5000 Ultra Low Power DSP Forum at the TI E2E Community website: http://e2e.ti.com/support/dsp/c5000/f/109