VCU and VCRC Software Libraries

USER'S GUIDE

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Revision Information

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Table of Contents

1 Introduction

The Texas Instruments® C28x has 3 different fully programmable blocks VCU (VCU 0/1, VCU-II and VCRC) designed to accelerate the performance of communications and digital signal processing algorithms. To determine the specific VCU module (if any) available on a specific device, see the C2000 Real-Time Control Peripherals Reference Guide.

VCU0/1 (VCU Type0 or Type1) and VCU-II (variously represented as VCU2, VCU-II) provide support for Viterbi, Complex Math and CRC computation and the software libraries vcu0_c28_library and vcu2_c28_library provides users with series of assembly routines, with C wrappers, to carry out many of the DSP algorithms listed below:

1. Complex and Real FFT
2. Viterbi Decoding
3. CRC
4. Reed-Solomon Encoding/Decoding
5. Interleaver/Deinterleaver

VCRC - This is the latest version of the VCU module which contains only CRC functionality. Viterbi and Complex Math functionality have been removed. The module supports computation of fixed polynomial 8-bit, 16-bit, 24-bit, or 32-bit CRCs that existed in VCU2. The VCRC module newly supports user configurable polynomials, flexible both in value and size (1 to 32 bits). It also supports user configurable data sizes (1 to 8 bits). The software library c28x_vcrc_library_fpu32 and c28x_vcrc_library_fpu64 provide users with APIs that can be used for CRC computation. Note that the fixed polynomial APIs running on VCU-II will run as is on VCRC and these APIs have been also included in the VCRC libraries mentioned. VCRC library provides APIs for

1. Fixed Polynomial for 8, 16, 24 and 32 bit CRC
2. Configurable Polynomial and Size for 1 to 32 bit polynomial and 1 to 8 bits size

Chapter 2 provides links for E2E and C2000 web-page and compiler versions used.

Chapter 3 describes the directory structure of the package.

Chapter 4 provides step-by-step instructions on how to integrate the library into a project and use any of the math routines.

Chapter 5 describes the programming interface, structures and routines available for VCU0

Chapter 6 describes the programming interface, structures and routines available for VCU2

Chapter 7 describes the programming interface, structures and routines available for VCRC

The performance of each of the library routines is provided in **Chapter** 8 .

Chapter 9 provides a revision history of the library.

Examples have been provided for each library routine. They can be found in the *examples* directory. For the current revision, all examples for VCU-0 and VCU-II have been written for the *F2837x, F2838x, F28003x, F280013x, F280015x, F28P55x and F28P65x* device and tested on an *F2837x, F2838x, F28003x, F280013x, F280015x, F28P55x and F28P65xcontrolCard* platform. The VCRC examples have been written for the *F2837x, F2838x, F28003x, F280013x, F280015x, F28P55x and F28P65x* devices and tested on *F2837x, F2838x, F28003x, F280013x, F280015x, F28P55x and F28P65xcontrolCard* and *F2837x, F2838x, F28003x, F280013x, F280015x, F28P55x and F28P65xcontrolCard*. Each example has a script **"SetupDebugEnv.js"** that can be launched from the *Scripting Console* in CCS. These scripts will setup the watch variables fro the example. In some examples graphs (.graphProp) are provided; these can be imported into CCS during debug.

2 Other Resources

The user can get answers to their questions using the TI community website: http://e2e.ti.com

Also check out the TI C2000 page: http://www.ti.com/c2000

Also check out the TI C2000 extended instruction set guide to know more about VCU and VCRC capabilities.
Building the VCU-0 aand VCU-II library and examples requires **Codegen Tools v22.6.0** and VCRC library and examples require **Codegen Tools v22.6.0**

3 Library Structure

By default, the libraries and source code is installed into the following directory:

```
C:\ti\c2000\C2000Ware_X_XX_XX_XX\libraries\dsp\VCU
```

There are 8 libraries provided and the table below describes each of them briefly.

Library Name	Description
c28x vcrc library fpu32.lib	Runs on devices which have VCRC and FPU32 and provides CRC functions
c28x vcrc library fpu64.lib	Runs on devices which have VCRC and FPU64 and provides CRC functions
c28x vcu0 crctables library.lib	CRC tables for VCU-0
c28x vcu0 crctables library fpu32.lib	CRC tables for VCU-0 built for devices with fpu32
c28x vcu0 library.lib	Runs on devices which have VCU-0 provides Viterbi, Complex Math and CRC computation
c28x vcu0 library fpu32.lib	Runs on devices which have VCU-0 and FPU32 provides Viterbi, Complex Math and CRC computation
c28x vcu2 library.lib	Runs on devices which have VCU-II provides Viterbi, Complex Math and CRC computation
c28x vcu2 library fpu32.lib	Runs on devices which have VCU-II and FPU32 provides Viterbi, Complex Math and CRC computation

Table 3.1: VCRC and VCU Libraries Description

Figure. 3.1 shows the directory structure while the subsequent table 3.2 provides a description for each folder.

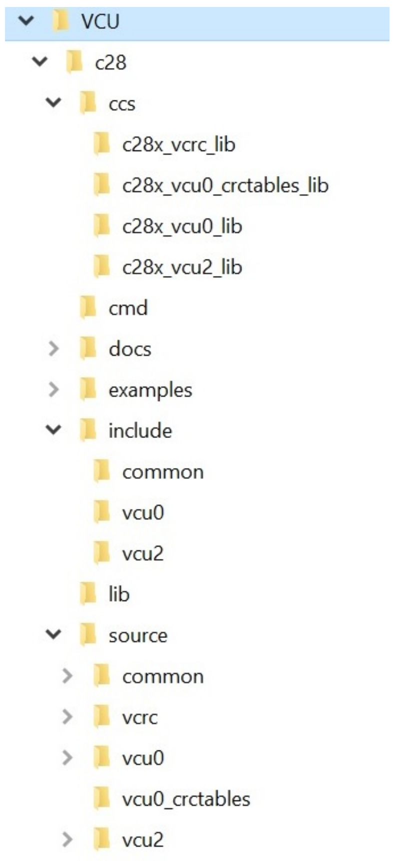


Figure 3.1: Directory Structure of the VCU Library

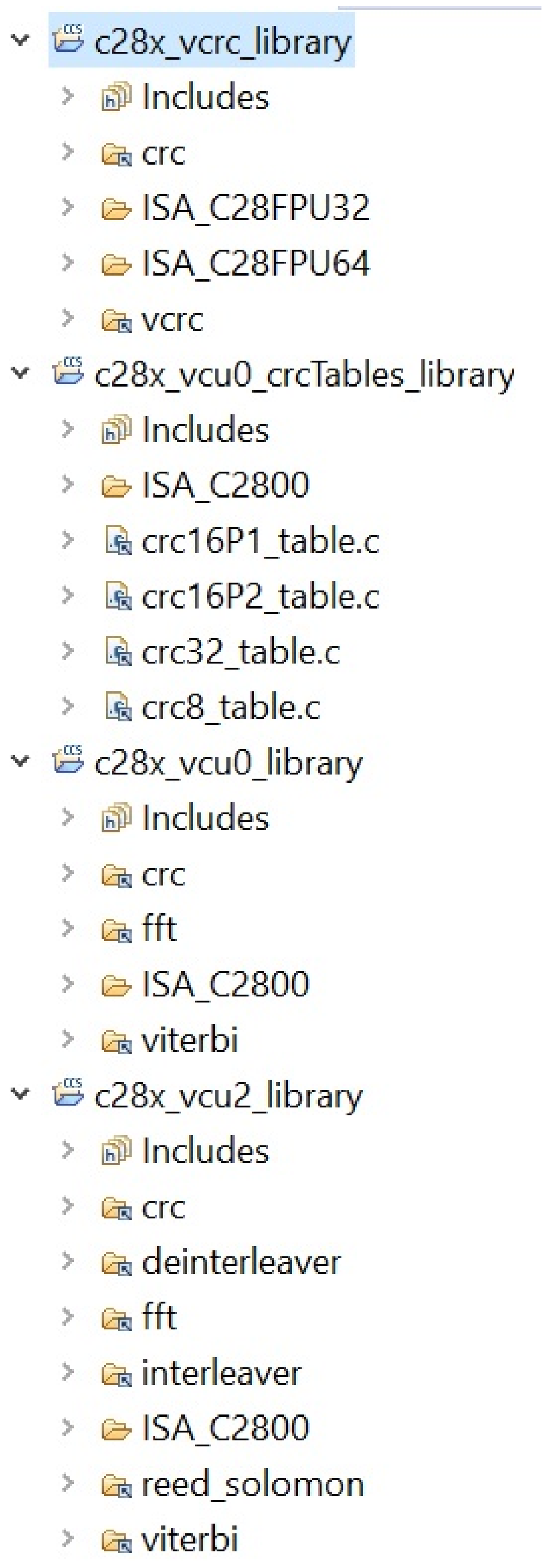
Folder	Description
<base>	Base install directory. By default this is C:/ti/c2000/C2000Ware_X_XX_XX_XX/libraries/dsp/VCU For the rest of this document <base> will be omitted from the directory names
<base>/ccs	Project files for the library. Allows the user to reconfigure, modify and re-build the library to suit their particular needs
<base>/cmd	Linker command files used in the examples
<base>/doc	Documentation for the current revision of the library including revision history
<base>/examples	Examples that illustrate the library functions. VCU-0 and VCU-II examples were built for the F2837x device using the CCS6.0.0.00190 platform and VCRC examples were built for F28003x device using the CCS10.x.
<base>/include	Header files for the VCU library
<base>/lib	Pre-built VCU and VCRC libraries
<base>/source	Source files for the library.

Table 3.2: VCU Library Directory Structure Description

The user will note (Figure. 3.1) that the source, header and project files for the two VCU types, 0 and 2 and VCRC, are maintained in separate sub-directories titled vcu0, vcu2 and vcrc. Each VCU type has its own CCS project and .lib output. This allows for legacy compatibility and easy migration of projects that use the older versions of the library.

4 Using the VCRC and VCU Library

The source code and project(s) for the VCU and VCRC libraries are provided. If you import the library project(s) into CCSv6(or later) you will be able to view and modify the source code for all routines and lookup tables (see Fig. 4.1)



```
c28x_vcrc_library
    Includes
    crc
    ISA_C28FPU32
    ISA_C28FPU64
    vcrc
c28x_vcu0_crcTables_library
    Includes
    ISA_C2800
    crc16P1_table.c
    crc16P2_table.c
    crc32_table.c
    crc8_table.c
c28x_vcu0_library
    Includes
    crc
    fft
    ISA_C2800
    viterbi
c28x_vcu2_library
    Includes
    crc
    deinterleaver
    fft
    interleaver
    ISA_C2800
    reed_solomon
    viterbi
```

Figure 4.1: VCU Library Project View

The current version of the VCU-0 and VCU-II library(s) has two build configurations (Fig. 4.2) **ISA_C2800** and **ISA_C28FPU32**. The difference between the two is the **ISA_C28FPU32** configuration is built with the **–fpu_support=fpu32** run-time support option turned on. This allows the VCU library to be integrated into a project which has the **fpu32** option turned on. Each build configuration, when compiled, yields differently titled libraries: **c28x_vcu<n>_library.lib** for the ISA C2800 build configuration and **c28x_vcu<n>_library_fpu32.lib** for the floating-point supported build. The libraries can be built for either COFF or EABI, with EABI being the default build. The VCRC library has been built for two build configurations **ISA_C28FPU64** and **ISA_C28FPU32**. This allows the VCRC library to be intergrated into a project which has the **fpu32** or **fpu64** option turned on. The VCRC libraries have been built for EABI format only. To use the vcrc ensure to enable the **–vcu_support** option in the **Processor Options** to **vcrc**.

NOTE: ATTEMPTING TO LINK IN THE STANDARD BUILD LIBRARY INTO ANOTHER PROJECT WHICH HAS FPU32 OR FPU64 SUPPORT TURNED ON WILL RESULT IN A COMPILER ERROR ABOUT MISMATCHING INSTRUCTION SET ARCHITECTURES, HENCE THE NEED FOR THE ISA_C28FPU32 AND ISA_C28FPU64 BUILD CONFIGURATION

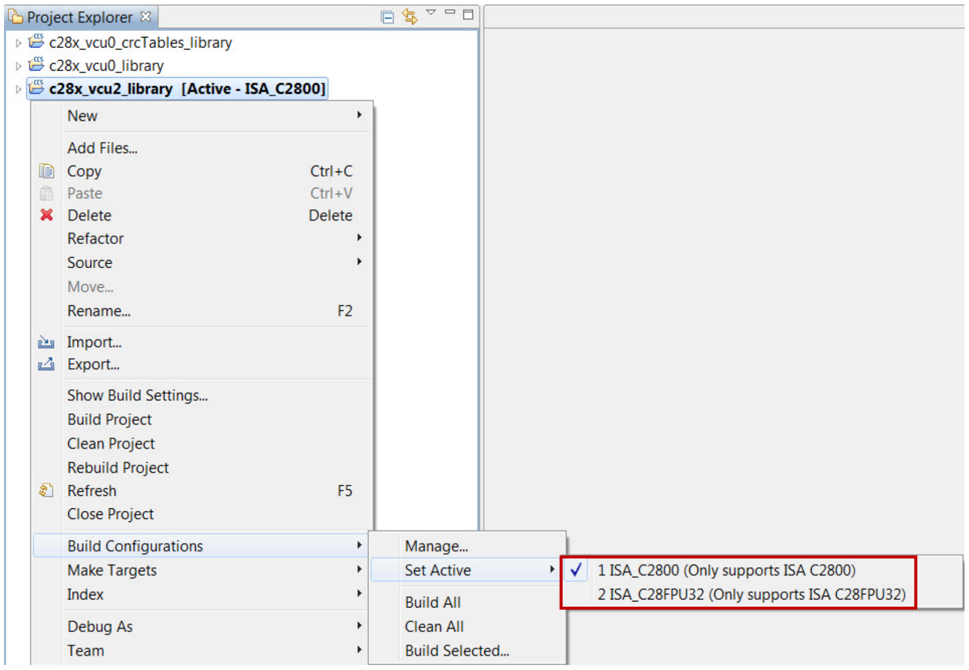
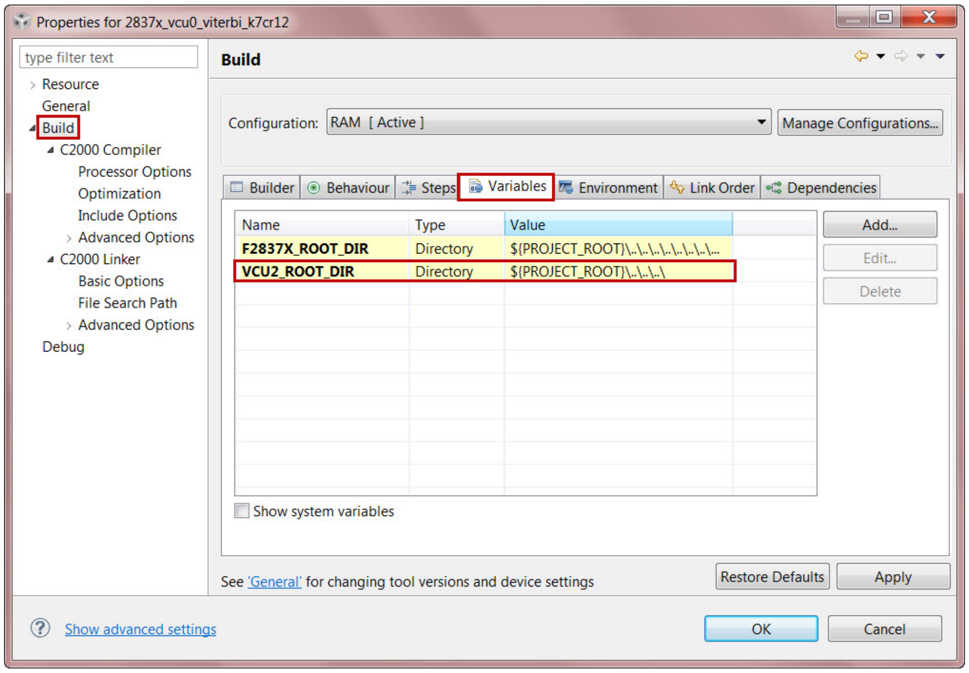


Figure 4.2: Library Build Configurations

To begin integrating the library into your project follow these easy steps:

1. Go to the **Project Properties->Build->Variables(Tab)** and add a new variable (see Fig. 4.3), VCU2_ROOT_DIR, and point it to the root directory of the VCU library in **C2000Ware**.



Configuration: RAM [Active]   Manage Configurations...

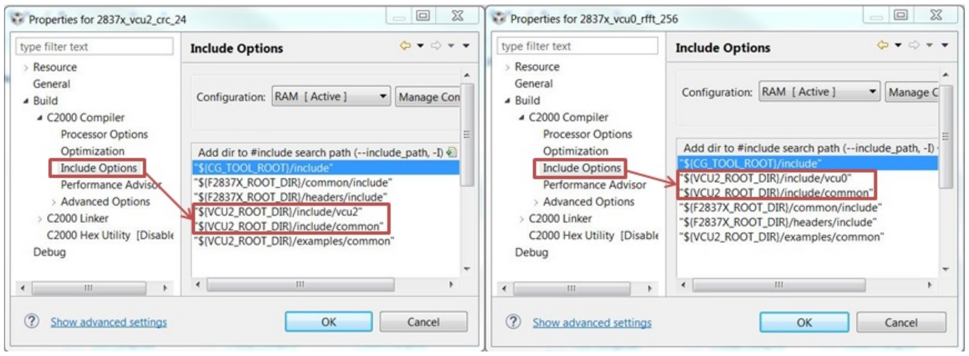
Name	Type	Value
F2837X_ROOT_DIR	Directory	${PROJECT_ROOT}\..\..\..\..\..\..\...
VCU2_ROOT_DIR	Directory	${PROJECT_ROOT}\..\..\..\

☐ Show system variables

See 'General' for changing tool versions and device settings

Figure 4.3: Creating a new build variable

Add the new path, **VCU2_ROOT_DIR**, to the list of search directories. The paths differ depending on whether you are using the vcu0 or vcu2 libraries. Fig. 4.4 shows the Include options of two projects each using a different vcu library.



Configuration: RAM [Active]

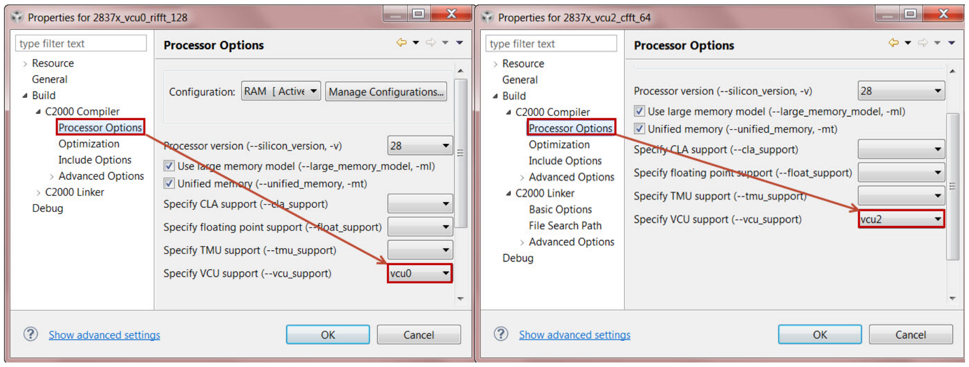
```
Add dir to #include search path (--include_path, -I)
"${CG_TOOL_ROOT}/include"
"${F2837X_ROOT_DIR}/common/include"
"${F2837X_ROOT_DIR}/headers/include"
"${VCU2_ROOT_DIR}/include/vcu2"
"${VCU2_ROOT_DIR}/include/common"
"${VCU2_ROOT_DIR}/examples/common"
```

Configuration: RAM [Active]

```
Add dir to #include search path (--include_path, -I)
"${CG_TOOL_ROOT}/include"
"${VCU2_ROOT_DIR}/include/vcu0"
"${VCU2_ROOT_DIR}/include/common"
"${F2837X_ROOT_DIR}/common/include"
"${F2837X_ROOT_DIR}/headers/include"
"${VCU2_ROOT_DIR}/examples/common"
```

Figure 4.4: Adding the Include Search Path for the Library

2. Enable the **–vcu_support** option in the **Runtime Model Options** to either **vcu0** or **vcu2** depending on the library used (Fig. 4.5).



Properties for 2837x_vcu0_rifft_128

type filter text
- Resource
- General
- Build
  - C2000 Compiler
    - Processor Options
    - Optimization
    - Include Options
    - Advanced Options
  - C2000 Linker
- Debug

Processor Options

Configuration: RAM [Active] Manage Configurations...

Processor version (--silicon_version, -v) 28
☑ Use large memory model (--large_memory_model, -ml)
☑ Unified memory (--unified_memory, -mt)
Specify CLA support (--cla_support)
Specify floating point support (--float_support)
Specify TMU support (--tmu_support)
Specify VCU support (--vcu_support) vcu0

Show advanced settings OK Cancel

Properties for 2837x_vcu2_cfft_64

type filter text
- Resource
- General
- Build
  - C2000 Compiler
    - Processor Options
    - Optimization
    - Include Options
    - Advanced Options
  - C2000 Linker
    - Basic Options
    - File Search Path
    - Advanced Options
- Debug

Processor Options

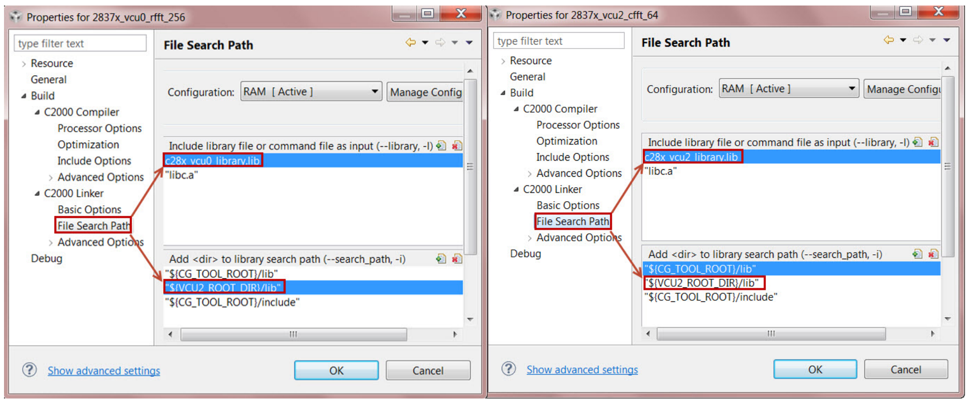
Processor version (--silicon_version, -v) 28
☑ Use large memory model (--large_memory_model, -ml)
☑ Unified memory (--unified_memory, -mt)
Specify CLA support (--cla_support)
Specify floating point support (--float_support)
Specify TMU support (--tmu_support)
Specify VCU support (--vcu_support) vcu2

Show advanced settings OK Cancel

Figure 4.5: Turning on VCU support

3. Add the name of the library and its location to the **File Search Path** as shown in Fig. 4.6. The figure shows build properties for two projects, each using a different vcu library.

   NOTE: IF YOUR PROJECT HAS FPU32 SUPPORT TURNED ON YOU WILL NEED TO ADD THE **c28x_vcu<n>_library_fpu32.lib** LIBRARY IN THE UPPER BOX



Properties for 2837x_vcu0_rfft_256

type filter text
- Resource
- General
- Build
  - C2000 Compiler
    - Processor Options
    - Optimization
    - Include Options
    - Advanced Options
  - C2000 Linker
    - Basic Options
    - File Search Path
    - Advanced Options
- Debug

File Search Path

Configuration: RAM [Active] Manage Config

Include library file or command file as input (--library, -l)
c28x_vcu0_library.lib
"libc.a"

Add <dir> to library search path (--search_path, -i)
"${CG_TOOL_ROOT}/lib"
"${VCU2_ROOT_DIR}/lib"
"${CG_TOOL_ROOT}/include"

Show advanced settings OK Cancel

Properties for 2837x_vcu2_cfft_64

type filter text
- Resource
- General
- Build
  - C2000 Compiler
    - Processor Options
    - Optimization
    - Include Options
    - Advanced Options
  - C2000 Linker
    - Basic Options
    - File Search Path
    - Advanced Options
- Debug

File Search Path

Configuration: RAM [Active] Manage Config

Include library file or command file as input (--library, -l)
c28x_vcu2_library.lib
"libc.a"

Add <dir> to library search path (--search_path, -i)
"${CG_TOOL_ROOT}/lib"
"${VCU2_ROOT_DIR}/lib"
"${CG_TOOL_ROOT}/include"

Show advanced settings OK Cancel

Figure 4.6: Adding the library and location to the file search path

5 Application Program Interface for using VCU0 libraries

5.1 VCU0 Type Defintions

Data Structures

- cplx16

Enumerations

- CRC_parity_e

5.1.1 Data Structure Documentation

5.1.1.1 cplx16

Definition:

```
typedef struct
{
    SINT16 real;
    SINT16 imag;
}
cplx16
```

Members:

real Real Part.

imag Imaginary Part.

Description:

Complex data.

5.1.2 Enumeration Documentation

5.1.2.1 CRC_parity_e

Description:

Parity enumeration.

The parity is used by the CRC algorithm to determine whether to begin calculations from the low byte (EVEN) or from the high byte (ODD) of the first word (16-bit) in the message.

For example, if your message had 10 bytes and started at the address 0x8000 but the first byte was at the high byte position of the first 16-bit word, the user would call the CRC function with odd parity i.e. CRC_parity_odd

Address: HI LO

0x8000 : B0 XX

0x8001 : B2 B1

0x8002 : B4 B3

0x8003 : B6 B5

0x8004 : B8 B7

0x8005 : XX B9

However, if the first byte was at the low byte position of the first 16-bit word, the user would call the CRC function with even parity i.e. CRC_parity_even

Address: HI LO

0x8000 : B1 B0

0x8001 : B3 B2

0x8002 : B5 B4

0x8003 : B7 B6

0x8004 : B9 B8

Enumerators:

CRC_parity_even	Even parity, CRC starts at the low byte of the first word.
CRC_parity_odd	Odd parity, CRC starts at the high byte of the first word.

5.2 Fast Fourier Transform (VCU0)

Data Structures

- cfft16_t

Defines

- cfft16_128P_DEFAULTS
- cfft16_256P_DEFAULTS
- cfft16_64P_BREV_DEFAULTS
- cfft16_64P_DEFAULTS
- rfft16_128P_DEFAULTS
- rfft16_256P_DEFAULTS
- rfft16_512P_DEFAULTS
- rifft16_128P_DEFAULTS
- rifft16_256P_DEFAULTS
- rifft16_64P_DEFAULTS

Functions

- void cfft16_128p_calc (cfft16_t ∗cfft16_handle_s)
- void cfft16_256p_calc (cfft16_t ∗cfft16_handle_s)
- void cfft16_64p_calc (cfft16_t ∗cfft16_handle_s)
- void cfft16_brev (cfft16_t ∗cfft16_handle_s)
- void cfft16_flip_re_img (cfft16_t ∗cfft16_handle_s)
- void cfft16_flip_re_img_conj (cfft16_t ∗cfft16_handle_s)
- void cfft16_init (cfft16_t ∗cfft16_handle_s)
- void cfft16_unpack_asm (cfft16_t ∗cfft16_handle_s)
- void cifft16_pack_asm (cfft16_t ∗cfft16_handle_s)

5.2.1 Data Structure Documentation

5.2.1.1 cfft16_t

Definition:

```
typedef struct
{
    int *ipcbptr;
    int *workptr;
    int *tfptr;
    int size;
    int nrstage;
    int step;
```

```
        int *brevptr;
        void (*init)(void *);
        void (*calc)(void *);
    }
    cfft16_t
```

Members:

ipcbptr input buffer pointer
workptr work buffer pointer
tfptr twiddle factor table pointer
size Number of data points.
nrstage Number of FFT stages.
step Twiddle factor table search step.
brevptr Bit reversal table pointer.
init Function pointer to initialization routine.
calc Function pointer to calculation routine.

Description:

Complex FFT data structure.

5.2.2 Define Documentation

5.2.2.1 cfft16_128P_DEFAULTS

Definition:

```
#define cfft16_128P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 128 sample points.

5.2.2.2 cfft16_256P_DEFAULTS

Definition:

```
#define cfft16_256P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 256 sample points.

5.2.2.3 cfft16_64P_BREV_DEFAULTS

Definition:

```
#define cfft16_64P_BREV_DEFAULTS
```

Description:

Default values for the complex FFT structure for 64 sample points if using bit reversal lookup table (Deprecated)

5.2.2.4 cfft16_64P_DEFAULTS

Definition:

```
#define cfft16_64P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 64 sample points.

5.2.2.5 rfft16_128P_DEFAULTS

Definition:

```
#define rfft16_128P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 128 real sample points.

5.2.2.6 rfft16_256P_DEFAULTS

Definition:

```
#define rfft16_256P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 256 real sample points.

5.2.2.7 rfft16_512P_DEFAULTS

Definition:

```
#define rfft16_512P_DEFAULTS
```

Description:

Default values for the complex FFT structure for 512 real sample points.

5.2.2.8 rifft16_128P_DEFAULTS

Definition:

```
#define rifft16_128P_DEFAULTS
```

Description:

Default values for the Real Inverse FFT structure for 128 points.

5.2.2.9 rifft16_256P_DEFAULTS

Definition:

```
#define rifft16_256P_DEFAULTS
```

Description:

Default values for the Real Inverse FFT structure for 256 points.

5.2.2.10 rifft16_64P_DEFAULTS

Definition:

```
#define rifft16_64P_DEFAULTS
```

Description:

Default values for the Real Inverse FFT structure for 64 points.

5.2.3 Typedef Documentation

5.2.3.1 cfft16_handle_s

Definition:

```
typedef cfft16_t *cfft16_handle_s
```

Description:

Handle to structure.

5.2.4 Function Documentation

5.2.4.1 cfft16_128p_calc

Calculate the 128 pt Complex FFT.

Prototype:

```
void
cfft16_128p_calc(cfft16_t *cfft16_handle_s)
```

Parameters:

cfft16_handle_s Handle to the FFT structure

See also:

cfft16_brev for memory alignment requirements

5.2.4.2 void cfft16_256p_calc (cfft16_t ∗ *cfft16_handle_s*)

Calculate the 256 pt Complex FFT.

Parameters:

cfft16_handle_s Handle to the FFT structure

See also:

cfft16_brev for memory alignment requirements

5.2.4.3 void cfft16_64p_calc (cfft16_t ∗ *cfft16_handle_s*)

Calculate the 64 pt Complex FFT.

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.4.4 void cfft16_brev (cfft16_t ∗ *cfft16_handle_s*)

Bit-Reversed Indexing.

Rearranges the input data in bit-revereesed index format. If the number of FFT stages is even, the data is bit-reversed into the work buffer and then copied back to the input buffer. In this respect the bit reversal is considered to be in-place. For an odd number of stages the bit-reversed output is placed in the work buffer (off-place). The FFT (not the bit reversal function) will then transfer the data back to the input buffer pointed to by ipcbptr

Parameters:
cfft16_handle_s Handle to the FFT structure

Attention:
For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 128 point complex FFT requires an input buffer of size 256 words (16-bit), therefore it must be aligned to a boundary of 256. This can be done by assigning the array to a named section (fftInput) using compiler pragmas (in the example, the input is assigned to .econst and aligned to a boundary of 256 using the .align assembler directive)

```
#pragma DATA_SECTION (CFFT16_128p_in_data, "fftInput")
```

and then either assigning this memory to the start of a RAM block in the linker command file, as is done in the examples, or aligning it to a boundary using the align directive

```
fftInput  : > RAMLS4, ALIGN = 256, PAGE = 1
```

5.2.4.5 void cfft16_flip_re_img (cfft16_t ∗ *cfft16_handle_s*)

Flip real and imaginary parts of complex number.

This functions is needed in the computation of real FFTs to ensure that the real part of the complex number always ends up at the high word (16-bit) of a 32 bit address

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.4.6 void cfft16_flip_re_img_conj (cfft16_t ∗ *cfft16_handle_s*)

Flip real and imaginary parts of complex number and conjugate.

This functions is needed in the computation of real IFFTs to ensure that the real part of the complex number always ends up at the high word (16-bit) of a 32 bit address

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.4.7 void cfft16_init (cfft16_t ∗ *cfft16_handle_s*)

Twiddle Factor Table Initialization.

Initializes the tfptr (twiddle factor pointer)to the start of the twiddle factor table in memory

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.4.8 void cfft16_unpack_asm (cfft16_t ∗ *cfft16_handle_s*)

Real FFT Unpack.

When using an N/2 pt complex FFT to compute the N-pt real FFT, the result of the complex FFT must be unpacked to get the real value. Refer to http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM for the complete derivation and explanation of the algorithm

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.4.9 void cifft16_pack_asm (cfft16_t ∗ *cfft16_handle_s*)

complex IFFT pack

When calculating the IFFT of a Real FFT, the data must be packed before using the complex IFFT to get the result. Refer to http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM for the complete derivation and explanation of the algorithm

Parameters:
cfft16_handle_s Handle to the FFT structure

5.2.5 Real Fast Fourier Transform

It is possible to run the Fast Fourier Transform on a sequence of real data using the complex FFT. For a 2N point real sequence, the user would treat the data as N-pt complex (no rearrangement required) and run it through an N point complex FFT. In order to derive the correct spectrum, you would have to “unpack” the output. The derivations can be found here:

http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM

Similarly, to run an inverse Real FFT, the user would “pack” the data and either run it through an N-point Inverse Complex FFT or an N-point Forward Complex FFT and then conjugating its complex output. Please see the examples folder for how this is done.

Note 1 When running an inverse real FFT after the forward real FFT, the user must take care to first switch the **Input** and **Output** pointers in the FFT object before calling the FFT routine again

Note 2 Because the buffers are switched for the inverse FFT, they must both be aligned to a 2N word boundary.

Note 3 The **pack**, **unpack**, and **FFT** routines scale down the input data to prevent overflows. Therefore, the output of the real inverse FFT process will be a scaled down version of the original. The user may choose to scale the output of intermediate operations to prevent small values being zeroed out

See also:
cfft16_unpack_asm, cifft16_pack_asm, cfft16_flip_re_img, cfft16_flip_re_img_conj

5.3 Cyclic Redundancy Check (VCU0)

Defines

- INIT_CRC16
- INIT_CRC32
- INIT_CRC8
- POLYNOMIAL16_1
- POLYNOMIAL16_2
- POLYNOMIAL32
- POLYNOMIAL8

Functions

- void CRC_reset (void)
- void flipInputBuf_cpu (uint16 ∗dst, uint16 ∗src, uint16 rxLen)
- void genCRC16P1Table ()
- void genCRC16P2Table ()
- void genCRC32Table ()
- void genCRC8Table ()
- uint16 getCRC16P1_cpu (uint16 input_crc16_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint16 getCRC16P1_vcu (uint32 input_crc16_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint16 getCRC16P2_cpu (uint16 input_crc16_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint16 getCRC16P2_vcu (uint32 input_crc16_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint32 getCRC32_cpu (uint32 input_crc32_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint32 getCRC32_vcu (uint32 input_crc32_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint32 getCRC32_vcu_hilo_order_swap (uint32 input_crc32_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint16 getCRC8_cpu (uint16 input_crc8_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)
- uint16 getCRC8_vcu (uint32 input_crc8_accum, uint16 ∗msg, CRC_parity_e parity, uint16 rxLen)

5.3.1 Define Documentation

5.3.1.1 INIT_CRC16

Definition:

```
#define INIT_CRC16
```

Description:
Initial CRC Register Value.

5.3.1.2 INIT_CRC32

Definition:
```
#define INIT_CRC32
```

Description:
Initial CRC Register Value.

5.3.1.3 INIT_CRC8

Definition:
```
#define INIT_CRC8
```

Description:
Initial CRC Register Value.

5.3.1.4 POLYNOMIAL16_1

Definition:
```
#define POLYNOMIAL16_1
```

Description:
CRC16 802.15.4 Polynomial.

5.3.1.5 POLYNOMIAL16_2

Definition:
```
#define POLYNOMIAL16_2
```

Description:
CRC16 Alternate Polynomial.

5.3.1.6 POLYNOMIAL32

Definition:
```
#define POLYNOMIAL32
```

Description:
CRC32 PRIME Polynomial.

5.3.1.7 POLYNOMIAL8

Definition:

```
#define POLYNOMIAL8
```

Description:

CRC8 PRIME Polynomial.

5.3.2 Function Documentation

5.3.2.1 CRC_reset

Workaround to the silicon issue of first VCU calculation on power up being erroneous.

Prototype:

```
void
CRC_reset(void)
```

Description:

Due to the internal power-up state of the VCU module, it is possible that the first CRC result will be incorrect. This condition applies to the first result from each of the eight CRC instructions. This rare condition can only occur after a power-on reset, but will not necessarily occur on every power on. A warm reset will not cause this condition to reappear. The application can reset the internal VCU CRC logic by performing a CRC calculation of a single byte in the initialization routine. This routine only needs to perform one CRC calculation and can use any of the CRC instructions

5.3.2.2 void flipInputBuf_cpu (uint16 ∗ *dst*, uint16 ∗ *src*, uint16 *rxLen*)

VCU(ASM)- function to flip a 16b input buffer.

Flip/Bit-reverse an input buffer This function is added on VCU0 where the VCU hardware does not contain support (unlike in VCU2) to input bytes in bit reversed order for CRC computation hence this "Reflection" needs to be done in software

Parameters:

dst Pointer to the 16b output buffer

src Pointer to the 16b input buffer

rxLen Number of 16b words to be flipped

5.3.2.3 genCRC16P1Table

Generate the CRC lookup table using the polynomial 0x8005.

Prototype:

```
void
genCRC16P1Table()
```

Description:

This function generates the CRC16 table for every possible byte, i.e. 2^8 = 256 table values, using the CRC16_802_15_4 polynomial 0x8005. It expects a global array, crc16p1_table, to be defined in the application code

5.3.2.4 void genCRC16P2Table ()

Generate the CRC lookup table using the polynomial 0x1021.

This function generates the CRC16 table for every possible byte, i.e. 2^8 = 256 table values, using the CRC16_ALT polynomial 0x1021. It expects a global array, crc16p2_table, to be defined in the application code

5.3.2.5 void genCRC32Table ()

Generate the CRC lookup table using the polynomial 0x04c11db7.

This function generates the CRC32 table for every possible byte, i.e. 2^8 = 256 table values, using the CRC32_PRIME polynomial 0x04c11db7. It expects a global array, crc32_table, to be defined in the application code

5.3.2.6 void genCRC8Table ()

Generate the CRC lookup table using the polynomial 0x7.

This function generates the CRC8 table for every possible byte, i.e. 2^8 = 256 table values, using the CRC8_PRIME polynomial 0x07. It expects a global array, crc8_table, to be defined in the application code

5.3.2.7 uint16 getCRC16P1_cpu (uint16 *input_crc16_accum*, uint16 ∗ *msg*, CRC_parity_e *parity*, uint16 *rxLen*)

C- function to get the 16-bit CRC.

Calculate the 16-bit CRC of a message buffer by using the lookup table, crc16p1_table, based on the polynomial 0x8005.

Parameters:

input_crc16_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc16 can be used as the initial value for the current segment crc16 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.8 getCRC16P1_vcu

VCU(ASM)- function to get the 16-bit CRC.

Prototype:

```
uint16
getCRC16P1_vcu(uint32 input_crc16_accum,
               uint16 *msg,
               CRC_parity_e parity,
               uint16 rxLen)
```

Description:
Calculate the 16-bit CRC of a message buffer by using the VCU instructions VCRC16P1H_1 and VCRC16P1L_1

Parameters:

input_crc16_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc16 can be used as the initial value for the current segment crc16 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:
CRC result

5.3.2.9 getCRC16P2_cpu

C- function to get the 16-bit CRC.

Prototype:

```
uint16
getCRC16P2_cpu(uint16 input_crc16_accum,
               uint16 *msg,
               CRC_parity_e parity,
               uint16 rxLen)
```

Description:
Calculate the 16-bit CRC of a message buffer by using the lookup table, crc16p2_table, based on the polynomial 0x1021.

Parameters:

input_crc16_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc16 can be used as the initial value for the current segment crc16 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:
CRC result

5.3.2.10 getCRC16P2_vcu

VCU(ASM)- function to get the 16-bit CRC.

Prototype:

```
uint16
getCRC16P2_vcu(uint32 input_crc16_accum,
               uint16 *msg,
               CRC_parity_e parity,
               uint16 rxLen)
```

Description:

Calculate the 16-bit CRC of a message buffer by using the VCU instructions VCRC16P2H_1 and VCRC16P2L_1

Parameters:

input_crc16_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc16 can be used as the initial value for the current segment crc16 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.11 getCRC32_cpu

C- function to get the 32-bit CRC.

Prototype:

```
uint32
getCRC32_cpu(uint32 input_crc32_accum,
             uint16 *msg,
             CRC_parity_e parity,
             uint16 rxLen)
```

Description:

Calculate the 32-bit CRC of a message buffer by using the lookup table, crc32_table, based on the polynomial 0x04c11db7.

Parameters:

input_crc32_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc32 can be used as the initial value for the current segment crc32 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.12 getCRC32_vcu

VCU(ASM)- function to get the 32-bit CRC.

Prototype:

```
uint32
getCRC32_vcu(uint32 input_crc32_accum,
             uint16 *msg,
             CRC_parity_e parity,
             uint16 rxLen)
```

Parameters:

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.13 uint32 getCRC32_vcu_hilo_order_swap (uint32 *input_crc32_accum*, uint16 ∗ *msg*, CRC_parity_e *parity*, uint16 *rxLen*)

VCU(ASM)- function to get the 32-bit CRC.

Calculate the 32-bit CRC of a message buffer by using the VCU instructions VCRC32L_1 and VCRC32H_1 For a given 16b memory word, CRC is computed first on the high byte in memory followed by the low byte in memory

Parameters:

input_crc32_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc32 can be used as the initial value for the current segment crc32 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.14 uint16 getCRC8_cpu (uint16 *input_crc8_accum*, uint16 ∗ *msg*, CRC_parity_e *parity*, uint16 *rxLen*)

C- function to get the 8-bit CRC.

Calculate the 8-bit CRC of a message buffer by using the lookup table, crc8_table, based on the polynomial 0x7.

Parameters:

input_crc8_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc8 can be used as the initial value for the current segment crc8 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word

rxLen Length of the message in bytes

Returns:

CRC result

5.3.2.15 uint16 getCRC8_vcu (uint32 *input_crc8_accum*, uint16 ∗ *msg*, CRC_parity_e *parity*, uint16 *rxLen*)

VCU(ASM)- function to get the 8-bit CRC.

Calculate the 8-bit CRC of a message buffer by using the VCU instructions, VCRC8L_1 and VCRC8H_1

Parameters:

input_crc8_accum The seed value for the CRC, in the event of a multi-part message, the result of the previous crc8 can be used as the initial value for the current segment crc8 calculation until the final crc is derived.

msg Address of the message buffer

parity Parity of the first message word. The parity determines whether the CRC begins at the low byte (CRC_parity_even) or at the high byte (CRC_parity_odd) of the first word determines whether the CRC begins at the low byte (EVEN) or at the high byte (ODD).

rxLen Length of the message in bytes

Returns:

CRC result

5.4 Viterbi Decoding (VCU0)

Enumerations

- vitMode_t

Functions

- void cnvDec_asm (int nBits, int ∗in_p, int ∗out_p, int flag)
- void cnvDecInit_asm (int nTranBits)
- void cnvDecMetricRescale_asm ()

Variables

- int32 VIT_gold_vt_data[ ]
- int16 VIT_in_data[ ]
- int16 VIT_quant_data[ ]

5.4.1 Enumeration Documentation

5.4.1.1 vitMode_t

Description:
Viterbi decode mode enumeration.

Enumerators:

CNV_DEC_MODE_DEC_ALL Decodes all output bits.

CNV_DEC_MODE_OVLP_INIT Use window overlap method, only metrics and transitions update

CNV_DEC_MODE_OVLP_DEC Use window overlap method, update transitions/metrics/trace through current & previous blocks, decode previous block only

CNV_DEC_MODE_OVLP_LAST last block in overlap

5.4.2 Function Documentation

5.4.2.1 cnvDec_asm

Viterbi Decoder

Prototype:

```
void
cnvDec_asm(int nBits,
           int *in_p,
           int *out_p,
           int flag)
```

Description:

This routine performs the trellis decoding. It has four modes of operation

- 0: Update metrics and transition history, trace and decodes all (for header packets)
- 1: Update metrics and transition history for only 1st block in payload
- 2: Update metrics and transition history, trace back through the current and previous blocks, decodes previos block giving nBits/2 bits
- 3: Update metrics and transition history, trace back through the current and previous blocks, decodes current and previos block giving nBits/2 bits

Parameters:

nBits Number of Coded bits for this block

in_p Address of input buffer

out_p Address of output buffer

flag Mode of operation

5.4.2.2 cnvDecInit_asm

Initialize Viterbi Decoder.

Prototype:

```
void
cnvDecInit_asm(int nTranBits)
```

Description:

Initialize state metric table to a large negative value given by CNV_DEC_METRIC_INIT and initialize the transition and wrap pointers

Parameters:

nTranBits Number of Coded bits

5.4.2.3 cnvDecMetricRescale_asm

State Metrics Rescale.

Prototype:

```
void
cnvDecMetricRescale_asm()
```

Description:

Rescale the state metrics by finding the lowest metric and dividing the rest by it. This prevents overflow between successive decoder stages

5.4.3 Variable Documentation

5.4.3.1 int32 VIT_gold_vt_data[ ]

Golden trace history (VT0/VT1); can be used to verify functionality.

5.4.3.2 int16 VIT_in_data[ ]

Input fed into the C-model encoder.

5.4.3.3 int16 VIT_quant_data[ ]

Output from the C-model encoder.

6 Application Program Interface for using VCU2 libraries

6.1 VCU2 Type Defintions

Data Structures

- complexShort_t

Enumerations

- Bool_e

6.1.1 Data Structure Documentation

6.1.1.1 complexShort_t

Definition:

```
typedef struct
{
    int16_t real;
    int16_t imag;
}
complexShort_t
```

Members:

real Real Part.

imag Imaginary Part.

Description:

Complex data (CPACK = 0).

On reset the CPACK bit is 0, therefore, this is the default complex structure

6.1.2 Enumeration Documentation

6.1.2.1 Bool_e

Description:

Boolean enumeration.

6.2 Fast Fourier Transform (VCU2)

Data Structures

- _CFFT_Obj_

Functions

- void CFFT_conjugate (void ∗pBuffer, uint16_t size)
- void CFFT_init1024Pt (CFFT_Handle hndCFFT)
- void CFFT_init128Pt (CFFT_Handle hndCFFT)
- void CFFT_init256Pt (CFFT_Handle hndCFFT)
- void CFFT_init32Pt (CFFT_Handle hndCFFT)
- void CFFT_init512Pt (CFFT_Handle hndCFFT)
- void CFFT_init64Pt (CFFT_Handle hndCFFT)
- void CFFT_pack (CFFT_Handle hndCFFT)
- void CFFT_run1024Pt (CFFT_Handle hndCFFT)
- void CFFT_run128Pt (CFFT_Handle hndCFFT)
- void CFFT_run256Pt (CFFT_Handle hndCFFT)
- void CFFT_run32Pt (CFFT_Handle hndCFFT)
- void CFFT_run512Pt (CFFT_Handle hndCFFT)
- void CFFT_run64Pt (CFFT_Handle hndCFFT)
- void CFFT_unpack (CFFT_Handle hndCFFT)
- void ICFFT_run1024Pt (CFFT_Handle hndCFFT)
- void ICFFT_run128Pt (CFFT_Handle hndCFFT)
- void ICFFT_run256Pt (CFFT_Handle hndCFFT)
- void ICFFT_run32Pt (CFFT_Handle hndCFFT)
- void ICFFT_run512Pt (CFFT_Handle hndCFFT)
- void ICFFT_run64Pt (CFFT_Handle hndCFFT)

Variables

- const int16_t ∗ vcu0_twiddleFactors
- const int16_t ∗ vcu2_twiddleFactors

6.2.1 Data Structure Documentation

6.2.1.1 _CFFT_Obj_

Definition:

```
typedef struct
{
    int16_t *pInBuffer;
    int16_t *pOutBuffer;
    const int16_t *pTwiddleFactors;
    int16_t nSamples;
    int16_t nStages;
    int16_t twiddleSkipStep;
    void (*init)(void *);
    void (*run)(void *);
}
_CFFT_Obj_
```

Members:

pInBuffer Input buffer pointer.
pOutBuffer Output buffer pointer.
pTwiddleFactors Twiddle Factor pointer.
nSamples Number of samples.
nStages HASH(0x555f9214d590)
twiddleSkipStep Twiddle factor table search(skip) step.
init Function pointer to CFFT initialization routine.
run Function pointer to CFFT computation routine.

Description:

CFFT structure.

6.2.2 Function Documentation

6.2.2.1 CFFT_conjugate

Take the complex conjugate of the entries in an array of complex numbers.

Prototype:

```
void
CFFT_conjugate(void *pBuffer,
               uint16_t size)
```

Parameters:

pBuffer Pointer to the buffer of complex data to be conjugated
← ***size*** Size of the buffer (multiple of 2 32-bits locations)

6.2.2.2 void CFFT_init1024Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.3 void CFFT_init128Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.4 void CFFT_init256Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.5 void CFFT_init32Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

This routine is used to initialize the CFFT object and must be called atleast once before using either the CFFT or ICFFT routines

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.6 void CFFT_init512Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.7 void CFFT_init64Pt (CFFT_Handle *hndCFFT*)

Initializes the CFFT object.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

6.2.2.8 void CFFT_pack (CFFT_Handle *hndCFFT*)

Pack the input prior to running the inverse complex FFT to get the real inverse FFT.

In order to reverse the process of the forward real FFT,

$$F_e(k) = \frac{F(k) + F(\frac{N}{2} - k)^*}{2}$$

$$F_o(k) = \frac{F(k) - F(\frac{N}{2} - k)^*}{2} e^{\frac{j2\pi k}{N}}$$

where f_e is the even elements, f_o the odd elements. The array for the IFFT then becomes:

$$Z(k) = F_e(k) + jF_o(k),\ k = 0...\frac{N}{2} - 1$$

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

Note:
- This is an in-place algorithm; the routine writes the output to the input buffer itself
- The assumption is that the user will run the packed sequence through an IFFT sequence i.e. conjugate -> Forward FFT -> conjugate. The packed output is conjugated in this routine obviating the need for the first conjugate in the IFFT sequence

See also:
http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM for the entire derivation

6.2.2.9 void CFFT_run1024Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

Attention:
For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 1024 point complex FFT requires an input buffer of size 2048 words (16-bit), therefore it must be aligned to a boundary of 2048. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMGS4, ALIGN = 2048, PAGE = 1
```

Note:
The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.10 void CFFT_run128Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 128 point complex FFT requires an input buffer of size 256 words (16-bit), therefore it must be aligned to a boundary of 256. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 256, PAGE = 1
```

6.2.2.11 void CFFT_run256Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 256 point complex FFT requires an input buffer of size 512 words (16-bit), therefore it must be aligned to a boundary of 512. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 512, PAGE = 1
```

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.12 void CFFT_run32Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 32 point complex FFT requires an input buffer of size 64 words (16-bit), therefore it must be aligned to a boundary of 64. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 64, PAGE = 1
```

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.13 void CFFT_run512Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 512 point complex FFT requires an input buffer of size 1024 words (16-bit), therefore it must be aligned to a boundary of 1024. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMGS4, ALIGN = 1024, PAGE = 1
```

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.14 void CFFT_run64Pt (CFFT_Handle *hndCFFT*)

Runs the Complex FFT routine.

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 64 point complex FFT requires an input buffer of size 128 words (16-bit), therefore it must be aligned to a boundary of 128. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 128, PAGE = 1
```

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.15 void CFFT_unpack (CFFT_Handle *hndCFFT*)

Unpack the complex FFT output to get the FFT of two interleaved real sequences.

In order to get the FFT of a real N-pt sequences, we treat the input as an N/2 pt complex sequence, take its complex FFT, use the following properties to get the N-pt Fourier transform of the real sequence

$$FFT_n(k,f) = FFT_{N/2}(k,f_e) + e^{\frac{-j2\pi k}{N}} FFT_{N/2}(k,f_o)$$

where f_e is the even elements, f_o the odd elements and

$$F_e(k) = \frac{Z(k) + Z(\frac{N}{2}-k)^*}{2}$$

$$F_o(k) = -j\frac{Z(k) - Z(\frac{N}{2}-k)^*}{2}$$

We get the first N/2 points of the FFT by combining the above two equations

$$F(k) = F_e(k) + e^{\frac{-j2\pi k}{N}} F_o(k)$$

Parameters:

← ***hndCFFT*** handle to the CFFT object

Note:

This is an in-place algorithm; the routine writes the output to the input buffer itself

See also:

http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM for the entire derivation

6.2.2.16 void ICFFT_run1024Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N-n), n \in \{1, N-1\}$$

, where N is the sample size

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 1024 point complex FFT requires an input buffer of size 2048 words (16-bit), therefore it must be aligned to a boundary of 2048. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMGS4, ALIGN = 2048, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pIn-Buffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOut-Buffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.17 void ICFFT_run128Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N-n), n \in \{1, N-1\}$$

, where N is the sample size

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 128 point complex FFT requires an input buffer of size 256 words (16-bit), therefore it must be aligned to a boundary of 256. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 256, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pIn-Buffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.18 void ICFFT_run256Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N - n), n \in \{1, N - 1\}$$

, where N is the sample size

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

Attention:
For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 256 point complex FFT requires an input buffer of size 512 words (16-bit), therefore it must be aligned to a boundary of 512. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 512, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

6.2.2.19 void ICFFT_run32Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N - n), n \in \{1, N - 1\}$$

, where N is the sample size

Parameters:
$\leftarrow$ ***hndCFFT*** handle to the CFFT object

Attention:
For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 32 point complex FFT requires an input buffer of size 64 words (16-bit), therefore it must be aligned to a boundary of 64. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 64, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.20 void ICFFT_run512Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N-n), n \in \{1, N-1\}$$

, where N is the sample size

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 512 point complex FFT requires an input buffer of size 1024 words (16-bit), therefore it must be aligned to a boundary of 1024. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMGS4, ALIGN = 1024, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.2.21 void ICFFT_run64Pt (CFFT_Handle *hndCFFT*)

Runs the Complex Inverse FFT routine.

Run the forward FFT on the input and rearrange the output as follows:

$$x(0) = x'(0)$$

$$x(n) = x'(N - n), n \in \{1, N - 1\}$$

, where N is the sample size

Parameters:

← ***hndCFFT*** handle to the CFFT object

Attention:

For bit reverse addressing to work, the input buffer must be aligned to size of the buffer in words (16-bit). For example, the 64 point complex FFT requires an input buffer of size 128 words (16-bit), therefore it must be aligned to a boundary of 128. This can be done by assigning the array to a named section (buffer1) using compiler pragmas

```
#pragma DATA_SECTION(buffer1Q15,"buffer1")
```

and then either assigning this memory to the start of a RAM block in the linker command file or aligning it to a boundary using the align directive

```
buffer1 : > RAMLS3, ALIGN = 128, PAGE = 1
```

If the output buffer of the forward FFT becomes the input to the IFFT, then it must be aligned to the same word (16-bit) boundary as well.

Note:

The algorithm ping-pongs between the two buffers, i.e. the buffers pointed to by **pInBuffer** and **pOutBuffer**, at every stage. Depending on the number of stages the output may be in either of the two buffers; the algorithm will switch the pointers **pOutBuffer** and **pInBuffer** in the event that the output ends up in the original input buffer, with the end result that **pOutBuffer** always points to the output.

6.2.3 Variable Documentation

6.2.3.1 const int16_t$*$ vcu0_twiddleFactors

VCU0 twiddle factors.

6.2.3.2 const int16_t$*$ vcu2_twiddleFactors

VCU2 twiddle factors.

6.2.4 Real Fast Fourier Transform

It is possible to run the Fast Fourier Transform on a sequence of real data using the complex FFT. For a 2N point real sequence, the user would treat the data as N-pt complex (no rearrangement required) and run it through an N point complex FFT. In order to derive the correct spectrum, you would have to “unpack” the output. The derivations can be found here:

http://www.engineeringproductivitytools.com/stuff/T0001/PT10.HTM

Similarly, to run an inverse Real FFT, the user would “pack” the data and run it through an N-point Forward Complex FFT and then conjugate its complex output to get the original signal.

Note 1 When running an inverse real FFT after the forward real FFT, the user must take care to first switch the **Input (pInBuffer)** and **Output (pOutBuffer)** pointers in the FFT object before calling the FFT routine again

Note 2 Because the buffers are switched for the inverse FFT, they must both be aligned to a 2N word boundary. **buffer1Q15** must be aligned since it is the input to the forward real FFT, while **buffer2Q15** is the input to the inverse real FFT; it must also be aligned

Note 3 The **pack**, **unpack**, and **FFT** routines scale down the input data to prevent overflows. Therefore, the output of the real inverse FFT process will be a scaled down version of the original. The user may choose to scale the output of intermediate operations to prevent small values being zeroed out

Note 4 Refer to the project, **2837x_vcu_rfft_128**, in the examples folder for a demonstration of the entire process

See also:
CFFT_pack, CFFT_unpack, CFFT_conjugate

6.3 Cyclic Redundancy Check (VCU2)

Data Structures

- _CRC_Obj_

Defines

- INIT_CRC16
- INIT_CRC24
- INIT_CRC32
- INIT_CRC8

Enumerations

- CRC_parity_e

Functions

- uint32_t CRC_bitReflect (uint32_t valToReverse, int16_t bitWidth)
- void CRC_init16Bit (CRC_Handle hndCRC)
- void CRC_init24Bit (CRC_Handle hndCRC)
- void CRC_init32Bit (CRC_Handle hndCRC)
- void CRC_init8Bit (CRC_Handle hndCRC)
- uint16_t CRC_pow2 (uint16_t power)
- void CRC_reset (void)
- void CRC_run16BitPoly1 (CRC_Handle hndCRC)
- void CRC_run16BitPoly1Reflected (CRC_Handle hndCRC)
- void CRC_run16BitPoly2 (CRC_Handle hndCRC)
- void CRC_run16BitPoly2Reflected (CRC_Handle hndCRC)
- void CRC_run16BitReflectedTableLookupC (CRC_Handle hndCRC)
- void CRC_run16BitTableLookupC (CRC_Handle hndCRC)
- void CRC_run24Bit (CRC_Handle hndCRC)
- void CRC_run24BitReflected (CRC_Handle hndCRC)
- void CRC_run24BitReflectedTableLookupC (CRC_Handle hndCRC)
- void CRC_run24BitTableLookupC (CRC_Handle hndCRC)
- void CRC_run32BitPoly1 (CRC_Handle hndCRC)

- void CRC_run32BitPoly1Reflected (CRC_Handle hndCRC)
- void CRC_run32BitPoly2 (CRC_Handle hndCRC)
- void CRC_run32BitPoly2Reflected (CRC_Handle hndCRC)
- void CRC_run32BitReflectedTableLookupC (CRC_Handle hndCRC)
- void CRC_run32BitTableLookupC (CRC_Handle hndCRC)
- void CRC_run8Bit (CRC_Handle hndCRC)
- void CRC_run8BitReflected (CRC_Handle hndCRC)
- void CRC_run8BitTableLookupC (CRC_Handle hndCRC)

6.3.1 Data Structure Documentation

6.3.1.1 _CRC_Obj_

Definition:

```
typedef struct
{
    uint32_t seedValue;
    uint16_t nMsgBytes;
    CRC_parity_e parity;
    uint32_t crcResult;
    void *pMsgBuffer;
    void *pCrcTable;
    uint32_t nMsgBits;
    uint32_t polynomial;
    uint16_t polySize;
    uint16_t dataSize;
    uint16_t reflected;
    void (*init)(void *);
    void (*run)(void *);
}
_CRC_Obj_
```

Members:

seedValue Initial value of the CRC calculation.
nMsgBytes the number of bytes in the message buffer
parity the location, in a word, of the first byte of the CRC calculation
crcResult the calculated CRC
pMsgBuffer Pointer to the message buffer.
pCrcTable Pointer to the CRC lookup table.
nMsgBits
polynomial
polySize
dataSize
reflected
init Function pointer to CRC initialization routine.
run Function pointer to CRC computation routine.

Description:
CRC structure.

6.3.2 Define Documentation

6.3.2.1 INIT_CRC16

Definition:
```
#define INIT_CRC16
```

Description:
Initial CRC Register Value.

6.3.2.2 INIT_CRC24

Definition:
```
#define INIT_CRC24
```

Description:
Initial CRC Register Value.

6.3.2.3 INIT_CRC32

Definition:
```
#define INIT_CRC32
```

Description:
Initial CRC Register Value.

6.3.2.4 INIT_CRC8

Definition:
```
#define INIT_CRC8
```

Description:
Initial CRC Register Value.

6.3.3 Typedef Documentation

6.3.3.1 CRC_Handle

Definition:
```
typedef CRC_Obj *CRC_Handle
```

Description:
Handle to the CRC structure.

6.3.3.2 CRC_Obj

Definition:

```
typedef struct _CRC_Obj_ CRC_Obj
```

Description:

CRC structure.

6.3.4 Enumeration Documentation

6.3.4.1 CRC_parity_e

Description:

Parity enumeration.

The parity is used by the CRC algorithm to determine whether to begin calculations from the low byte (EVEN) or from the high byte (ODD) of the first word (16-bit) in the message.

For example, if your message had 10 bytes and started at the address 0x8000 but the first byte was at the high byte position of the first 16-bit word, the user would call the CRC function with odd parity i.e. CRC_parity_odd

Address: HI LO

0x8000 : B0 XX

0x8001 : B2 B1

0x8002 : B4 B3

0x8003 : B6 B5

0x8004 : B8 B7

0x8005 : XX B9

However, if the first byte was at the low byte position of the first 16-bit word, the user would call the CRC function with even parity i.e. CRC_parity_even

Address: HI LO

0x8000 : B1 B0

0x8001 : B3 B2

0x8002 : B5 B4

0x8003 : B7 B6

0x8004 : B9 B8

Enumerators:

CRC_parity_even	Even parity, CRC starts at the low byte of the first word (16-bit).
CRC_parity_odd	Odd parity, CRC starts at the high byte of the first word (16-bit).

6.3.5 Function Documentation

6.3.5.1 CRC_bitReflect

Bit-reverse a value.

Prototype:

```
uint32_t
CRC_bitReflect(uint32_t valToReverse,
               int16_t bitWidth)
```

Description:
Bit reverse a given hex value, The number of bits must be a power of 2

Parameters:
valToReverse Value to reverse
bitWidth Bit-width of the input, must be a power of 2

Returns:
bit-reversed value

6.3.5.2 CRC_init16Bit

Initializes the CRC object.

Prototype:

```
void
CRC_init16Bit(CRC_Handle hndCRC)
```

Description:
Clears the CRCMSGFLIP bit is cleared ensuring the input is interpreted in normal bit-order

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.3 CRC_init24Bit

Initializes the CRC object.

Prototype:

```
void
CRC_init24Bit(CRC_Handle hndCRC)
```

Description:
Clears the CRCMSGFLIP bit is cleared ensuring the input is interpreted in normal bit-order

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.4 CRC_init32Bit

Initializes the CRC object.

Prototype:

```
void
CRC_init32Bit(CRC_Handle hndCRC)
```

Description:

Clears the CRCMSGFLIP bit is cleared ensuring the input is interpreted in normal bit-order

Parameters:

← ***hndCRC*** handle to the CRC object

6.3.5.5 CRC_init8Bit

Initializes the CRC object.

Prototype:

```
void
CRC_init8Bit(CRC_Handle hndCRC)
```

Description:

Clears the CRCMSGFLIP bit is cleared ensuring the input is interpreted in normal bit-order

Parameters:

← ***hndCRC*** handle to the CRC object

6.3.5.6 CRC_pow2

power of 2

Prototype:

```
uint16_t
CRC_pow2(uint16_t power)
```

Description:

recursive function to calculate a positive integer that is a power of two

Parameters:

power The exponent of two

Returns:

an integer that is a power of two

6.3.5.7 CRC_reset

Workaround to the silicon issue of first VCU calculation on power up being erroneous.

Prototype:

```
void
CRC_reset(void)
```

Description:

Details Due to the internal power-up state of the VCU module, it is possible that the first CRC result will be incorrect. This condition applies to the first result from each of the eight CRC instructions. This rare condition can only occur after a power-on reset, but will not necessarily occur on every power on. A warm reset will not cause this condition to reappear. Workaround(s): The application can reset the internal VCU CRC logic by performing a CRC calculation of a single byte in the initialization routine. This routine only needs to perform one CRC calculation and can use any of the CRC instructions

6.3.5.8 void CRC_run16BitPoly1 (CRC_Handle *hndCRC*)

Runs the CRC routine using polynomial 0x8005.

Calculates the 16-bit CRC using polynomial 0x8005 on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.9 CRC_run16BitPoly1Reflected

Runs the 16-bit CRC routine using polynomial 0x8005 with the input bits reversed.

Prototype:
```
void
CRC_run16BitPoly1Reflected(CRC_Handle hndCRC)
```

Description:
By setting the CRCMSGFLIP bit, the input is fed through the VCU 16-bit CRC calculator (polynomial 0x8005) in reverse bit order

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.10 CRC_run16BitPoly2

Runs the CRC routine using polynomial 0x1021.

Prototype:
```
void
CRC_run16BitPoly2(CRC_Handle hndCRC)
```

Description:
Calculates the 16-bit CRC using polynomial 0x1021 on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.11 CRC_run16BitPoly2Reflected

Runs the 16-bit CRC routine using polynomial 0x1021 with the input bits reversed.

Prototype:
```
void
CRC_run16BitPoly2Reflected(CRC_Handle hndCRC)
```

Description:
By setting the CRCMSGFLIP bit, the input is fed through the VCU 16-bit CRC calculator (polynomial 0x1021) in reverse bit order

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.12 CRC_run16BitReflectedTableLookupC

C table-lookup 16-bit CRC calculation(reflected algorithm).

Prototype:
```
void
CRC_run16BitReflectedTableLookupC(CRC_Handle hndCRC)
```

Description:
The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

See also:
http://www.ross.net/crc/download/crc_v3.txt

6.3.5.13 CRC_run16BitTableLookupC

C table-lookup 16-bit CRC calculation.

Prototype:

```
void
CRC_run16BitTableLookupC(CRC_Handle hndCRC)
```

Description:

The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

← ***hndCRC*** handle to the CRC object

See also:

http://www.ross.net/crc/download/crc_v3.txt

6.3.5.14 CRC_run24Bit

Runs the CRC routine.

Prototype:

```
void
CRC_run24Bit(CRC_Handle hndCRC)
```

Description:

Calculates the 24-bit CRC using polynomial 0x5d6dcb on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

← ***hndCRC*** handle to the CRC object

6.3.5.15 CRC_run24BitReflected

Runs the 24-bit CRC routine using polynomial 0x5d6dcb with the input bits reversed.

Prototype:

```
void
CRC_run24BitReflected(CRC_Handle hndCRC)
```

Description:

By setting the CRCMSGFLIP bit, the input is fed through the VCU 24-bit CRC calculator (polynomial 0x5d6dcb) in reverse bit order

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

← ***hndCRC*** handle to the CRC object

6.3.5.16 CRC_run24BitReflectedTableLookupC

C table-lookup 24-bit CRC calculation(reflected algorithm).

Prototype:

```
void
CRC_run24BitReflectedTableLookupC(CRC_Handle hndCRC)
```

Description:

The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

← ***hndCRC*** handle to the CRC object

See also:

http://www.ross.net/crc/download/crc_v3.txt

6.3.5.17 CRC_run24BitTableLookupC

C table-lookup 24-bit CRC calculation.

Prototype:

```
void
CRC_run24BitTableLookupC(CRC_Handle hndCRC)
```

Description:

The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

← ***hndCRC*** handle to the CRC object

See also:

http://www.ross.net/crc/download/crc_v3.txt

6.3.5.18 CRC_run32BitPoly1

Runs the 32-bit CRC routine using polynomial 0x04c11db7.

Prototype:

```
void
CRC_run32BitPoly1(CRC_Handle hndCRC)
```

Description:
Calculates the 32-bit CRC using polynomial 0x04c11db7 on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.19 CRC_run32BitPoly1Reflected

Runs the 32-bit CRC routine using polynomial 0x04c11db7 with the input bits reversed.

Prototype:
```
void
CRC_run32BitPoly1Reflected(CRC_Handle hndCRC)
```

Description:
By setting the CRCMSGFLIP bit, the input is fed through the VCU 32-bit CRC calculator (polynomial 0x04c11db7) in reverse bit order

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.20 CRC_run32BitPoly2

Runs the 32-bit CRC routine using polynomial 0x1edc6f41.

Prototype:
```
void
CRC_run32BitPoly2(CRC_Handle hndCRC)
```

Description:
Calculates the 32-bit CRC using polynomial 0x1edc6f41 on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.21 CRC_run32BitPoly2Reflected

Runs the 32-bit CRC routine using polynomial 0x1edc6f41 with the input bits reversed.

Prototype:

```
void
CRC_run32BitPoly2Reflected(CRC_Handle hndCRC)
```

Description:
By setting the CRCMSGFLIP bit, the input is fed through the VCU 32-bit CRC calculator (polynomial 0x1edc6f41) in reverse bit order

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.22 CRC_run32BitReflectedTableLookupC

C table-lookup 32-bit CRC calculation(reflected algorithm).

Prototype:

```
void
CRC_run32BitReflectedTableLookupC(CRC_Handle hndCRC)
```

Description:
The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

See also:
http://www.ross.net/crc/download/crc_v3.txt

6.3.5.23 CRC_run32BitTableLookupC

C table-lookup 32-bit CRC calculation.

Prototype:

```
void
CRC_run32BitTableLookupC(CRC_Handle hndCRC)
```

Description:
The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

See also:
http://www.ross.net/crc/download/crc_v3.txt

6.3.5.24 CRC_run8Bit

Calculate the 8-bit CRC using polynomial 0x7.

Prototype:
```
void
CRC_run8Bit(CRC_Handle hndCRC)
```

Description:
Calculates the 8-bit CRC using polynomial 0x7 on the VCU. Depending on the parity chosen the CRC begins at either the low byte (PARITY_LOWBYTE) or the high byte (PARITY_HIGHBYTE) of the first word (16-bit).

Note:
the size of the message (bytes) is limited to 65535 bytes. If attempting to process a larger message, the user must break it into pieces of size 65535 or smaller, and successively run the CRC on each block, with the CRC result of one block becoming the seed value for the next block. An example of this is shown in the FLASH build configuration of the example **2837x_vcu2_crc_8**.

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.25 CRC_run8BitReflected

Runs the 8-bit CRC routine using polynomial 0x7 with the input bits reversed.

Prototype:
```
void
CRC_run8BitReflected(CRC_Handle hndCRC)
```

Description:
By setting the CRCMSGFLIP bit, the input is fed through the VCU 8-bit CRC calculator (polynomial 0x7) in reverse bit order

Note:
the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:
← ***hndCRC*** handle to the CRC object

6.3.5.26 CRC_run8BitTableLookupC

C table-lookup 8-bit CRC calculation.

Prototype:
```
void
CRC_run8BitTableLookupC(CRC_Handle hndCRC)
```

Description:

The CRC is calculated using a table lookup method, where each byte of the input is an index into the table. The value at that index is XOR'd into a variable called the accumulator. Once the final byte's CRC is looked up and accumulated we get the CRC for the entire message block

Note:

the size of the message (bytes) is limited to 65535 bytes Please see the notes for the function **CRC_run8Bit** for details

Parameters:

$\leftarrow$ ***hndCRC*** handle to the CRC object

See also:

http://www.ross.net/crc/download/crc_v3.txt

6.4 Viterbi Decoding (VCU2)

Data Structures

- _VITERBI_DECODER_Obj_

Enumerations

- VITERBIMODE_e

Functions

- void VITERBI_DECODER_initK4CR12 (VITERBI_DECODER_Handle hndVITDecoder)
- void VITERBI_DECODER_initK7CR12 (VITERBI_DECODER_Handle hndVITDecoder)
- void VITERBI_DECODER_rescaleK4CR12 (VITERBI_DECODER_Handle hndVITDecoder)
- void VITERBI_DECODER_rescaleK7CR12 (VITERBI_DECODER_Handle hndVITDecoder)
- void VITERBI_DECODER_runK4CR12 (VITERBI_DECODER_Handle hndVITDecoder)
- void VITERBI_DECODER_runK7CR12 (VITERBI_DECODER_Handle hndVITDecoder)

6.4.1 Data Structure Documentation

6.4.1.1 _VITERBI_DECODER_Obj_

Definition:

```
typedef struct
{
    int16_t *pInBuffer;
    uint16_t *pOutBuffer;
    uint16_t *pTransitionHistory;
    const int32_t *pBMSELInit;
    int16_t stateMetricInit;
    int16_t nBits;
    int16_t constraintLength;
    int16_t nStates;
    int16_t codeRate;
    VITERBIMODE_e mode;
    uint16_t *pTransitionStart1;
    uint16_t *pTransitionStart2;
```

```
        uint16_t *pTransitionWrap1;
        uint16_t *pTransitionWrap2;
        uint16_t *pTransitionTemp;
        void (*init)(void *);
        void (*run)(void *);
        void (*rescale)(void *);
    }
    _VITERBI_DECODER_Obj_
```

Members:

pInBuffer Input buffer pointer.
pOutBuffer Output buffer pointer.
pTransitionHistory Transition History pointer.
pBMSELInit Initialization value for the BMSEL register.
stateMetricInit Initialization value for the state metrics.
nBits Total number of bits to be decoded.
constraintLength Constraint Length, i.e. K.
nStates HASH(0x555f921535c0)
codeRate The symbol code rate.
mode Viterbi mode enumerator.
pTransitionStart1 Points to the start of the tranistion history buffer.
pTransitionStart2 Points to the mid of the tranistion history buffer.
pTransitionWrap1 Points to the mid of the tranistion history buffer.
pTransitionWrap2 Points to the end of the tranistion history buffer.
pTransitionTemp Points to a temporary(scratch) tranistion history buffer.
init Function pointer to VITERBI initialization routine.
run Function pointer to VITERBI computation routine.
rescale Function pointer to VITERBI rescale routine.

Description:

VITERBI Decoder Structure.

6.4.2 Enumeration Documentation

6.4.2.1 VITERBIMODE_e

Description:

The Viterbi mode enumerator.

Enumerators:

VITERBIMODE_DECODEALL Decodes all output bits, upto a max of 256, at once.

VITERBIMODE_OVERLAPINIT no traceback is performed

Use window overlap method, This is used for the first block where state metrics and transition history is updated but

VITERBIMODE_OVERLAPDECODE Use window overlap method, update transitions/metrics for the current block (ith block), run a traceback using the ith and (i-1)st block's transition history but only decode the (i-1)st block

VITERBIMODE_OVERLAPLAST Trace back and decode the last block in overlap window method.

6.4.3 Function Documentation

6.4.3.1 VITERBI_DECODER_initK4CR12

Initializes the VITERBI object (constraint length 4, code rate 1/2).

Prototype:

```
void
VITERBI_DECODER_initK4CR12(VITERBI_DECODER_Handle
hndVITDecoder)
```

Description:
Sets the constraint length of the viterbi object and initialized the state metrcs to the object element, stateMetricInit

Parameters:
← ***hndVITDecoder*** handle to the VITERBI object

6.4.3.2 VITERBI_DECODER_initK7CR12

Initializes the VITERBI object (constraint length 7, code rate 1/2).

Prototype:

```
void
VITERBI_DECODER_initK7CR12(VITERBI_DECODER_Handle
hndVITDecoder)
```

Description:
Sets the constraint length of the viterbi object and initialized the state metrcs to the object element, stateMetricInit

Note:
This function uses a global variable to save off the metric registers and is, therefore, non re-entrant

Parameters:
← ***hndVITDecoder*** handle to the VITERBI object

6.4.3.3 VITERBI_DECODER_rescaleK4CR12

Rescales the viterbi state metrics (constraint length 4, code rate 1/2).

Prototype:

```
void
VITERBI_DECODER_rescaleK4CR12(VITERBI_DECODER_Handle
hndVITDecoder)
```

Description:
Rescale the state metrics by finding the lowest metric and dividing the rest by it. This prevents overflow between successive decoder stages.

Parameters:

← ***hndVITDecoder*** handle to the VITERBI object

6.4.3.4 VITERBI_DECODER_rescaleK7CR12

Rescales the viterbi state metrics (constraint length 7, code rate 1/2).

Prototype:

```
void
VITERBI_DECODER_rescaleK7CR12(VITERBI_DECODER_Handle
hndVITDecoder)
```

Description:

Rescale the state metrics by finding the lowest metric and dividing the rest by it. This prevents overflow between successive decoder stages.

Parameters:

← ***hndVITDecoder*** handle to the VITERBI object

6.4.3.5 VITERBI_DECODER_runK4CR12

Runs the VITERBI decoder for constraint length 4, code rate 1/2.

Prototype:

```
void
VITERBI_DECODER_runK4CR12(VITERBI_DECODER_Handle
hndVITDecoder)
```

Description:

The viterbi decode is done using a window overlap method with 4 modes of operation :

1. VITERBIMODE_DECODEALL, a one-shot decode mode typically used for header information where the entire block of data is processed through the trellis and decoded
2. VITERBIMODE_OVERLAPINIT, window overlap method – this is used for the first block where state metrics and transition history is updated but no traceback is performed
3. VITERBIMODE_OVERLAPDECODE, window overlap method – update transitions/metrics for the current block (ith block), run a traceback using the ith and (i-1)st block's transition history but only decode the (i-1)st block
4. VITERBIMODE_OVERLAPLAST, window overlap method– trace back and decode the last block

The window overlap method requires the transition history of two successive blocks to be recorded. The transition history buffer is used in a circular fashion and requires 5 pointers:

- pTransitionHistory(hist_p): start of the transition history buffer
- pTransitionStart1(S1_p): points to where the transition update should start
- pTransitionStart2(S2_p: points to the mid point of the overlap(S1_p + 4∗nUnencodedBits)
- pTransitionWrap1(W1_p): points to where trace overlap 2 should go (wrap, S1_p + 4∗nUnencodedBits)

- pTransitionWrap2(W2_p): points to the end of the overlap(S1_p + 2∗4∗nUnencodedBits)

```
 CBITS  = 128(coded bits per block)
 UBITS  = CBITS/2 = 64(uncoded bits per block)
 UWORDS = 4 (4 words (16-bits) required to store UBITS)

 Transition history(bits per stage)--->
              <-------64 bits----->
              +----+----+----+----+   ^
S1_p->hist_p->|    |    |    |    |   |
        ^     |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
    4*UBITS   |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
        v     |    |    |    |    |   |
  S2_p->W1_p->|    |    |    |    | 128 stages
        ^     |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
    4*UBITS   |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
        |     |    |    |    |    |   |
        v     |    |    |    |    |   |
        W2_p->|    |    |    |    |   |
              +----+----+----+----+   v
```

Parameters:

← ***hndVITDecoder*** handle to the VITERBI object

6.4.3.6 void VITERBI_DECODER_runK7CR12 (VITERBI_DECODER_Handle *hndVITDecoder*)

Runs the VITERBI decoder for constraint length 7, code rate 1/2.

Parameters:

← ***hndVITDecoder*** handle to the VITERBI object

See also:

VITERBI_DECODER_runK4CR12 for a description of the window overlap method

6.5 Reed Solomon Decoder (VCU2)

Data Structures

- _REEDSOLOMON_DECODER_Obj_

Defines

- RS_BLOCK_K
- RS_BLOCK_N
- RS_BLOCK_T
- RS_NROOTS

Functions

- void REEDSOLOMON_DECODER_berlekampMassey (REEDSOLOMON_DECODER_Handle hndRSDecoder)
- void REEDSOLOMON_DECODER_calcSyndrome (REEDSOLOMON_DECODER_Handle hndRSDecoder, int16_t ∗pData, int16_t nBytes)
- void REEDSOLOMON_DECODER_chienForney (REEDSOLOMON_DECODER_Handle hndRSDecoder, int16_t nBytes)
- void REEDSOLOMON_DECODER_initN255K239 (REEDSOLOMON_DECODER_Handle hndRSDecoder, int16_t ∗pSyndrome, int16_t ∗pLambda, int16_t ∗pOmega, int16_t ∗pPackedAlpha, int16_t ∗pPackedBeta, int16_t ∗pRS_expTable, int16_t ∗pRS_logTable, ERROR_LOCVAL_Obj ∗pErrorLoc)
- void REEDSOLOMON_DECODER_runN255K239 (REEDSOLOMON_DECODER_Handle hndRSDecoder, int16_t ∗pData, int16_t nBytes)

6.5.1 Data Structure Documentation

6.5.1.1 _REEDSOLOMON_DECODER_Obj_

Definition:

```
typedef struct
{
    uint16_t _n;
    uint16_t _k;
    uint16_t _t;
    uint16_t nRoots;
    int16_t *pSyndrome;
    int16_t *pLambda;
    int16_t *pOmega;
    int16_t *pPackedAlpha;
    int16_t *pPackedBeta;
    int16_t *pRS_expTable;
    int16_t *pRS_logTable;
    ERROR_LOCVAL_Obj *pErrorLoc;
```

```
        void (*init)(void *,
                     int16_t *,
                     int16_t *,
                     int16_t *,
                     int16_t *,
                     int16_t *,
                     int16_t *,
                     int16_t *,
                     ERROR_LOCVAL_Obj *);
        void (*run)(void *,
                    int16_t *,
                    int16_t);
    }
    _REEDSOLOMON_DECODER_Obj_
```

Members:

_n number of codeword symbols (bytes) in a block

_k number of message symbols (bytes) in a block

_t number of correctable errors in the block

nRoots number of roots for the code generator polynomial

pSyndrome pointer to the syndromes

pLambda pointer to the Lambdas

pOmega pointer to the Omega

pPackedAlpha Pointer to the roots of the code generator polynomial.

pPackedBeta Pointer to the first 2t elements of the Galois Field.

pRS_expTable Pointer to the lookup table (roots of the extension Galois Field) that converts index to decimal form.

pRS_logTable Pointer to the lookup table (roots of the extension Galois Field) that converts decimal to index form.

pErrorLoc Pointer to the error (location, value) pairs.

init Function pointer to Reed Solomon Decoder initialization routine.

run Function pointer to Reed Solomon Decoder computation routine.

Description:

Reed-Solomon Decoder structure.

6.5.2 Define Documentation

6.5.2.1 RS_BLOCK_K

Definition:

```
#define RS_BLOCK_K
```

Description:

Message size.

6.5.2.2 RS_BLOCK_N

Definition:

```
#define RS_BLOCK_N
```

Description:

Encoded block size.

6.5.2.3 RS_BLOCK_T

Definition:

```
#define RS_BLOCK_T
```

Description:

number of correctable errors

6.5.2.4 RS_NROOTS

Definition:

```
#define RS_NROOTS
```

Description:

Number of code generator polynomial roots.

6.5.3 Typedef Documentation

6.5.3.1 REEDSOLOMON_DECODER_Handle

Definition:

```
typedef REEDSOLOMON_DECODER_Obj *REEDSOLOMON_DECODER_Handle
```

Description:

Handle to the Reed-Solomon Decoder structure.

6.5.3.2 REEDSOLOMON_DECODER_Obj

Definition:

```
 typedef struct _REEDSOLOMON_DECODER_Obj_
REEDSOLOMON_DECODER_Obj
```

Description:

Reed-Solomon Decoder structure.

6.5.4 Function Documentation

6.5.4.1 REEDSOLOMON_DECODER_berlekampMassey

Error locator polynomial calculation (inversionless Berlekamp Massey Method).

Prototype:

```
void
REEDSOLOMON_DECODER_berlekampMassey(REEDSOLOMON_DECODER_Handle
hndRSDecoder)
```

Parameters:

← ***hndRSDecoder*** handle to the Reed Solomon Decoder object

Note:

Requires the lambda array to be even aligned

6.5.4.2 void REEDSOLOMON_DECODER_calcSyndrome (REEDSOLOMON_DECODER_Handle *hndRSDecoder*, int16_t ∗ *pData*, int16_t *nBytes*)

Syndrome calculation function (Horner's Method).

Parameters:

← ***hndRSDecoder*** handle to the Reed Solomon Decoder object
← ***pData*** pointer to the data
← ***nBytes*** number of bytes in the message block

Note:

Requires the syndrome array to be even aligned

6.5.4.3 void REEDSOLOMON_DECODER_chienForney (REEDSOLOMON_DECODER_Handle *hndRSDecoder*, int16_t *nBytes*)

caculate error locations using Chien search and magnitude using Forney's algorithm

Parameters:

← ***hndRSDecoder*** handle to the Reed Solomon Decoder object
← ***nBytes*** number of bytes in the message block

Note:

Requires the omega and error location arrays to be even aligned

6.5.4.4 void REEDSOLOMON_DECODER_initN255K239 (REEDSOLOMON_DECODER_Handle *hndRSDecoder*, int16_t ∗ *pSyndrome*, int16_t ∗ *pLambda*, int16_t ∗ *pOmega*, int16_t ∗ *pPackedAlpha*, int16_t ∗ *pPackedBeta*, int16_t ∗ *pRS_expTable*, int16_t ∗ *pRS_logTable*, ERROR_LOCVAL_Obj ∗ *pErrorLoc*)

Initializes the Reed Solomon Decoder object (n,k = 255, 239).

Parameters:

← ***hndRSDecoder*** handle to the Reed Solomon Decoder object
← ***pSyndrome*** Pointer to the syndromes
← ***pLambda*** Pointer to the error locator polynomial coefficients
← ***pOmega*** Pointer to the error magnitude polynomial coefficients

$\leftarrow$ ***pPackedAlpha*** Pointer to the roots of the generator polynomial $x + \alpha^i$
$\leftarrow$ ***pPackedBeta*** Pointer to the roots of the generator polynomial $x + \beta^i$
$\leftarrow$ ***pRS_expTable*** Pointer to the lookup table that converts index to decimal form
$\leftarrow$ ***pRS_logTable*** Pointer to the lookup table that converts decimal to index form
$\leftarrow$ ***pErrorLoc*** Pointer to the error (location, value) pairs

Note:
Requires the data array to be even aligned

6.5.4.5 void REEDSOLOMON_DECODER_runN255K239 (REEDSOLOMON_DECODER_Handle *hndRSDecoder*, int16_t $*$ *pData*, int16_t *nBytes*)

Runs the Reed Solomon Decoder (n,k = 255, 239).

Parameters:
$\leftarrow$ ***hndRSDecoder*** handle to the Reed Solomon Decoder object
$\leftarrow$ ***pData*** pointer to the received message block
$\leftarrow$ ***nBytes*** number of bytes in the message block

6.6 De-Interleaver (VCU2)

Data Structures

- _DEINTERLEAVER_Obj_

Functions

- void DEINTERLEAVER_run (DEINTERLEAVER_Handle hndDEINTERLEAVER)

6.6.1 Data Structure Documentation

6.6.1.1 _DEINTERLEAVER_Obj_

Definition:

```
typedef struct
{
    uint16_t *pInBuffer;
    uint16_t *pOutBuffer;
    uint16_t *pSymbol;
    uint16_t n;
    uint16_t m;
    uint16_t b;
    uint16_t v;
    uint16_t a;
    uint16_t u;
    uint16_t n_i;
    uint16_t n_j;
    uint16_t m_i;
    uint16_t m_j;
    void (*init)(void *);
    void (*run)(void *);
}
_DEINTERLEAVER_Obj_
```

Members:

pInBuffer Pointer to the input buffer.
pOutBuffer Pointer to the input buffer.
pSymbol Pointer to symbol storage.
n number of OFDM symbols in each interleaving block
m number of sub-carriers in each OFDM symbol
b beta
v mu
a alpha
u upsilon
n_i Circular shift of the rows.
n_j Circular shift of the rows.

m_i Circular shift of the columns.

m_j Circular shift of the columns.

init Function pointer to DEINTERLEAVER initialization routine (NULL as of current release).

run Function pointer to DEINTERLEAVER computation routine.

Description:
De-interleaver structure.

6.6.2 Function Documentation

6.6.2.1 DEINTERLEAVER_run

Runs the DEINTERLEAVER routine.

Prototype:

```
void
DEINTERLEAVER_run(DEINTERLEAVER_Handle hndDEINTERLEAVER)
```

Description:
The de-interleaver equations are:

$$J = (j \times n_j + i \times n_i)\%n$$

$$I = (i \times m_i + J \times m_j)\%m$$

The interleaver equations are:

$$i = (a \times I - u \times J)\%m$$

$$j = (b \times J - v \times i)\%n$$

$$b = \beta_j$$

$$v = \mu_{ij} = \beta_j \times n_i$$

$$a = \alpha_i$$

$$u = v_{ij} = alpha_i \times m_j$$

(i,j) - original bit position (I,J) - interleaved position

Parameters:
$\leftarrow$ ***hndDEINTERLEAVER*** handle to the DEINTERLEAVER object

7 Application Program Interface for using VCRC libraries

7.1 VCRC Configurable Polynomial APIs

Functions

- void CRC_runConfigPolyBits (CRC_Handle hndCRC)
- void CRC_runConfigPolyBitsReflected (CRC_Handle hndCRC)
- void CRC_runConfigPolyBytes (CRC_Handle hndCRC)
- void CRC_runConfigPolyBytesReflected (CRC_Handle hndCRC)

7.1.1 Function Documentation

7.1.1.1 CRC_runConfigPolyBits

Runs the CRC routine using provided polynomial with message size in bits.

Prototype:

```
void
CRC_runConfigPolyBits(CRC_Handle hndCRC)
```

Description:

The polynomial to be used is set by the element **polynomial** in the **CRC_Obj**. The size of the polynomial is set by the element **polySize** in the **CRC_Obj**. For example - to use a 1 bit polynomial **polySize** must be set to 0x0 and to use a 32 bit polynomial **polySize** must be set to 0x1F. The size of the data is set by the element **dataSize** in **the** CRC_Obj. **Datasize** refers to the integral unit on which the CRC is computed. For example - to use data size of 1 bit **dataSize** must be set to 0x0 and data size of 8 bit is set by setting **dataSize** to a value of 0x7. These values finally translate to elements in the **VCRCSIZE** register - **PSIZE** and **DSIZE** fields and they are set in the functions **_CRC_runConfigPolyBytes** implemented in the asm file **vcrc_configpoly_asm.asm**. Total size of the message on which the CRC to be computed is specified by the element **MsgBytes** in the **CRC_Obj**.

Parameters:

← ***hndCRC*** handle to the CRC object

7.1.1.2 CRC_runConfigPolyBitsReflected

Runs the CRC routine using provided polynomial with the input bits reversed, message size in bits.

Prototype:

```
void
CRC_runConfigPolyBitsReflected(CRC_Handle hndCRC)
```

Description:

The polynomial to be used is set by the element **polynomial** in the **CRC_Obj**. The size of the polynomial is set by the element **polySize** in the **CRC_Obj**. For example

- to use a 1 bit polynomial **polySize** must be set to 0x0 and to use a 32 bit polynomial **polySize** must be set to 0x1F. The size of the data is set by the element **dataSize** in **the** CRC_Obj. **Datasize** refers to the integral unit on which the CRC is computed. For example - to use data size of 1 bit **dataSize** must be set to 0x0 and data size of 8 bit is set by setting **dataSize** to a value of 0x7. These values finally translate to elements in the **VCRCSIZE** register - **PSIZE** and **DSIZE** fields and they are set in the functions **_CRC_runConfigPolyBytes** implemented in the asm file **vcrc_configpoly_asm.asm**. Total size of the message on which the CRC to be computed is specified by the element **MsgBytes** in the **CRC_Obj**.

Parameters:
← ***hndCRC*** handle to the CRC object

7.1.1.3 CRC_runConfigPolyBytes

Runs the CRC routine using provided polynomial with message size in bytes.

Prototype:
```
void
CRC_runConfigPolyBytes(CRC_Handle hndCRC)
```

Description:
The polynomial to be used is set by the element **polynomial** in the **CRC_Obj**. The size of the polynomial is set by the element **polySize** in the **CRC_Obj**. For example - to use a 1 bit polynomial **polySize** must be set to 0x0 and to use a 32 bit polynomial **polySize** must be set to 0x1F. The size of the data is set by the element **dataSize** in **the** CRC_Obj. **Datasize** refers to the integral unit on which the CRC is computed. For example - to use data size of 1 bit **dataSize** must be set to 0x0 and data size of 8 bit is set by setting **dataSize** to a value of 0x7. These values finally translate to elements in the **VCRCSIZE** register - **PSIZE** and **DSIZE** fields and they are set in the functions **_CRC_runConfigPolyBytes** implemented in the asm file **vcrc_configpoly_asm.asm**. Total size of the message on which the CRC to be computed is specified by the element **MsgBytes** in the **CRC_Obj**.

Parameters:
← ***hndCRC*** handle to the CRC object

7.1.1.4 CRC_runConfigPolyBytesReflected

Runs the CRC routine using provided polynomial with the input bits reversed, message size in bytes.

Prototype:
```
void
CRC_runConfigPolyBytesReflected(CRC_Handle hndCRC)
```

Description:
The polynomial to be used is set by the element **polynomial** in the **CRC_Obj**. The size of the polynomial is set by the element **polySize** in the **CRC_Obj**. For example - to use a 1 bit polynomial **polySize** must be set to 0x0 and to use a 32 bit polynomial **polySize** must be set to 0x1F. The size of the data is set by the element **dataSize** in **the** CRC_Obj. **Datasize** refers to the integral unit on which the CRC is computed. For example - to use data size of 1 bit **dataSize** must be set to 0x0

and data size of 8 bit is set by setting **dataSize** to a value of 0x7. These values finally translate to elements in the **VCRCSIZE** register - **PSIZE** and **DSIZE** fields and they are set in the functions **_CRC_runConfigPolyBytes** implemented in the asm file **vcrc_configpoly_asm.asm**. Total size of the message on which the CRC to be computed is specified by the element **MsgBytes** in the **CRC_Obj**.

Parameters:

← ***hndCRC*** handle to the CRC object

7.1.2 Fixed Polynomial APIs

The APIs mentioned in chapter 6 - section 6.3 can be run as is on the VCRC incase we need to compute CRC using the fixed polynomial for 8, 16, 24 and 32 bits. These APIs are supported in the vcrc libraries.

7.1.3 Description of the Examples

CRC examples can be found inside the CRC folder under examples folder of VCU. It has 11 different examples that the user can build and run to see how to use the APIs for CRC computation for VCU0, VCU2 and VCRC.

Example folder	Description
2837x_vcu0_crc_genTables	Shows how to use the vcu0 supported CRC routines. Uses a C based table lookup routine to run an 8,16,32-bit CRC check using predefined polynomials. It also demonstrate the link time CRC generation on a section of memory.
2837x_vcu0_crc_wTables	Shows how to use the vcu0 supported CRC routines. Uses a C based table lookup routine to run an 8,16,32-bit CRC check using predefined polynomials. The tables are included in the c28x_vcu0_crcTables_library(_fpu32).lib, The user must add the search path to the library to the linker options in the project properties. Example demonstrates the link time CRC generation on a section of memory.
2837x_vcu2_crc_8	Shows how to use the vcu2 supported 8-bit CRC routines, uses a C based table lookup routine to run an 8-bit CRC check using any 8-bit polynomial, and demonstrates the link time CRC generation(polynomial 0x07) on a section of memory.
2837x_vcu2_crc_16	Shows how to use the vcu2 supported 16-bit CRC routines, uses a C based table lookup routine to run a 16-bit CRC check using any 16-bit polynomial, and demonstrates the link time CRC generation(polynomials 0x8005, 0x1021) on a section of memory.
2837x_vcu2_crc_24	Shows how to use the vcu2 supported 24-bit CRC routines, use a C based table lookup routine to run a 24-bit CRC check using any 24-bit polynomial and demonstrates the link time CRC generation(polynomial 0x5D6DCB) on a section of memory.
2837x_vcu2_crc_32	Shows how to use the vcu2 supported 32-bit CRC routines, use a C based table lookup routine to run a 32-bit CRC check using any 32-bit polynomial and demonstrates the link time CRC generation(polynomials 0x04C11DB7, 0x1EDC6F41) on a section of memory.
2838x_vcrc_config_poly	Shows how to use the VCRC supported configurable polynomial capability with different polynomials, sizes and different data sizes. There are many simple examples in this single example showing how to configure and VCRC and also check the computed values against C based routines.
2838x_vcrc_crc_8	Shows how to use the vcrc supported 8-bit CRC routines, uses a C based table lookup routine to run an 8-bit CRC check using any 8-bit polynomial, and demonstrates the link time CRC generation(polynomial 0x07) on a section of memory.
2838x_vcrc_crc_16	Shows how to use the vcrc supported 16-bit CRC routines, uses a C based table lookup routine to run a 16-bit CRC check using any 16-bit polynomial, and demonstrates the link time CRC generation(polynomials 0x8005, 0x1021) on a section of memory.
2838x_vcrc_crc_24	Shows how to use the vcrc supported 24-bit CRC routines, use a C based table lookup routine to run a 24-bit CRC check using any 24-bit polynomial and demonstrates the link time CRC generation(polynomial 0x5D6DCB) on a section of memory.
2838x_vcrc_crc_32	Shows how to use the vcrc supported 32-bit CRC routines, use a C based table lookup routine to run a 32-bit CRC check using any 32-bit polynomial and demonstrates the link time CRC generation(the polynomials 0x04C11DB7, 0x1EDC6F41) on a section of memory.

Table 7.1: VCRC and VCU CRC Examples

8 Benchmarks

The benchmarks were obtained with the following compiler settings for the libraries:

VCU Type 0 (ISA_C2800)

```
-v28 -ml -mt --vcu_support=vcu0 -g --verbose_diagnostics
--diag_warning=225 --display_error_number --issue_remarks
```

VCU Type 2 (ISA_C2800)

```
-v28 -ml -mt --vcu_support=vcu2 -g --verbose_diagnostics
--diag_warning=225 --display_error_number --issue_remarks
```

The ISA_C28FPU32 build configuration adds the –float_support=fpu32 in addition to those specified above. The tables below list the performance metrics for all the library routines. These numbers were obtained by profiling the code in the examples directory

VCRC

The VCRC cycles are easy to compute. No specific benchmark has been included. All fixed polynomial VCRC instructions are executed in single cycle (irrespective of the 8 or 16 or 24or 32bit polynomial) for 1 byte of CRC.

Configurable polynomial instructions are executed in 3 cycles for specified dataSize.

Module	**Function**	**Cycles**[1]
CRC	CRC_reset	11
	getCRC8_vcu	1.515 [2]
	getCRC32_vcu	1.515 [2]
	getCRC16P2_vcu	1.515 [2]
	getCRC16P1_vcu	1.515 [2]
FFT	cfft16_init	13
	cfft16_flip_re_img	223, N = 128
		414, N = 256
		798, N = 512
	cfft16_flip_re_img_conj	532, N = 64
		1043, N = 128
		2067, N = 256
	cifft16_pack_asm	1182, N = 64
		2271, N = 128
		4511, N = 256
	cfft16_brev	348, N = 64
		459, N = 128
		1655, N = 256
	cfft16_unpack_asm	1218, N = 128
		2339, N = 256
		4643, N = 512
	cfft16_64p_calc	1402
	cfft16_128p_calc	3681
	cfft16_256p_calc	8135
Viterbi	cnvDec_asm	5921 [3]
	cnvDecInit_asm	92
	cnvDecMetricRescale_asm	212

Table 8.1: Benchmark for the VCU Type 0 Library Routines

[1] include call, return and store (if required) instructions

[2] average count per byte for a message size of 128 bytes

[3] Viterbi decoder block size is 128 coded bits, mode: overlap decode

Module	**Function**	**Cycles**[1]
CRC	CRC_reset	11
	CRC_init8Bit	11
	CRC_run8Bit	1.437 [2]
	CRC_run8BitReflected	1.515 [2]
	CRC_init16Bit	11
	CRC_run16BitPoly1	1.437 [2]
	CRC_run16BitPoly2	1.437 [2]
	CRC_run16BitPoly1Reflected	1.515 [2]
	CRC_run16BitPoly2Reflected	1.515 [2]
	CRC_init24Bit	11
	CRC_run24Bit	1.437[2]
	CRC_run24BitReflected	1.515[2]
	CRC_init32Bit	11
	CRC_run32BitPoly1	1.414 [2]
	CRC_run32BitPoly2	1.414 [2]
	CRC_run32BitPoly1Reflected	1.492 [2]
	CRC_run32BitPoly2Reflected	1.492 [2]
FFT	CFFT_init32Pt	32
	CFFT_run32Pt	330 [3]
	ICFFT_run32Pt	333 [3]
	CFFT_init64Pt	32
	CFFT_run64Pt	608 [3]
	ICFFT_run64Pt	641 [3]
	CFFT_init128Pt	32
	CFFT_run128Pt	1494 [3]
	ICFFT_run128Pt	1495 [3]
	CFFT_init256Pt	32
	CFFT_run256Pt	2908 [3]
	ICFFT_run256Pt	3036 [3]
	CFFT_init512Pt	32
	CFFT_run512Pt	7011 [3]
	ICFFT_run512Pt	7012 [3]
	CFFT_init1024Pt	32
	CFFT_run1024Pt	13920 [3]
	ICFFT_run1024Pt	14435 [3]
	CFFT_conjugate	293, N = 64
		549, N = 128
		1061, N = 256
	CFFT_pack	733, N = 64
		1437, N = 128
		2845, N = 256
	CFFT_unpack	740, N = 128
		1443, N = 256
		2851, N = 512
Viterbi	VITERBI_DECODER_initK4CR12	15
	VITERBI_DECODER_runK4CR12	954 [4]
	VITERBI_DECODER_rescaleK4CR12	54
	VITERBI_DECODER_initK7CR12	15
	VITERBI_DECODER_runK7CR12	949

Continued on next page

Table 8.2 – continued from previous page

Module	Function	Cycles
	VITERBI_DECODER_rescaleK7CR12	285
Reed-Solomon	REEDSOLOMON_DECODER_initN255K239	78
	REEDSOLOMON_DECODER_runN255K239	10372
	REEDSOLOMON_DECODER_calcSyndrome	1426
	REEDSOLOMON_DECODER_berlekampMassey	1311
	REEDSOLOMON_DECODER_chienForney	7610
Deinterleaver	DEINTERLEAVER_run	773 [5]

Table 8.2: Benchmark for the VCU Type 2 Library Routines

[1] include call, return and store (if required) instructions

[2] average count per byte for a message size of 128 bytes

[3] VCU Type 2 FFT is more efficient when $N_{stages} = 2k + 6, k \in \{0, 1, 2\}$

[4] Viterbi decoder block size is 128 coded bits, mode: overlap decode

[5] 72 sub-carriers (G3 Powerline Communications FCC band)

Module	**Function**	**Cycles**[1]
CRC	genCRC8Table	47116 [3]
	genCRC16P1Table	57189 [3]
	genCRC16P2Table	57444 [3]
	genCRC32Table	51468 [3]
	getCRC8_cpu	24.234 [2] [3]
	getCRC16P1_cpu	31.273 [2] [3]
	getCRC16P2_cpu	31.273 [2] [3]
	getCRC32_cpu	28.25 [2] [3]
	CRC_bitReflect	30.968(max avg) [3] [2]
	CRC_run8BitTableLookupC	35.453 [3] [2]
	CRC_run32BitTableLookupC	39.375 [3] [2]
	CRC_run32BitReflectedTableLookupC	40.351 [3] [2]
	CRC_run24BitTableLookupC	40.398 [3] [2]
	CRC_run24BitReflectedTableLookupC	40.375 [3] [2]
	CRC_run16BitTableLookupC	31.406 [3] [2]
	CRC_run16BitReflectedTableLookupC	31.406 [3] [2]
Viterbi	VITERBI_ENCODER_init	114 [3]
	VITERBI_ENCODER_blockUnpack2Bits	16157 [3] [6]
	VITERBI_ENCODER_quantizeBits	104496 [3] [6]
	VITERBI_ENCODER_runK4CR12	49303 [3] [6]
	VITERBI_ENCODER_runK7CR12	47194 [3] [6]
Reed-Solomon	REEDSOLOMON_ENCODER_init	54 [3] [7]
	REEDSOLOMON_ENCODER_run	412755 [3] [7]
Interleaver	INTERLEAVER_findParams	132 [4]
	INTERLEAVER_run	3999 [4]

Table 8.3: Benchmark for the Library 'C' Routines

[1]include call, return and store (if required) instructions

[2]average count per byte for a message size of 128 bytes

[3]C routines compiled with default optimization (Optimization Off)

[4]72 sub-carriers (G3 Powerline Communications FCC band)

9 Revision History

V2.28.00.00: Moderate Revision
- CRC examples ported to F28P55x

V2.27.00.00: Moderate Revision
- CRC lib updated to include CRC32 compute with High-Low bytes swapped, Flip Input buffer function updated to include destination pointer, VCU CRC example updated to run original and modified examples (2 of them - CRC32 and CRC32-MPEG2)

V2.26.00.00: Moderate Revision
- CRC examples ported to F28P65x

V2.25.00.00: Moderate Revision
- Updated VCU0/VCU2 examples updated to work with COFF/EABI

V2.24.00.00: Moderate Revision
- Updated VCU0 library to support reflected CRC compute in software

V2.23.00.00: Moderate Revision
- Added support for F280015x

V2.22.00.00: Moderate Revision
- Added support for F28003x

V2.21.00.00: Moderate Revision
- Migrated to compiler version 20.2.1 for VCRC library and examples

V2.20.00.00: Moderate Revision
- Added VCRC library and examples to demontrate the configurable polynomial, size and data

V2.10.00.00: Moderate Revision
- Shortened, and eliminated when unnecessary, the context save/restores for all functions
- Changed the linker command file and example for the crc_8 example to show how to run the crc on blocks larger than 65535 bytes
- Viterbi Decode - shortened the traceback loops (within the RPTB) from 6 instructions to 4
- Added De-interleaver assembly source code and example
- Added Interleaver ‘C’ source code
- Added VCU2 Real Inverse FFT source code and examples
- Corrected documentation for the RIFFT routines
- Eliminated global object definitions (‘extern’ qualifier) from the vcu2 header files
- Fixed bug in the rescale routine for Viterbi decode K7CR12 that was causing an overwrite
- Fixed bug with Inverse Berleykamp Massey routine, where size of the local frame was incorrect

V2.00.00.00: Initial Release
- First release of the library to work with VCU types 0, 2
- Added legacy VCU0 routines

IMPORTANT NOTICE

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

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