AN0009.0: Getting Started with EFM32 and EZR32 Series 0

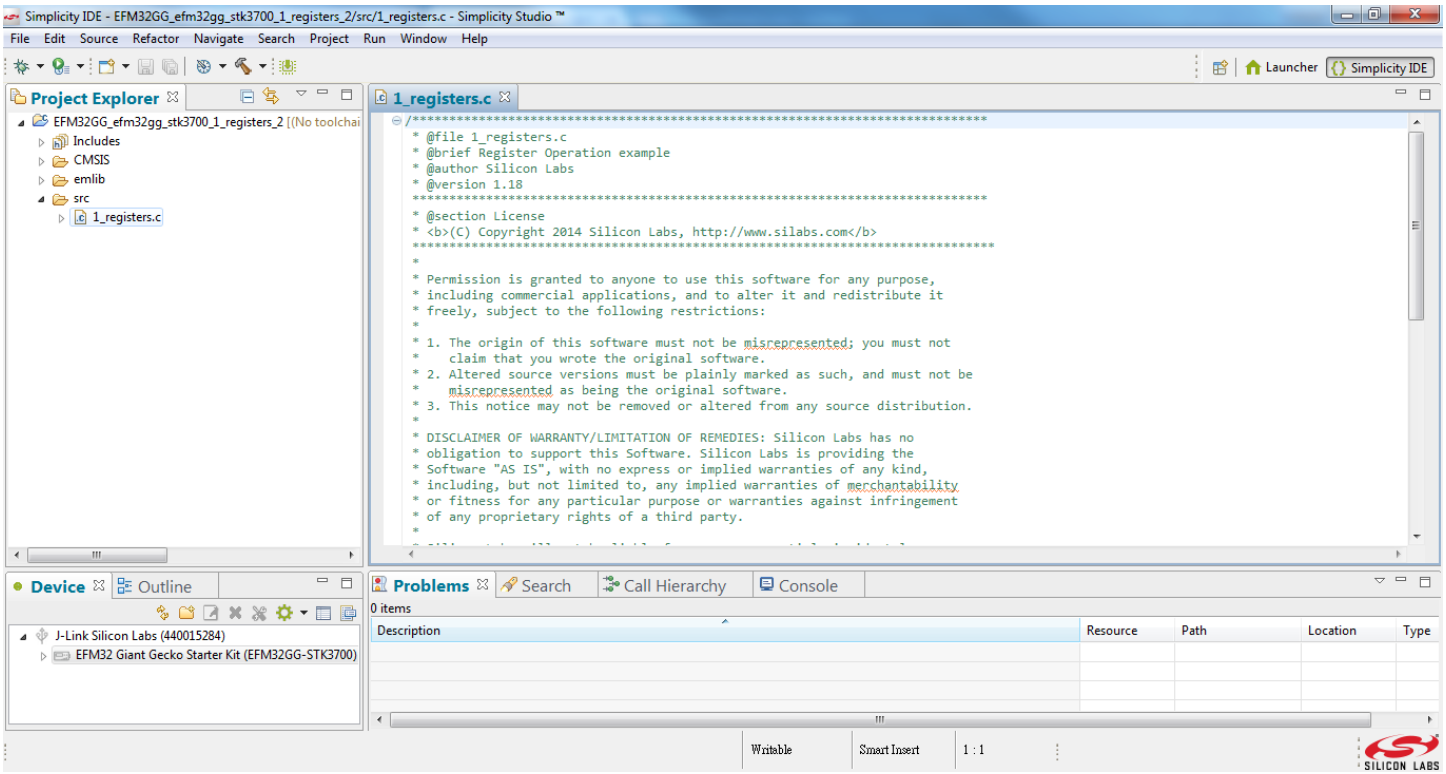
This application note introduces the software examples, libraries, documentation, and software tools available for EFM32 and EZR32 Series 0.

In addition to providing a basic introduction to the tools available for these devices, this document includes several basic firmware exercises to familiarize the reader with the Starter Kit hardware, the emlib firmware library, and the Simplicity Studio software tools.

Note that this document focuses on the MCU portion of the devices. For wireless products (EZR32), see the additional wireless getting started information available in the user guide specifically for the product. More information on the hardware for any product can be found in the kit user guide. More information about Simplicity Studio in general can be found in *AN0822: Simplicity Studio™ User Guide*. Application notes can be found on the Silicon Labs website (www.silabs.com/32bit-appnotes) or in Simplicity Studio.

KEY POINTS

- Simplicity Studio contains everything needed to develop with EFM32 and EZR32 Series 0.
- Things you will learn:
  - Basic register operation
  - Using emlib functions
  - Blinking LEDs and reading buttons
  - LCD controller
  - Energy Modes
  - Real-Time Counter operation



1. Device Compatibility

This application note supports multiple device families, and some functionality is different depending on the device.

MCU Series 0 consists of:

- EFM32 Gecko (EFM32G)
- EFM32 Giant Gecko (EFM32GG)
- EFM32 Wonder Gecko (EFM32WG)
- EFM32 Leopard Gecko (EFM32LG)
- EFM32 Tiny Gecko (EFM32TG)
- EFM32 Zero Gecko (EFM32ZG)
- EFM32 Happy Gecko (EFM32HG)

Wireless MCU Series 0 consists of:

- EZR32 Wonder Gecko (EZR32WG)
- EZR32 Leopard Gecko (EZR32LG)
- EZR32 Happy Gecko (EZR32HG)

2. Introduction

2.1 Prerequisites

The examples in this application note require access to a supported Silicon Labs device. Supported devices include the EFM32 Series 0 Starter Kit. Before working on this tutorial, ensure a compatible IDE is available by either:

- Installing Simplicity Studio from Silabs.com (http://www.silabs.com/simplicity), or
- If IAR is preferred, install the latest Segger J-Link drivers to support the kit (https://www.segger.com/jlink-software.html)

In Simplicity Studio, ensure that all the available packages are installed and up to date by clicking on the [**Update Software**] button at the top-left of the main window:

Note: While Simplicity Studio includes a fully-functional integrated IDE, it also supports some third party IDEs, including IAR. For this reason, it is recommended to install Simplicity Studio regardless of the preferred IDE for easy access to these examples as well as the full suite of features provided to facilitate development of EFM32 and EZR32 Series 0 solutions.

2.2 How to Use this Application Note

The source code for this application note is placed in the root folder `an0009_efm32_getting_started`.

The easiest way to access the example source code and projects is through the [**Application Notes**] dialogue box under [**Getting Started**] tab in Simplicity Studio. Simply click one of the application notes to open the [**Application Notes**] dialog.

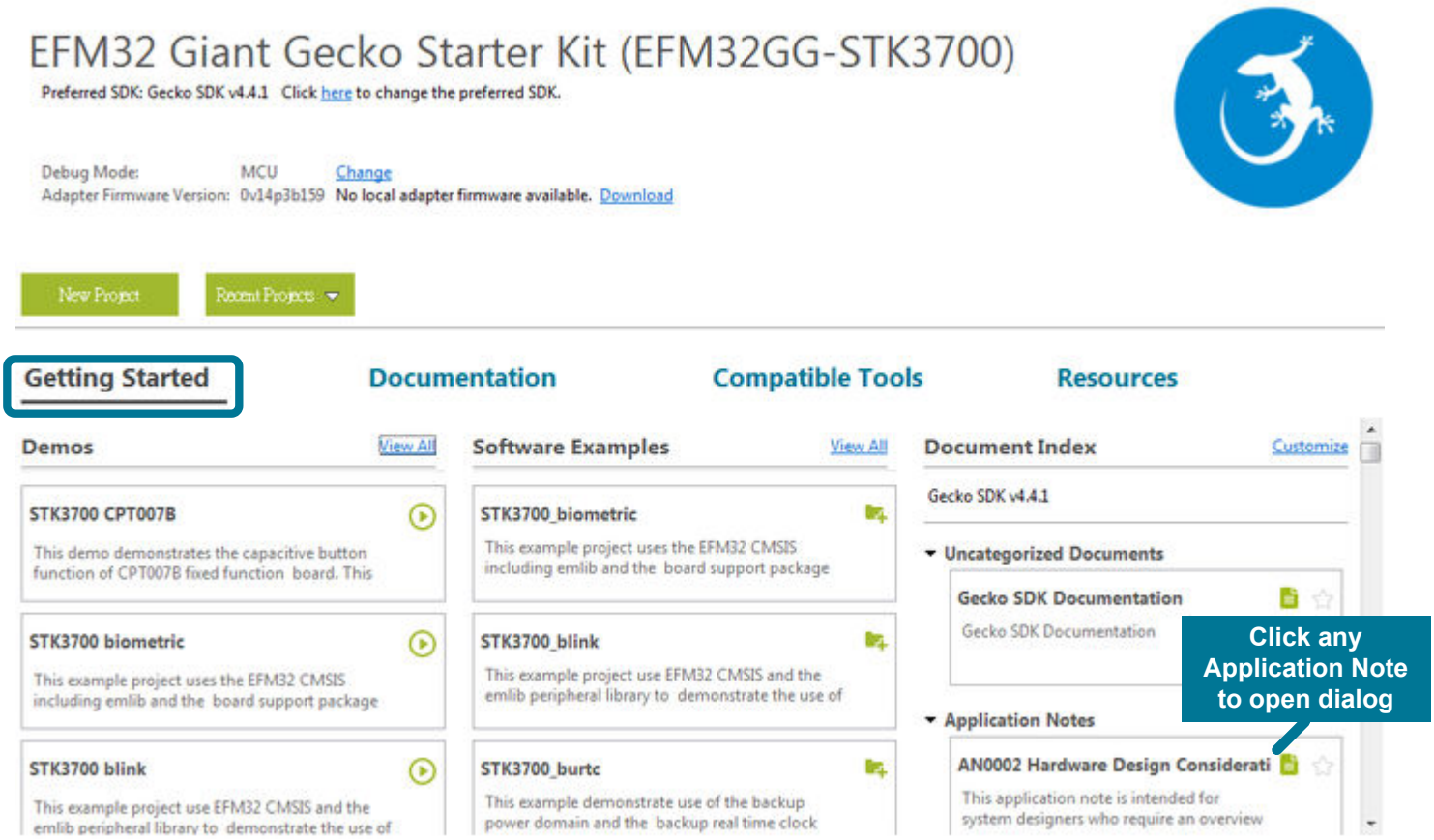


Figure 2.1. Application Notes in Simplicity Studio

Within the [**Application Notes**] dialog, navigate to and select the [**AN0009 Getting Started with EFM32**] entry, then click the [**Import Project...**] button to view the list of available example projects. Use the project names to identify examples compatible with the kit and select one to import that project into the IDE (by default, this is the Simplicity IDE, but this configuration can be changed to an alternative IDE, if desired).

Alternatively, projects for multiple IDEs are stored in separate folders (`iar`, `arm`, etc.) in the filesystem that hosts these examples, accessible with the [**Open Folder**] button in the Simplicity Studio [**Applications Notes**] dialog. These projects can be manually loaded in the appropriate IDE. All of the IAR projects are also collected in one common workspace called `efm32.eww`. Since the projects are slightly different for the various kits, make sure to open the project that is prefixed with the name of the kit in use.

Note: The code examples in this application note are not complete, and the reader is required to fill in small pieces of code throughout the exercises. A completed code file (postfixed with `*_solution.c`) also exists for each example.

3. Register Operation

This chapter explains the basics of how to write C-code for the EFM32 and EZR32 Series 0 devices using the defines and library functions supplied in the [**CMSIS**] and [**emlib**] software libraries.

3.1 Address

The EFM32 and EZR32 Series 0 devices consist of several different types of peripherals (CMU, RTC, ADC...). Some peripherals in the device exist only as one instance, such as the Clock Management Unit (CMU). Other peripherals like Timers (TIMERn) exist as several instances and the name is postfixed by a number (n) denoting the instance number. Usually, two instances of a peripheral are identical, but are placed in different regions of the memory map. However, some peripherals have a different feature set for each of the instances. For example, USART0 can have an IrDA interface, while USART1 cannot. Such differences will be explained in the device data sheet and the reference manual.

EFM32 and EZR32 Series 0 peripherals are memory mapped, meaning each peripheral instance has a dedicated address region which contains registers that can be accessed by read/write operations. The peripheral instances and memory regions are found in the device data sheet. The starting address of a peripheral instance is called the base address. The reference manual for the device series contains a complete description of the registers within each peripheral. The address for each register is given as an offset from the base address for the peripheral instance.

3.2 Register Description

The EFM32 and EZR32 Series 0 devices use a 32-bit bus for write/read access to the peripherals, and each register in a peripheral contains 32 bits, numbered 0-31. Unused bits are marked as reserved and should not be modified. The bits used by the peripheral can either be single bits (e.g. OUTEN bit in the figure below) or grouped together in bitfields (e.g. PRSSEL bitfield in the figure below). Each bitfield is described with the following attributes:

- Bit position
- Name
- Reset value
- Access type
- Description

24.5.1 IDAC_CTRL - Control Register

Offset	Bit Position																													
0x000	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reset										0x0						0		0	0	0					0x00				0	0	0	0
Access										RW						RW		RW	RW	RW					RW				RW	RW	RW	RW
Name										PRSSEL						OUTENPRS		APORTMASTERDIS	EM2DELAY	PWRSEL					APORTOUTSEL				OUTEN	MINOUTTRANS	CURSINK	EN

Bit	Name	Reset	Access	Description
31:24	*Reserved*	*To ensure compatibility with future devices, always write bits to 0. More information in 1.2 Conventions*		
23:20	PRSSEL	0x0	RW	**IDAC Output PRS channnel Select**

Selects which PRS channel to use, when OUTENPRS is set.

Value	Mode	Description
0	PRSCH0	PRS Channel 0 selected.
1	PRSCH1	PRS Channel 1 selected.
2	PRSCH2	PRS Channel 2 selected.
3	PRSCH3	PRS Channel 3 selected.
4	PRSCH4	PRS Channel 4 selected.
5	PRSCH5	PRS Channel 5 selected.
6	PRSCH6	PRS Channel 6 selected.
7	PRSCH7	PRS Channel 7 selected.
8	PRSCH8	PRS Channel 8 selected.
9	PRSCH9	PRS Channel 9 selected.
10	PRSCH10	PRS Channel 10 selected.
11	PRSCH11	PRS Channel 11 selected.

Figure 3.1. Example Register Description

3.3 Access Types

Each register has a set access type for all of the bit fields within that register. The access type describes the reaction to read or write operations to the bit field. The different access types found for the registers in the devices are described in the table below.

Table 3.1. Register Access Types

Access Type	Description
R	Read only. Writes are ignored
RW	Readable and writable
RW1	Readable and writable. Only writes to 1 have effect
(R)W1	Sometimes readable. Only writes to 1 have effect. Currently only used for IFC registers
W1	Read value undefined. Only writes to 1 have effect
W	Write only. Read value undefined.
RWH	Readable, writable, and updated by hardware
RW(nB), RWH(nB), etc.	"(nB)" suffix indicates that register explicitly does not support peripheral bit set or clear
RW(a), R(a), etc.	"(a)" suffix indicates that register has actionable reads

3.4 CMSIS and emlib

The Cortex Microcontroller Software Interface Standard (CMSIS) is a common coding standard for all ARM Cortex devices. The CMSIS library provided by Silicon Labs contains header files, defines (for peripherals, registers and bitfields), and startup files for all devices. In addition, CMSIS also includes functions that are common to all Cortex devices, like interrupt handling, intrinsic functions, etc. Although it is possible to write to registers using hard coded address and data values, it is recommended to use the defines to ensure portability and readability of the code.

In order to use these defines, projects must include `em_device.h` in the c-file. This is a common header file for all EFM32 and EZR32 Series 0 devices. Within this file, the header file content for the appropriate device is included in the project builds according to the preprocessor symbols defined for the project.

To simplify the programming of EFM32 and EZR32 Series 0 devices, Silicon Labs developed and maintains a complete C-function library called [**emlib**] that provides efficient, clear, and robust access to and control of all peripherals and core functions in the device. This library resides within the `em_xxx.c` (e.g. `em_dac.c`) and `em_xxx.h` (e.g. `em_dac.h`) files in the `emlib` folder under path below (where v1.1 is the Gecko SDK Suite version number).

```
C:\SiliconLabs\SimplicityStudio\v4\developer\sdks\gecko_sdk_suite\v1.1\platform\emlib
```

In the source files included with this application note, the `em_chip.h` is included in each and a call to `CHIP_Init()` exists near the beginning of every `main()` function. Like the content of `em_device.h`, the actions taken within the `CHIP_Init()` function depends on the specific part in use, but will include correcting for known errata and otherwise ensuring consistent behavior across devices. For this reason, do not run any code in the main function prior to running the `CHIP_Init()` function.

3.4.1 CMSIS Documentation

Complete Doxygen documentation for the EFM32 and EZR32 Series 0 [**CMSIS**] library and [**emlib**] is available via the [**Gecko SDK Documentation**] box under [**Documentation**] in the Simplicity Studio main window when the corresponding device or kit is selected. This documentation is also available on the Silicon Labs website at http://devtools.silabs.com/dl/documentation/doxygen/ or on GitHub at https://siliconlabs.github.io/Gecko_SDK_Doc/.

3.4.2 Peripheral Structs

In the emlib header files, the register defines for each peripheral type are grouped in structs as defined in the example below:

```
typedef struct
{
__IO uint32_t CTRL;
__I uint32_t STATUS;
__IO uint32_t CH0CTRL;
__IO uint32_t CH1CTRL;
__IO uint32_t IEN;
__I uint32_t IF;
__O uint32_t IFS;
__O uint32_t IFC;
__IO uint32_t CH0DATA;
__IO uint32_t CH1DATA;
__O uint32_t COMBDATA;
__IO uint32_t CAL;
__IO uint32_t BIASPROG;
} DAC_TypeDef;
```

Recall that a register address consists of a base address for the peripheral instance plus an additional offset. The peripheral structs in [**emlib**] simplify writing to a register and abstract away these underlying addresses and offsets. Hence, writing to CH0DATA in the DAC0 peripheral instance can then be done like this:

```
DAC0->CH0DATA = 100;
```

Similarly, reading a register can be done like this:

```
myVariable = DAC0->STATUS;
```

3.4.3 Bit Field Defines

Every device has relevant bit fields defined for each peripheral. These definitions are found within the `efm32xx_xxx.h` (e.g. `efm32tg_dac.h`) files and are automatically included with the appropriate [**emlib**] peripheral header file.

```
#define _DAC_CTRL_REFRSEL_SHIFT              20
#define _DAC_CTRL_REFRSEL_MASK               0x300000UL
#define _DAC_CTRL_REFRSEL_DEFAULT            0x00000000UL
#define _DAC_CTRL_REFRSEL_8CYCLES            0x00000000UL
#define _DAC_CTRL_REFRSEL_16CYCLES           0x00000001UL
#define _DAC_CTRL_REFRSEL_32CYCLES           0x00000002UL
#define _DAC_CTRL_REFRSEL_64CYCLES           0x00000003UL
#define DAC_CTRL_REFRSEL_DEFAULT             (_DAC_CTRL_REFRSEL_DEFAULT << 20)
#define DAC_CTRL_REFRSEL_8CYCLES             (_DAC_CTRL_REFRSEL_8CYCLES << 20)
#define DAC_CTRL_REFRSEL_16CYCLES            (_DAC_CTRL_REFRSEL_16CYCLES << 20)
#define DAC_CTRL_REFRSEL_32CYCLES            (_DAC_CTRL_REFRSEL_32CYCLES << 20)
#define DAC_CTRL_REFRSEL_64CYCLES            (_DAC_CTRL_REFRSEL_64CYCLES << 20)
```

For every register bitfield, associated shift, mask and default value bit fields are also defined.

```
#define DAC_CTRL_DIFF                        (0x1UL << 0)
#define _DAC_CTRL_DIFF_SHIFT                 0
#define _DAC_CTRL_DIFF_MASK                  0x1UL
#define _DAC_CTRL_DIFF_DEFAULT               0x00000000UL
#define DAC_CTRL_DIFF_DEFAULT                (_DAC_CTRL_DIFF_DEFAULT << 0)
```

3.4.4 Register Access Examples

When setting a bit in a control register, it is important to make sure firmware does not unintentionally clear other bits in the register. To ensure this, the mask containing the bit firmware needs to set can be OR'ed with the original contents, as shown in the example below:

```
DAC0->CTRL = DAC0->CTRL | DAC_CTRL_LPFEN;
```

A more compact version is:

```
DAC0->CTRL |= DAC_CTRL_LPFEN;
```

Clearing a bit is done by ANDing the register with a value with all bits set except for the bit to be cleared:

```
DAC0->CTRL = DAC0->CTRL & ~DAC_CTRL_LPFEN; // or
DAC0->CTRL &= ~DAC_CTRL_LPFEN;
```

When setting a new value to a bit field containing multiple bits, a simple OR function will not do, since this will risk that the original bit field contents OR'ed with the mask will give a wrong result. Instead, make sure to clear the entire bit field (and only the bit field) before ORing in the new value:

```
DAC0->CTRL = (DAC0->CTRL & ~_DAC_CTRL_REFRSEL_MASK) | DAC_CTRL_REFRSEL_16CYCLES;
```

3.4.5 Grouped Registers

Some registers are grouped together within each peripheral. An example of such a group is the registers associated with each GPIO port, like the Data Out Register (DOUT) in the figure below. Each GPIO port (A, B, C, ...) contains a DOUT register and the description below is common for all of these. The x in GPIO_Px_DOUT indicates the port wild card.

27.5.4 GPIO_Px_DOUT - Port Data Out Register

Offset	Bit Position																													
0x00C	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reset																									0x0000						
Access																									RW						
Name																									DOUT						

Bit	Name	Reset	Access	Description
31:16	*Reserved*	*To ensure compatibility with future devices, always write bits to 0. More information in 1.2 Conventions*		
15:0	DOUT	0x0000	RW	**Data Out**
	Data output on pin.			

Figure 3.2. Grouped Registers in GPIO

In the CMSIS defines, the port registers are grouped in an array P[x]. When using this array, we must index it using numbers instead of the port letters (A=0, B=1, C=2, ...). Accessing the DOUT register for port C can be done like this:

```
GPIO->P[2].DOUT = 0x000F;
```

4. Example 1 — Register Operation

This example will show how to write and read registers using the CMSIS defines. This tutorial also shows how to observe and manipulate register contents through the debugger in Simplicity Studio or IAR Embedded Workbench. While the examples are shown only for Simplicity Studio and IAR, the tasks can also be completed in other supported IDEs.

For Simplicity Studio:

1. Connect the kit to the PC and open Simplicity Studio.
2. Once the kit appears, click on the kit (e.g. EFM32 Giant Gecko Starter Kit (EFM32GG-STK3700)) in [**Device**] window.
3. Click one of the application notes under [**Getting Started**] tab to open [**Application Notes**] dialog.
4. Search for [**AN0009 Getting Started with EFM32**] and click the document in the list, then click the [**Import Project...**] button.
5. Select the [**<kit_name>_1_registers.slsproj**] option in the dialog and click [**OK**].
6. Double-click on the `1_registers.c` file to open it in the editor view. There's a marker where custom code should be added.

For IAR:

1. Open up the efm32 workspace (`an\an0009_efm32_getting_started\iar\efm32.eww`).
2. Select the [**<kit_name>_1_registers**] project in IAR Embedded Workbench.
3. In the main function in the `1_registers.c` (inside Source Files), there's a marker where custom code should be added.

4.1 Step 1 — Enable Timer Clock

In this example, we are going to use TIMER0. The high frequency RC oscillator (HFRCO) is running at default frequency band, but all peripheral clocks are disabled, so we must turn on the clock for TIMER0 before we use it. If we look in the CMU chapter of the reference manual, we see that the clock to TIMER0 can be switched on by setting the TIMER0 bit in the HFPERCLKEN0 register in the CMU peripheral.

4.2 Step 2 — Start Timer

Starting the Timer is done by writing a 1 to the START bit in the CMD register in TIMER0.

4.3 Step 3 — Wait for Threshold

Create a while-loop that waits until the counter is 1000 before proceeding.

4.4 Observation

For Simplicity IDE, make sure the [**<kit_name>_1_registers**] project is active by clicking the project in the left-hand [**Project**] view. Then, press the [**Debug**] button to automatically build and download the code to the device. Click the [**Registers**] view and find the STATUS register in TIMER0. After expanding the register, notice that the RUNNING bit set to 0.

In the code view, double-click the left pane to place a breakpoint before firmware starts the timer and click the [**Resume**] button. Then, watch the RUNNING bit get set to 1 in the [**Registers**] view when single stepping over the expression using the [**Step Over**] button. Continue to single step and note that the content of the CNT registers is increasing. Try writing a different value to the CNT register by entering it directly in the [**Registers**] view.

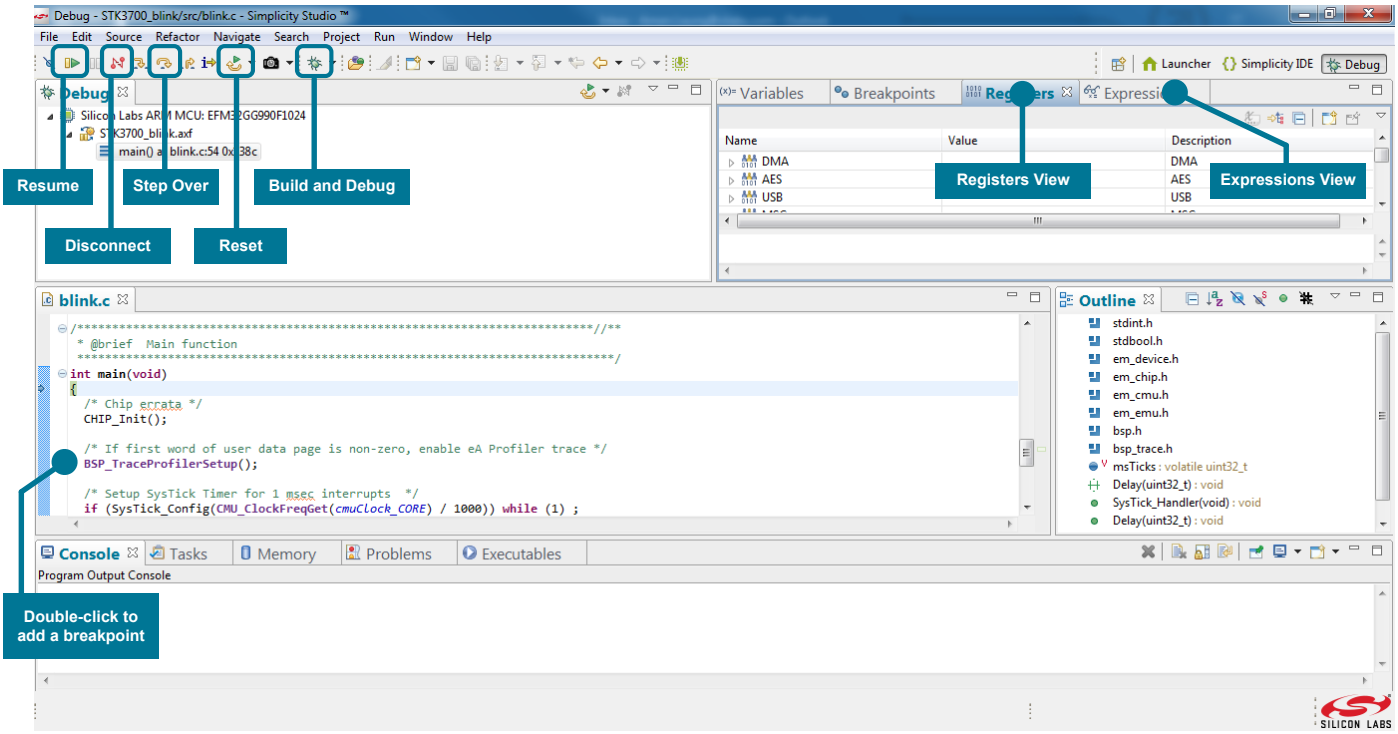


Figure 4.1. Debug View in Simplicity IDE

For IAR, make sure the [**<kit_name>_1_registers**] project is active by pressing the corresponding tab at the bottom of the Workspace window. Then, press the [**Download & Debug**] button and go to [**View**]->[**Register**] and find the STATUS register in TIMER0. After expanding the register, notice that the RUNNING bit is set to 0.

Place the cursor in front of the line where firmware starts the timer and press [**Run to Cursor**]. Then, watch the RUNNING bit get set to 1 in the [**Register**] view when clicking the [**Step Into**] button to move over the expression. Continue to click the [**Step Into**] button to see the content of the CNT registers increasing. Try writing a different value to the CNT register by entering it directly in the [**Register**] view.

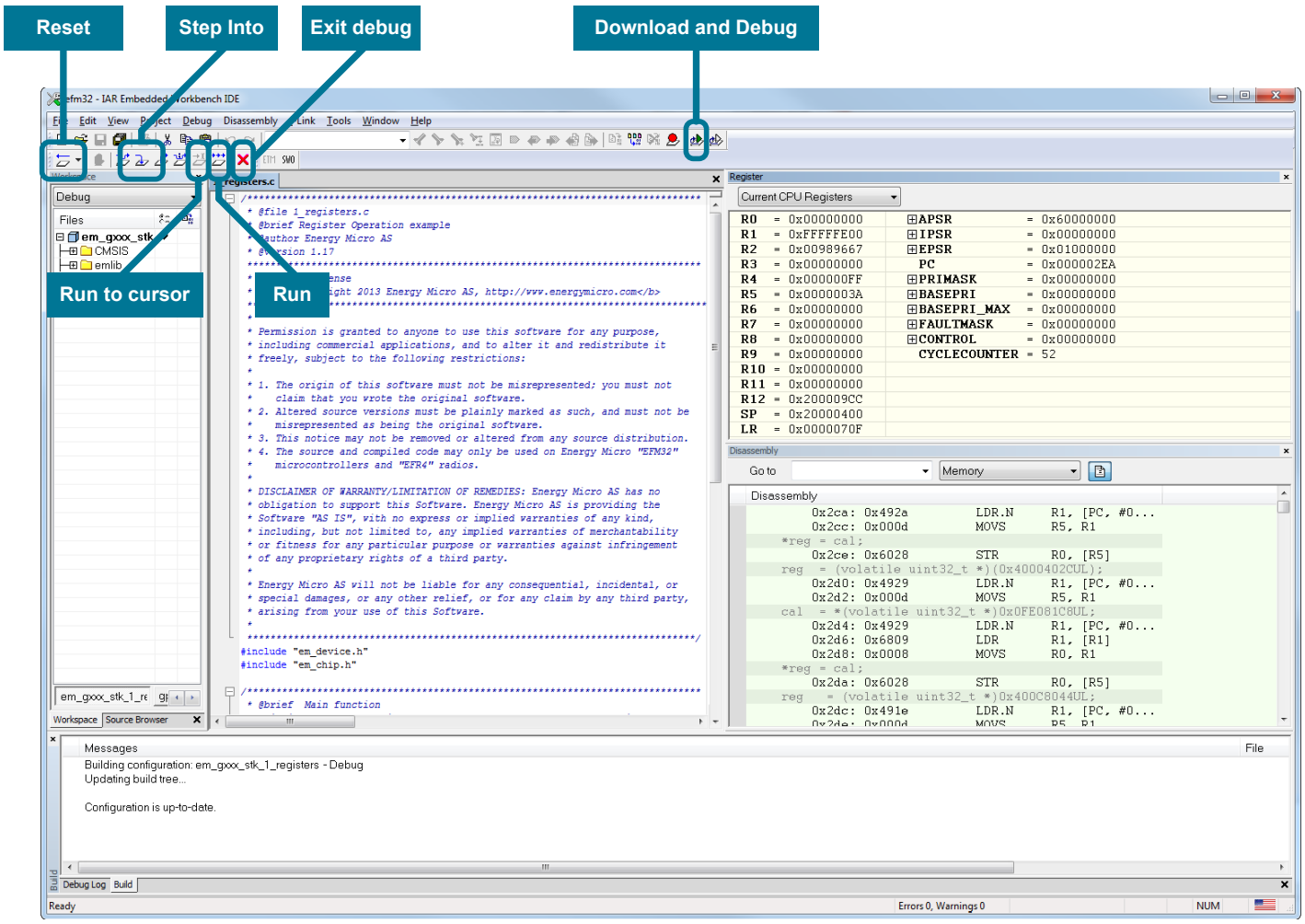


Figure 4.2. Debug View in IAR

5. Example 2 — Blinking LEDs with an STK

In this example, the aim is to use the GPIO pins to light up the LEDs on the STK and change the LED configuration every time a button is pressed. Instead of accessing the registers directly, use the emlib functions to configure the peripherals.

The AN0009 application note includes a [**<kit_name>_2_leds**] project in Simplicity Studio and the IAR efm32 workspace, which will be used in this example. The emlib C-files are included in the project. The corresponding header files are included at the beginning of the C-files.

For details on which emlib functions exist and how to use them, open the API documentation through Simplicity Studio using the [**Gecko SDK Documentation**] under [**Documentation**] (or by going to http://devtools.silabs.com/dl/documentation/doxygen/). After clicking on the software documentation link for the correct device (e.g. Giant Gecko), open up [**Modules->EMLIB**] and select the [**CMU**] peripheral. Find a list of functions for this peripheral by clicking on the [**Functions**] link at the top-right of the window. These functions can be used to to easily operate the Clock Management Unit.

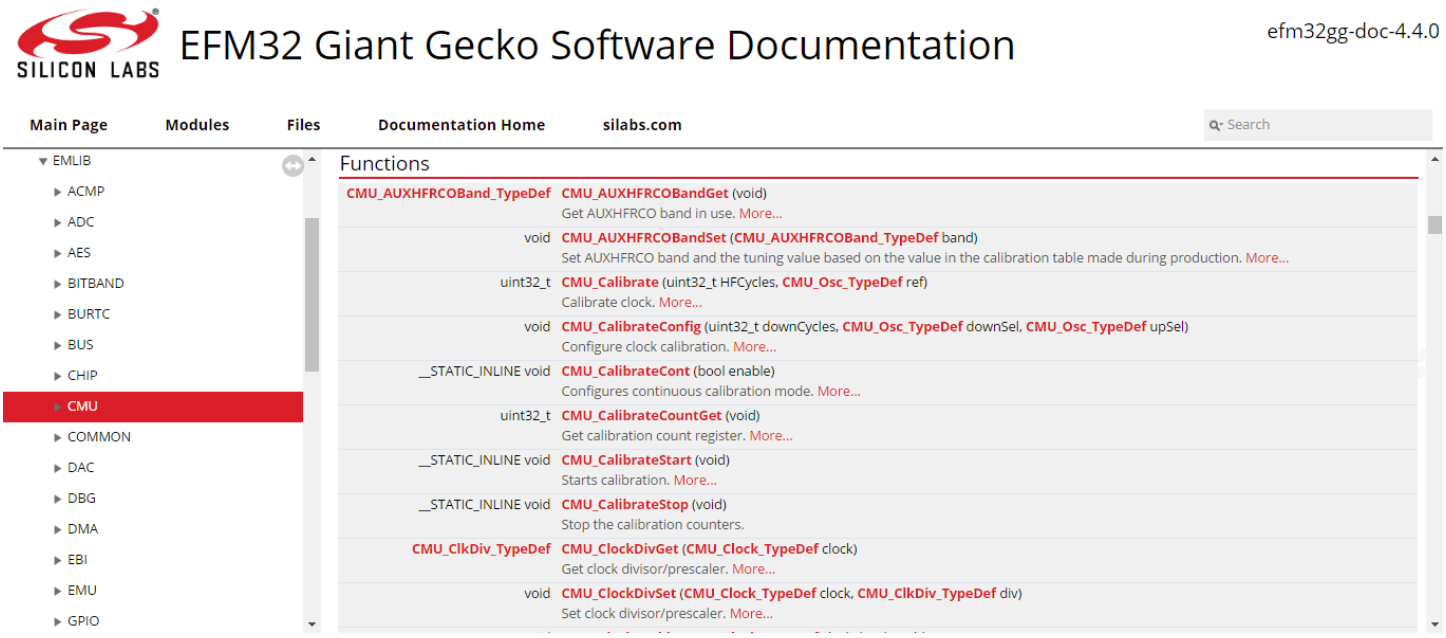


Figure 5.1. Documentation for the CMU-specific emlib Functions

5.1 Step 1 — Turn on GPIO clock

In the list of CMU functions we find the following function to turn on the clock to the GPIO:

```
void CMU_ClockEnable(CMU_Clock_TypeDef clock, bool enable)
```

If we click on the function, we are shown a description of how to use the function. Clicking on the [**CMU_Clock_TypeDef**] link goes to a list of the allowed enumerators for the clock argument. To turn on the GPIO, add the following:

```
CMU_ClockEnable(cmuClock_GPIO, true);
```

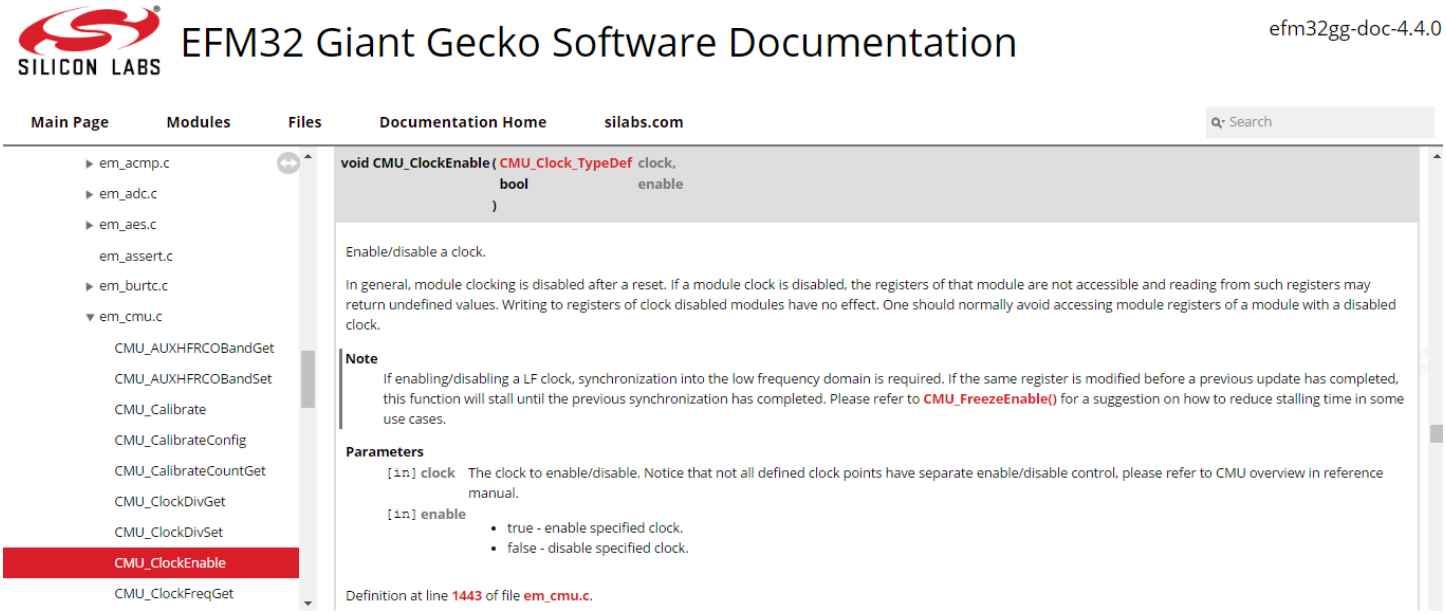


Figure 5.2. CMU_ClockEnable Function Description

5.2 Step 2 — Configure GPIO Pins for LEDs

The User Manual for a kit is available in Simplicity Studio under the [**Documentation**] when the corresponing kit is selected in the Device or Solutions window. This document describes the usage of all the pins, including the user LED(s). These LED(s) are connected as follows on these EFM32 Series 0 kits:

- EFM32-Gxxx-STK: 4 LEDs on port C, pins 0-3
- EFM32TG-STK3300: 1 LED on port D, pin 7
- EFM32GG-STK3700: 2 LEDs on port E, pins 2-3
- EFM32ZG-STK3200: 2 LEDs on port C, pins 10-11

Consult the user manual for information specific to the kit in use.

Looking into the available functions for the GPIO, the following function can be used to configure the mode of the GPIO pins:

```
void GPIO_PinModeSet(GPIO_Port_TypeDef port, unsigned int pin,
   GPIO_Mode_TypeDef mode, unsigned int out)
```

Use this function to configure the LED pin(s) as Push-Pull outputs with the initial DOUT value set to 0.

5.3 Step 3 — Configure a GPIO Pin for a Button

Look at the User Manual for the STK to find where Push Button 0 (PB0) is connected on the kit in use. This button is connected on several example kits as follows:

- EFM32-Gxxx-STK: Port B, pin 9
- EFM32TG-STK3300: Port D, pin 8
- EFM32GG-STK3700: Port B, pin 9
- EFM32ZG-STK3200: Port C, pin 8

Configure this pin as an input to be able to detect the button state.

5.4 Step 4 — Change LED Status when a Button is Pressed

Write a loop that toggles the LED(s) every time PB0 is pressed. Make sure to not only check that the button is pressed, but also that it is released, so that the LED(s) only toggle once for each button press. PB0 is pulled high by an external resistor.

5.5 Extra Task — LED Animation

Experiment with creating different blinking patterns on the LED(s), like fading and running LEDs (if there are multiple LEDs). Because the device typically runs in the HFRCO frequency band by default, add a delay function to be able to see the LEDs changing in real-time. Using the code for TIMER0 in Example 1, create the following function:

```
void Delay(uint16_t milliseconds)
```

Use the PRESC bitfield in TIMER0_CTRL to reduce the clock frequency to a desired value.

6. Example 3a — Segment LCD Controller

This example requires an STK with a Segment LCD. This example will demonstrate how to use the Segment LCD controller and display information on the LCD display. The LCD controller includes an autonomous animation feature which will also be demonstrated. The AN0009 application note includes a [**<kit_name>_3_lcd**] project in Simplicity Studio and the IAR efm32 workspace, which will be used in this example.

6.1 Step 1 — Initialize the LCD controller

The LCD controller driver is located in the starter kit library. First, run the initialize function `SegmentLCD_Init()`found in `segmentlcd.h` to set up the LCD controller.

6.2 Step 2 — Write to the LCD display

By default, all LCD segments are switched off after initialization. The LCD controller driver includes several functions to control the different segment groups on the display. A few examples are:

```
void SegmentLCD_Number(int value)
void SegmentLCD_Write(char *string)
void SegmentLCD_Symbol(lcdSymbol s, int on);
```

Experiment with putting custom text, numbers, or symbols on the display and try to make things move about a bit. Use the Delay function from Example 2. A Delay function can also be found in the solution file.

6.3 Step 3 — Animate Segments

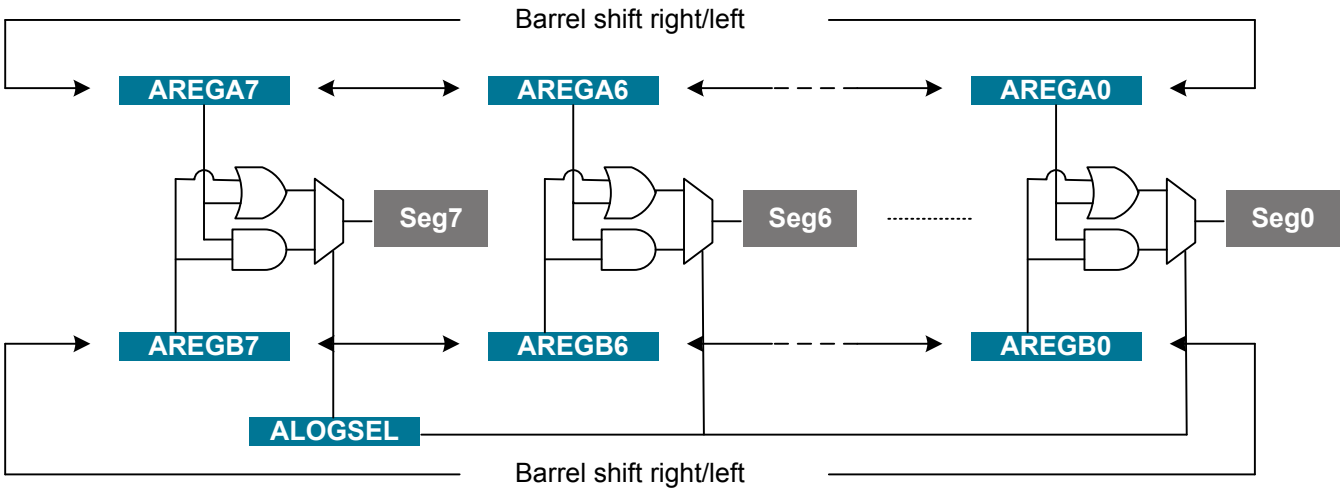


Figure 6.1. Animation Function

The LCD controller contains an animation feature which can animate up to 8 segments (8-segment ring on the LCD display) autonomously. The data displayed in the animated segments is a logic function (AND or OR) of two register bits for each segment. The two register arrays (LCD_AREGA, LCD_AREGB) can then be set up to be barrel shifted either left or right every time the Frame Counter overflows. The Frame Counter can be set up to overflow after a configurable number of frames. The firmware manipulates the LCD registers by doing direct register writes. The following registers must be set up:

LCD_BACTRL:

- Set Frame Counter Enable bit
- Configure Frame Counter period by setting the FCTOP field
- Set Animation Enable bit
- Select either AND or OR as logic function
- Configure AREGA and AREGB shift direction
- For the Giant Gecko STK (STK3700), also set the ALOC bit to SEG8TO15

LCD_AREGA/LCD_AREGB:

- Write data used for animation to these registers.

Play around a bit with the configuration of the animated segments and watch the results on the LCD display.

7. Example 3b — Memory LCD

This example requires an STK equipped with a Memory LCD (e.g. Happy Gecko, Zero Gecko, Pearl Gecko, and EFR32xG Wireless STKs). This example shows how to configure the Memory LCD driver and write text on the Memory LCD. The software project called [**<kit_name>_3_lcd_mem**] will be used in this example.

The Gecko SDK includes a driver for the memory LCD. Documentation for this display driver is found in the [**Display**] under the [**Kit Drivers**] section in corresponding kit [**Software Documentation**].

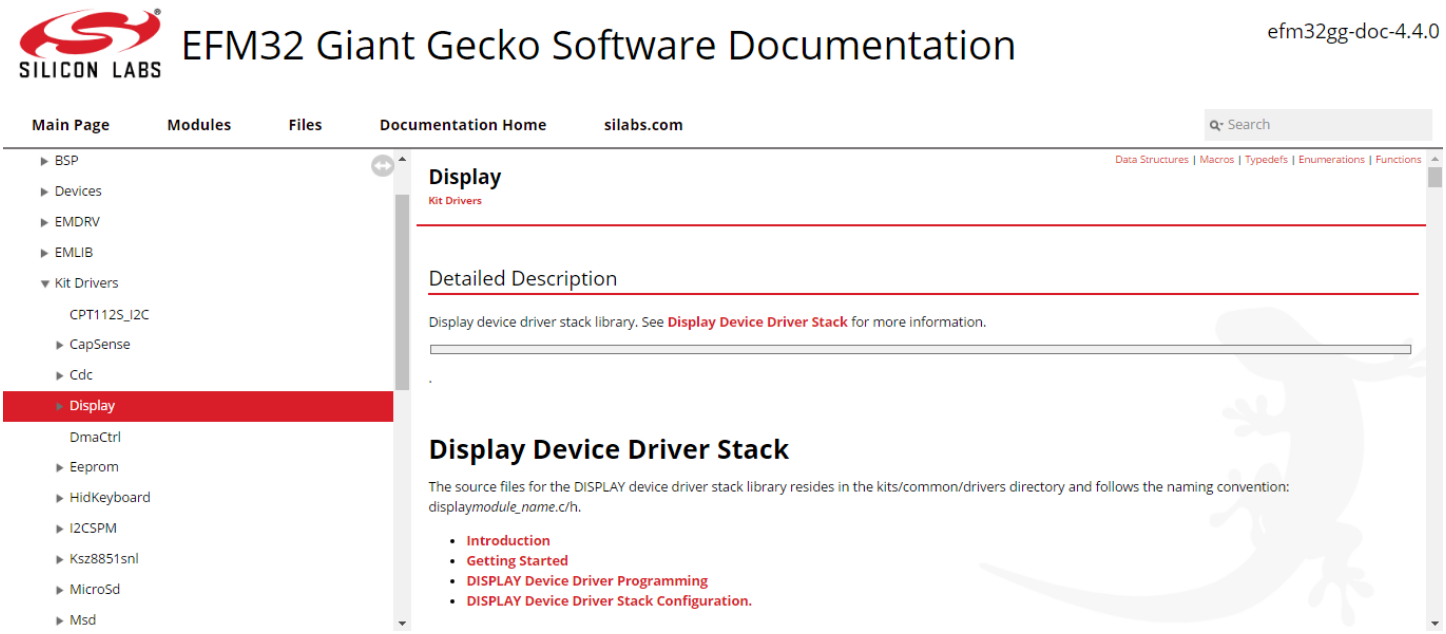


Figure 7.1. Documentation for the Display Driver

7.1 Step 1 — Configure the Display Driver

First, initialize the DISPLAY driver with `DISPLAY_Init()`.

The display driver includes TEXTDISPLAY, which is an interface for printing text to a dispaly device. Use `TEXTDISPLAY_New()` to create a new TEXTDISPLAY interface.

7.2 Step 2 — Write Text to the Memory LCD

TEXTDISPLAY implements basic functions for writing text to the Memory LCD. Try `TEXTDISPLAY_WriteString()` and `TEXTDISPLAY_WriteChar()`.

8. Example 4 — Energy Modes

This example shows how to enter different Energy Modes (EMx) and wake up using an RTC or RTCC interrupt. The project called [**<kit_name>_4_energymodes**] is used in this example.

8.1 Advanced Energy Monitor with STK

The Starter Kits include current measurement of the VMCU power domain, which is used to power the device and the LCD display in addition to other components in the application part of the starter kit. The real-time current measurement can be monitored on a PC using the Energy Profiler available in Simplicity Studio.

8.2 Step 1 — Enter EM1

To enter EM1, execute a Wait-For-Interrupt instruction with the SLEEPDEEP bit in the SCB_SCR register clear. An intrinsic function for this instruction (part of CMSIS) is shown below:

```
SCB->SCR &= ~SCB_SCR_SLEEPDEEP_Msk;
__WFI();
```

After executing this instruction, observe that the current consumption drops.

In addition, the EMU emlib functions include functions for entering Energy Modes, which firmware can use instead of clearing the SLEEPDEEP bit and executing the WFI-instruction manually:

```
void EMU_EnterEM1()
```

8.3 Step 2 — Enter EM2

Entering EM2 is also done by executing the WFI-instruction, except with the SLEEPDEEP bit in the SCB_SCR register also set, and with a low frequency oscillator enabled. To enter EM2, first enable a low frequency oscillator (either LFRCO or LFXO) before going to deep sleep. In this example, enable the LFRCO and wait for it to stabilize by using the following emlib function:

```
void CMU_OscillatorEnable(CMU_Osc_Typedef osc, bool enable, bool wait)
```

Now, enter EM2 by setting SLEEPDEEP and executing the WFI-instruction:

```
SCB->SCR |= SCB_SCR_SLEEPDEEP_Msk;
__WFI();
```

In addition, the EMU emlib functions include functions for entering Energy Modes, which firmware can use instead of setting the SLEEPDEEP bit and executing the WFI-instruction manually:

```
void EMU_EnterEM2(bool restore)
```

It is strongly recommended to take advantage of this function. This emlib function will also avoid or workaround any errata issues affecting the Energy Modes operation.

Note: When in an active debug session, the device will not be allowed to go below EM1. To measure the current consumption in EM2, end the debugging session and reset the device with the reset button on the STK.

8.4 Step 3 — Enter EM3

To enter EM3, first disable all low frequency oscillators before going to deep sleep (which is accomplished by using the same technique as for EM2). Disable the LFRCO originally enabled in Step 2 by using the following emlib function:

```
void CMU_OscillatorEnable(CMU_Osc_Typedef osc, bool disable, bool wait)
```

Now, enter EM3 by setting SLEEPDEEP and executing the WFI-instruction:

```
SCB->SCR |= SCB_SCR_SLEEPDEEP_Msk;
__WFI();
```

In addition, the EMU emlib functions include functions for entering Energy Modes, which firmware can use instead of disabling LF oscillators, setting the SLEEPDEEP bit, and executing the WFI-instruction manually:

```
void EMU_EnterEM3(bool restore)
```

It is strongly recommended to take advantage of this function. This emlib function will also avoid or workaround any errata issues affecting the Energy Modes operation.

Note: When in an active debug session, the device will not be allowed to go below EM1. To measure the current consumption in EM3, end the debugging session and reset the device with the reset button on the STK.

8.5 Step 4 — Configure the Real-Time Counter (RTC) of MCU Series 0

To wake up from EM2, configure the Real-Timer Counter (RTC) to give an interrupt after 5 seconds. First, enable the clock to the RTC by using the CMU emlib functions. To communicate with Low Energy/Frequency peripherals like the RTC, also enable the clock for the LE interface (cmuClock_HFLE).

The emlib initialization function for the RTC requires a configuration struct as an input:

```
void RTC_Init(const RTC_Init_TypeDef *init)
```

The struct is already declared in the code, but firmware must set the 3 parameters in the struct before using it with the `RTC_Init` function:

```
rtcInit.comp0Top = true;
```

Next, set compare value 0 (COMP0) in the RTC, which will set interrupt flag COMP0 when the compare value matches the counter value. Chose a value that will equal 5 seconds given that the RTC runs at 32.768 kHz:

```
void RTC_CompareSet(unsigned int comp, uint32_t value)
```

Now the RTC COMP0 flag will be set on a compare match, but the corresponding enable bit must also be set to generate an interrupt request from the RTC:

```
void RTC_IntEnable(uint32_t flags)
```

The RTC interrupt request is enabled on a comparator match, but to trigger an interrupt, the RTC interrupt request line must be enabled in the Cortex-M. The IRQn_Type to use is RTC_IRQn.

```
NVIC_EnableIRQ(RTC_IRQn);
```

An interrupt handler for the RTC is already included in the code (RTC_IRQHandler), but it is empty. In this function, add a function call to clear the RTC COMP0 interrupt flag. If firmware does not do this, the Cortex-M will be stuck in the interrupt handler, since the interrupt is never deasserted. Look for the RTC emlib function to clear the interrupt flag.

8.6 Extra Task — Segment LCD Controller in EM2

As an extra task, enable the LCD controller (assuming there's a Segment LCD on the kit in use) and write something on the LCD display before going to EM2. Use the segment animation from the previous example in EM2.

Note: Since the RTC or RTCC is used by the Memory LCD display driver, this extra task does not apply to the kits that feature a Memory LCD instead of a segment LCD.

9. Summary

Congratulations! You now know the basics of Energy Friendly Programming, including register and GPIO operation, use of basic functions on the STK and LCD, in addition to handling different Energy Modes in the device and the emlib/CMSIS functions. The [**Software Examples**] and [**Application Notes**] under [**Getting Started**] tab in Simplicity Studio provide more examples and Application Notes to explore.

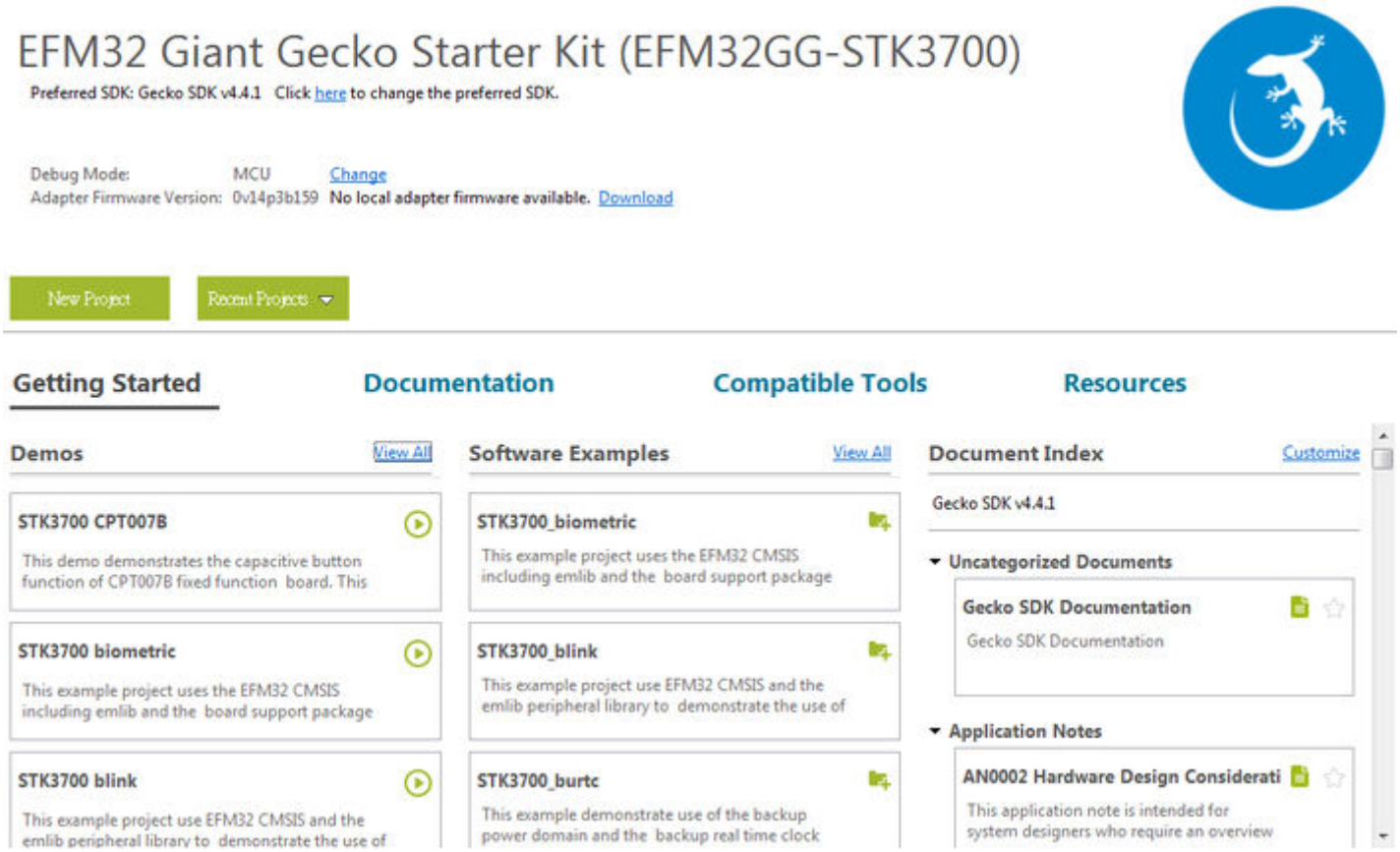


Figure 9.1. Software Examples and Application Notes in Simplicity Studio

10. Revision History

Revision 1.22

January 2018

- Removed references to EFM32PG13/EFM32JG13
- Added examples for EFM32TG11 starter kit.

Revision 1.21

June 2017

- Split AN0009 into AN0009.0 and AN0009.1 for MCU/Wireless MCU Series 0 and MCU/Wireless SoC Series 1, respectively.
- Removed RTC configuration instructions from Example 4 text.
- Added examples for EFM32PG12, EFM32GG11, EFR32MG1, EFR32MG12, and EFR32MG13 starter kits.

Revision 1.20

January 2017

- Updated for Simplicity Studio V4.
- Removed example for EFM32G development kit.
- Added example for EFM32PG1 starter kit.

Revision 1.19

November 2017

- Added support for EFM32 Gemstones and the EFR32 Wireless Gecko portfolio.

Revision 1.18

May 2014

- Updated example code to CMSIS 3.20.5
- Changed to Silicon Labs license on code examples
- Added example projects for Simplicity IDE
- Removed example makefiles for Sourcery CodeBench Lite

Revision 1.17

October 2013

- Added missing header file

Revision 1.16

October 2013

- New cover layout
- Added support for the Zero Gecko Starter Kit (EFM32ZG-STK3200)
- New text in the Bit field defines chapter
- Fixed issue with STK3700 and LCD animation

Revision 1.15

May 2013

- Added software projects for ARM-GCC and Atollic TrueStudio.

Revision 1.14

November 2012

- Added support for the Giant Gecko Starter Kit(EFM32GG-STK3700)
- Adapted software projects to new kit-driver and bsp structure

Revision 1.13

April 2012

- Adapted software projects to new peripheral library naming and CMSIS_V3

Revision 1.12

March 2012

- Added efm32lib file efm32_emu.c to LED projects
- Fixed makefile-error for CodeSourcery projects

Revision 1.11

October 2011

- Updated IDE project paths with new kits directory

Revision 1.10

September 2011

- Added support for Tiny Gecko Starter Kit (EFM32TG-STK3300)

Revision 1.03

May 2011

- Updated projects to align with new bsp version

Revision 1.02

November 2010

- Corrected solution c-files for new EFM32LIB functions
- Corrected pdf document for new EFM32LIB functions

Revision 1.01

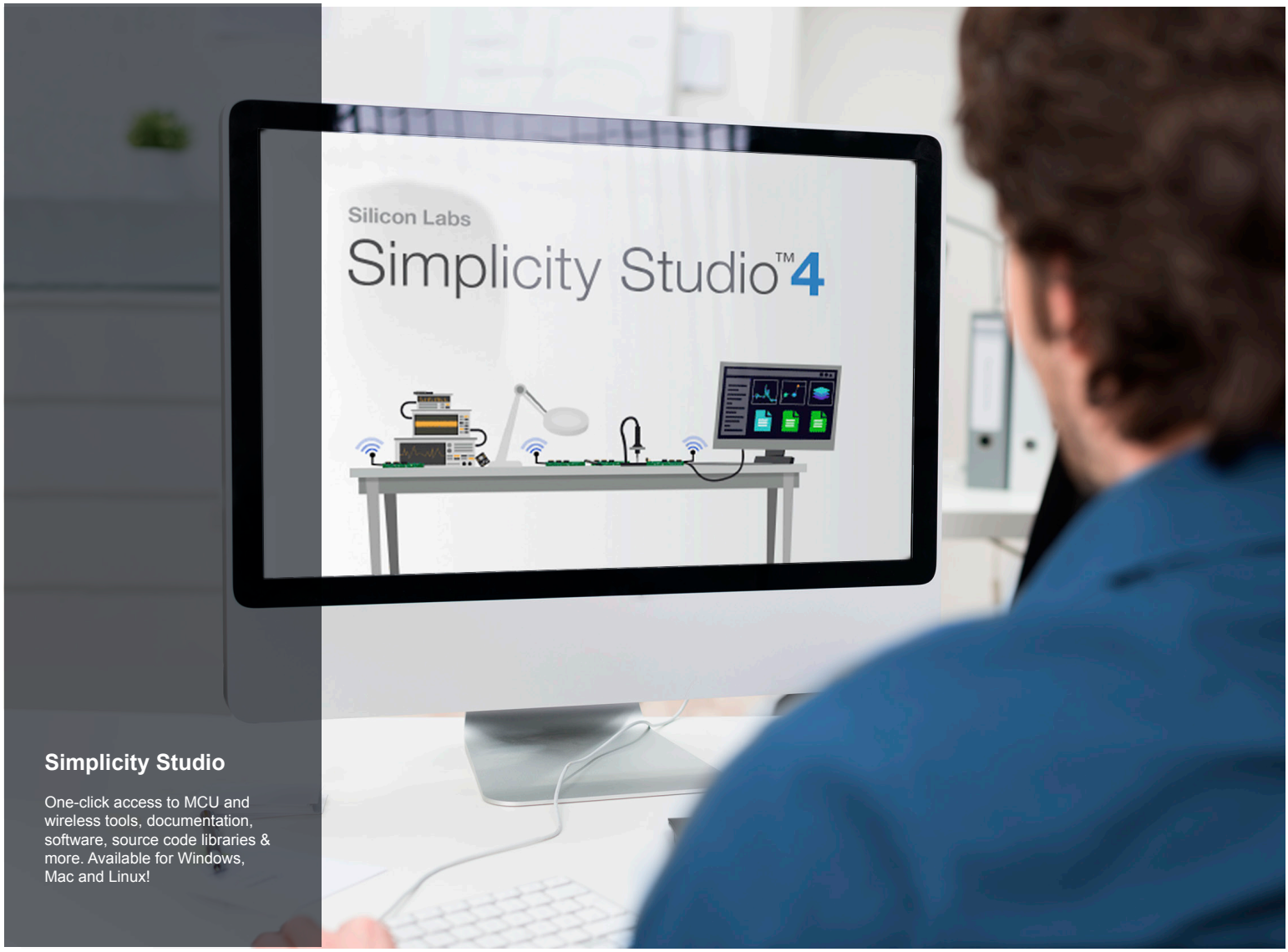
November 2010

- Changed software/documentation to use the segmentlcd.c functions, lcdcontroller.c is deprecated
- Added section about CMSIS Doxygen documentation
- Changed example folder structure, removed build and src folders
- Updated chip init function to newest efm32lib version

Revision 1.00

September 2010

- Initial revision



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