ECEN 4856

Lecture 9: Launchpad

Texas Instruments

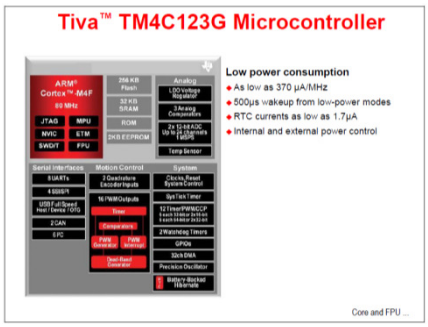
Getting Started with the Tiva™ TM4C123G LaunchPad Workshop

Student Guide and Lab Manual

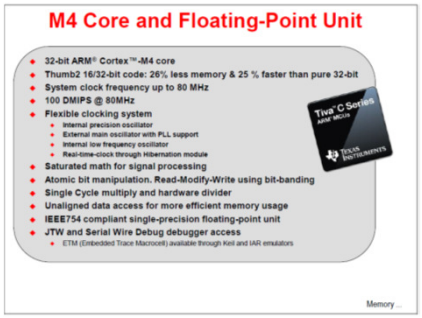
Revision 1.21
October 2013

TTO Technical Training Organization

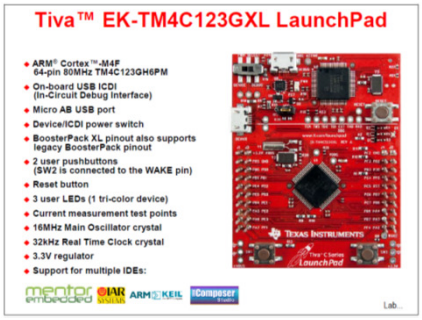
Tiva Microcontroller



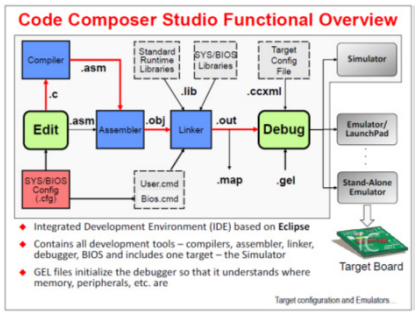
Tiva Microcontroller



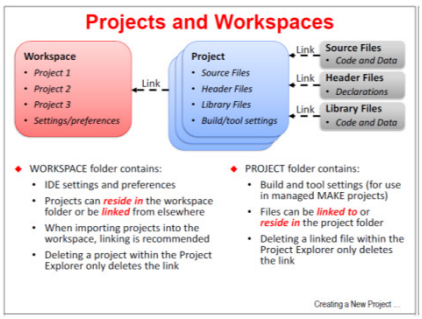
LaunchPad



Code Composer Studio

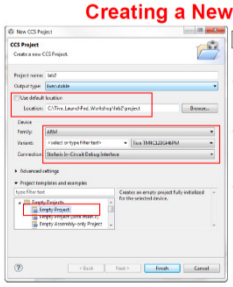


Code Composer Studio



Code Composer Studio

Creating a New Project



File→New→CCS Project

(in Edit perspective…)

- **Project Location**
  - Default = workspace
  - Manual = anywhere you like
- **Connection**
  - If target is specified, user can choose "connection" (i.e. the target configuration file)
- **Project templates**
  - Empty
  - Empty but with a main.c
  - Assembly only
  - BIOS
  - others

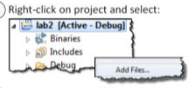
Adding Files to a Project …

Code Composer Studio

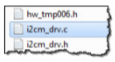
Adding Files to a Project

- **Users can ADD (copy or link) files into their project**
  - SOURCE files are typically COPIED
  - LIBRARY files are typically LINKED (referenced)

1. Right-click on project and select:



2. Select file(s) to add to the project:



3. Select "Copy" or "Link"

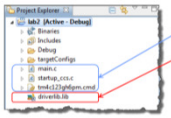
- **COPY**
  - Copies file from original location to *project folder* (two copies)
- **LINK**
  - References (points to) source file in the *original folder*
  - Can select a "reference" point – typically PROJECT_LOC

Making a Project Portable …

Code Composer Studio

Portable Projects

- **Why make your projects "portable"?**
  - Simplifies project sharing
  - You can easily re-locate your projects
  - Allow simple changes to link to new releases of software libraries



Copied files are not a problem (they move with the project folder)
Linked files may be an issue. They are located outside the project folder via a:
- absolute path, or
- relative path

This is the Path Variable for a relative path. This can be specified for every linked file.

Path and Build Variables …

Code Composer Studio

Path Variables and Build Variables

- **Path Variables**
  - Used by CCS (Eclipse) to store the base path for relative linked files
  - Example: PROJECT_LOC is set to the path of your project, say `c:/Tiva_LaunchPad_Workshop/lab2/project`
  - Used as a reference point for relative paths, e.g. `${PROJECT_LOC}/../files/main.c`

- **Build Variables**
  - Used by CCS (Eclipse) to store base path for build libraries or files
  - Example: CG_TOOL_ROOT is set to the path for the code generation tools (compiler/linker)
  - Used to find #include .h files, or object libraries, e.g. `${CG_TOOL_ROOT}/include` or `${CG_TOOL_ROOT}/lib`

- **How are these variables defined?**
  - The variables in these examples are automatically defined when you create a new project (PROJECT_LOC) and when you install CCS with the build tools (CG_TOOL_ROOT)
  - What about TivaWare or additional software libraries? You can define some new variables yourself

Adding Variables …

Code Composer Studio

Adding Variables

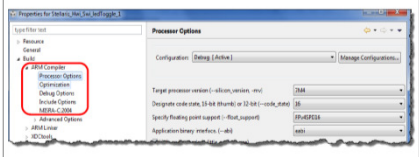
- **Why are we doing this?**
  - We could use PROJECT_LOC for all linked resources or PROJECT_ROOT as the base for build variables
  - It is "almost" portable, BUT if you move or copy your project, you have to put it at the same "level" in the file system
  - Defining a link and build variable for TivaWare location gives us a relative path that does NOT depend on location of the project (much more portable)
  - Also, if we install a new version of TivaWare, we only need to change these variables – which is much easier than creating new relative links
- **How to add Path and Build Variables**
  - *Project → Properties*, expand the *Resource* category, click on *Linked Resources*. You will see a tab for *Path Variables*, click *New* to add a new path variable
  - *Project → Properties*, click on *Build* category, click on the *Variables* tab, Click *New* to add a new build variable
  - In the lab, we'll add a path variable and build variable TIVAWARE_INSTALL to be the path of the latest TivaWare release
- **Note:**
  - This method defines the variables as part of the project (finer control)
  - You can also define variables as part of your workspace (do it once)

Build Configurations …

Code Composer Studio

Build Configurations

- Code Composer has two pre-defined BUILD CONFIGURATIONS:
  - *Debug* (symbols, no optimization) – great for LOGICAL debug
  - *Release* (no symbols, optimization) – great for PERFORMANCE
- Users can create their own custom build configurations
  - Right-click on the project and select *Properties*
  - Then click "*Processor Options*" or any other category:



CCS Licensing and Pricing …

Tivaware

In System Programming Options

Tiva Serial Flash Loader

- Small piece of code that allows programming of the flash without the need for a debugger interface.
- All Tiva C Series MCUs ship with the loader in flash
- UART or SSI interface option
- The LM Flash Programmer interfaces with the serial flash loader
- See application note SPMA029

Tiva Boot Loader

- Preloaded in ROM or can be programmed at the beginning of flash to act as an application loader
- Can also be used as an update mechanism for an application running on a Tiva microcontroller.
- Interface via UART (default), I²C, SSI, Ethernet, USB (DFU H/D)
- Included in the Tiva Peripheral Driver Library with full applications examples

Fundamental Clocks...

Clocks

Fundamental Clock Sources

Precision Internal Oscillator (PIOSC)
- 16 MHz ± 3%

Main Oscillator (MOSC) using…
- An external single-ended clock source
- An external crystal

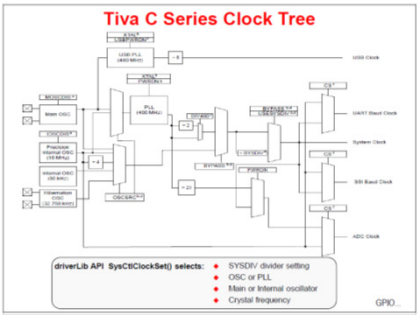
Internal 30 kHz Oscillator
- 30 kHz ± 50%
- Intended for use during Deep-Sleep power-saving modes

Hibernation Module Clock Source
- 32.768Hz crystal
- Intended to provide the system with a real-time clock source

SysClk Sources...

Clocks

Tiva C Series Clock Tree



GPIO...

GeneralPurpose IO

General Purpose IO

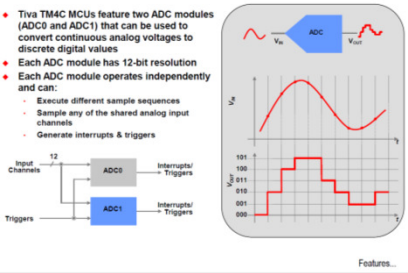
- **Any GPIO can be an interrupt:**
  - Edge-triggered on rising, falling or both
  - Level-sensitive on high or low values
- **Can directly initiate an ADC sample sequence or µDMA transfer**
- **Toggle rate up to the CPU clock speed on the Advanced High-Performance Bus. ½ CPU clock speed on the Standard.**
- **5V tolerant in input configuration**
- **Programmable Drive Strength (2, 4, 8mA or 8mA with slew rate control)**
- **Programmable weak pull-up, pull-down, and open drain**
- **Pin state can be retained during Hibernation mode**

Pin Mux Utility...

Analog to Digital

Analog-to-Digital Converter

- **Tiva TM4C MCUs feature two ADC modules (ADC0 and ADC1) that can be used to convert continuous analog voltages to discrete digital values**
- **Each ADC module has 12-bit resolution**
- **Each ADC module operates independently and can:**
  - **Execute different sample sequences**
  - **Sample any of the shared analog input channels**
  - **Generate interrupts & triggers**



Features...

Analog to Digital

TM4C123GH6PM ADC Features

- **Two 12-bit 1MSPS ADCs**
- **12 shared analog input channels**
- **Single ended & differential input configurations**
- **On-chip temperature sensor**
- **Maximum sample rate of one million samples/second (1MSPS).**
- **Fixed references (VDDA/GNDA) due to pin-count limitations**
- **4 programmable sample conversion sequencers per ADC**
- **Separate analog power & ground pins**
- **Flexible trigger control**
  - **Controller/ software**
  - **Timers**
  - **Analog comparators**
  - **GPIO**
- **2x to 64x hardware averaging**
- **8 Digital comparators / per ADC**
- **2 Analog comparators**
- **Optional phase shift in sample time, between ADC modules, programmable from 22.5 ° to 337.5°**

Sequencers...

Analog to Digital

ADC Sample Sequencers

- Tiva TM4C ADC's collect and sample data using programmable sequencers.
- Each sample sequence is a fully programmable series of consecutive (back-to-back) samples that allows the ADC module to collect data from multiple input sources without having to be re-configured.
- Each ADC module has 4 sample sequencers that control sampling and data capture.
- All sample sequencers are identical except for the number of samples they can capture and the depth of their FIFO.
- To configure a sample sequencer, the following information is required:
  - Input source for each sample
  - Mode (single-ended, or differential) for each sample
  - Interrupt generation on sample completion for each sample
  - Indicator for the last sample in the sequence
- Each sample sequencer can transfer data independently through a dedicated µDMA channel.

Sequencer	Number of Samples	Depth of FIFO
SS 3	1	1
SS 2	4	4
SS 1	4	4
SS 0	8	8

Lab...

Hibernation

Key Features

- Real Time Clock is a 32-bit seconds counter with a 15-bit sub seconds counter & add-in trim capability
- Dedicated pin for waking using an external signal
- RTC operational and hibernation memory valid as long as V_{BAT} is valid
- GPIO pins state retention provided during VDD3ON mode
- Two mechanisms for power control
  - System Power Control for CPU and other on-board hardware
  - On-chip Power Control for CPU only
- Low-battery detection, signaling, and interrupt generation, with optional wake on low battery
- 32,768 Hz external crystal or an external oscillator clock source
- 16 32-bit words of battery-backed memory are provided for you to save the processor state to during hibernation
- Programmable interrupts for RTC match, external wake, and low battery events.

Low Power Modes...

Power Modes

Power Mode Comparison

Mode → / Parameter ↓	Run Mode	Sleep Mode	Deep Sleep Mode	Hibernation (VDD3ON)	Hibernation (RTC)	Hibernation (no RTC)
I_{DD}	32 mA	10 mA	1.05 mA	5 µA	1.7 µA	1.5 µA
V_{DD}	3.3 V	3.3 V	3.3 V	3.3 V	0 V	0 V
V_{BAT}	N.A.	N.A.	N.A.	3 V	3 V	3 V
System Clock	80 MHz with PLL	40 MHz with PLL	30 kHz	Off	Off	Off
Core	Powered On	Powered On	Powered On	Off	Off	Off
	Clocked	Not Clocked	Not Clocked	Not Clocked	Not Clocked	Not Clocked
Peripherals	All On	All Off	All Off	All Off	All Off	All Off
Code	while(1)	N.A.	N.A.	N.A.	N.A.	N.A.

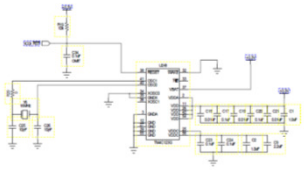
Box denotes power modes available on LaunchPad board

LaunchPad Considerations ...

Power

LaunchPad Considerations

- The low-cost LaunchPad board does not have a battery holder
- VDD and VBAT are wired together on the board (this disables battery-only powered low-power modes)
- Device current is measured between test points H24 and H25



Lab ...

USB

USB Basics

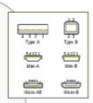
Multiple connector sizes

4 pins – power, ground and 2 data lines
(5th pin ID for USB 2.0 connectors)

Configuration connects power 1st, then data

Standards:

- **USB 1.1**
  - Defines **Host** (master) and **Device** (slave)
  - Speeds to 12Mbits/sec
  - Devices can consume 500mA (100mA for startup)
- **USB 2.0**
  - Speeds to 480Mbits/sec
  - OTG addendum
- **USB 3.0**
  - Speeds to 4.8Gbits/sec
  - New connector(s)
  - Separate transmit/receive data lines



USB Basics...

USB Basics

USB Basics

USB Device … most USB products are slaves

USB Host … usually a PC, but can be embedded

USB OTG … On-The-Go

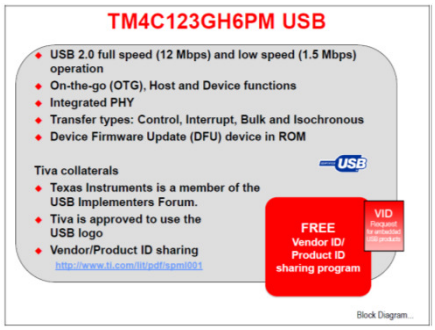
- Dynamic switching between host and device roles
- Two connected OTG ports undergo host negotiation

Host polls each Device at power up. Information from Device includes:

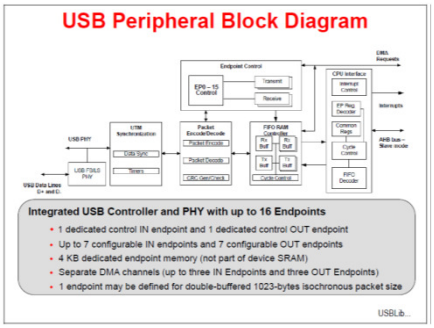
- Device Descriptor (Manufacturer & Product ID so Host can find driver)
- Configuration Descriptor (Power consumption and Interface descriptors)
- Endpoint Descriptors (Transfer type, speed, etc)
- Process is called *Enumeration* … allows Plug-and-Play

TM4C123GH6PM USB...

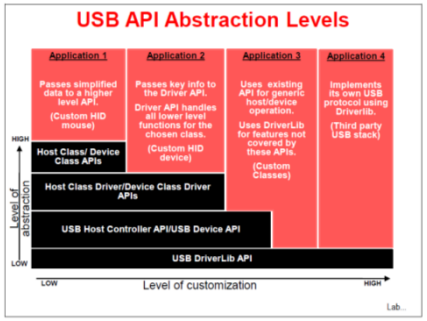
Tiva USB



Block Diagram



USB API



Reference

- *Getting Started With the Tiva C Series TM4C123G LaunchPad Workshop* , Revision1.21, October 2013, Texas Instruments