Chapter 2: Using the BT SDK to Connect Inputs and Outputs to MCU Peripherals

At the end of this chapter you should be able to write firmware for the MCU peripherals (GPIOs, UARTs, Timers, PWMs, NVRAM, I2C, ADC and RTC). In addition, you will understand the role of the critical files related to the kit hardware platform and you will know how to re-map pin functions to different peripherals.

2.1 Introduction to Bluetooth SoC Peripherals

The Bluetooth devices include a useful set of MCU peripherals, such as UART, I2C and SPI communications, plus PWM, ADC and GPIO, which we are going to use to blink LEDs, print messages, measure acceleration and light levels, and so on. The Device Configurator is a graphical tool that helps you extend the BSP for your hardware, for example by choosing to drive an LED from a PWM instead of firmware.

Be aware, though, that the WICED example apps and snips predate the availability of the configurator and often rely on firmware-only configuration. As a result, you cannot assume that a peripheral or GPIO that is disabled in the configurator is not actually in use by the application. As ModusToolbox and its associated examples mature you will see a greater utilization of the configurator-generated code and more powerful set of configuration options (e.g. PWM duty cycle and UART baud rate).

2.2 Board Support Package

Every ModusToolbox application makes use of a Board Support Package (BSP), which is chosen in the first step of the New Application wizard (every kit has exactly one BSP). The BSP makes it easier to work with the peripherals on the kit. A BSP is a collection of files that specify which device is on the board, how it is programmed, what peripherals are available, which pins they are mapped to, etc.

In case you design your own hardware, you can either create a new BSP (beyond the scope of this course) or create an application with the BSP that most closely matches your hardware then modify the files as necessary. For example, you may have buttons and LEDs connected to different pins, so you would update the appropriate file to make those changes for your hardware.

Most of the configurable content of the BSP is managed by the design.modus file, which is the database for the Device Configurator. It generates the GeneratedSource/cycfg_pins.c file, which contains constant arrays that are used to configure the peripherals and to initialize the pins to the correct state. For example, LED pins are initialized as outputs, and the button pins are initialized as inputs with a resistive pullup. For example, for LED1:

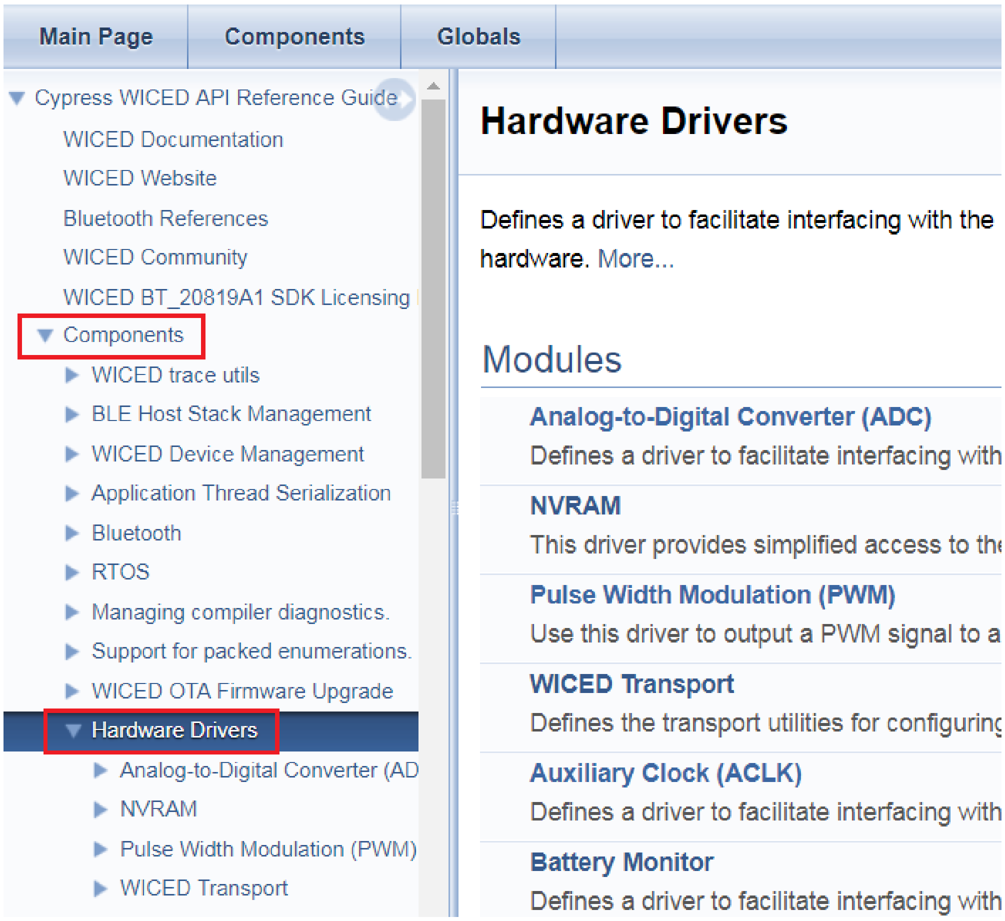
```
#define LED1_config \
{\
    .gpio =
(wiced_bt_gpio_numbers_t*)&platform_gpio_pins[PLATFORM_GPIO_3].gpio_pin, \
    .config = GPIO_OUTPUT_ENABLE | GPIO_PULL_UP, \
    .default_state = GPIO_PIN_OUTPUT_HIGH, \
}
```

The other key file here is wiced_platform.h, which contains #define and type definitions used to set up and access the various kit peripherals. For example, the CYW920819EVB-02 kit contains two LEDs and one mechanical button. These are identified in wiced_platform.h using the names WICED_GPIO_PIN_BUTTON_1, WICED_GPIO_PIN_LED_1 and WICED_GPIO_PIN_LED_2:

```
/*! pin for button 1 */
#define WICED_GPIO_PIN_BUTTON_1       WICED_P00
#define WICED_GPIO_PIN_BUTTON         WICED_GPIO_PIN_BUTTON_1

/*! pin for LED 1 */
#define WICED_GPIO_PIN_LED_1     WICED_P27
/*! pin for LED 2 */
#define WICED_GPIO_PIN_LED_2     WICED_P26
```

2.3 Documentation

CPU peripheral documentation can be found in the Documents tab in the lower left panel (next to the Quick Panel) or in the Help menu under *ModusToolbox API Reference->WICED API Reference*. The peripheral APIs are presented under Components->Hardware Drivers as shown below. We will be using GPIO, Pulse Width Modulation (PWM), Peripheral UART (PUART), I2C, and Real-Time Clock (RTC).



Click on GPIO to see the list of GPIO APIs, and then click on the *wiced_hal_gpio_configure_pin* function for a description.

```
void wiced_hal_gpio_configure_pin ( UINT32 pin,
                                    UINT32 config,
                                    UINT32 outputVal
                                  )
```

Configures a GPIO pin.

Note that the GPIO output value is programmed before the GPIO is configured. This ensures that the GPIO will activate with the correct external value. Also note that the output value is always written to the output register regardless of whether the GPIO is configured as input or output.

Enabling interrupts here isn't sufficient; you also want to register with registerForMask().

All input parameter values must be in range or the function will have no effect.

Parameters

- **pin** - pin id (0-39).
- **config** - Gpio configuration. See Parameters section above for possible values.

For example, to enable interrupts for all edges, with a pull-down, you could use:

```
/// GPIO_EDGE_TRIGGER | GPIO_EDGE_TRIGGER_BOTH |
/// GPIO_INTERRUPT_ENABLE_MASK | GPIO_PULL_DOWN_MASK
///
```

```
\param outputVal - output value.

\return none
```

The description tells you what the function does but does not give complete information on the configuration value that is required. To find that information, once you create a project in ModusToolbox IDE, you can highlight the function in the C code, right click, and select "Open Declaration" (F3). This will take you to the function declaration in the file wiced_hal_gpio.h. If you scroll to the top of this file, you will find a list of allowed choices. A subset of the choices is shown here:

```
/* Interrupt Enable
 * GPIO configuration bit 3, interrupt enable/disable defines
 */
GPIO_INTERRUPT_ENABLE_MASK   = 0x0008, /**< GPIO configuration bit 3 mask */
GPIO_INTERRUPT_ENABLE        = 0x0008, /**< Interrupt Enabled */
GPIO_INTERRUPT_DISABLE       = 0x0000, /**< Interrupt Disabled */

/* Interrupt Config
 * GPIO configuration bit 0:3, Summary of Interrupt enabling type
 */
GPIO_EN_INT_MASK             = GPIO_EDGE_TRIGGER_MASK | GPIO_TRIGGER_POLARITY_MASK | GPIO_DUAL_EDGE_TRIGGER_MASK | GPIO_INTERRUPT_ENABLE_MASK,
GPIO_EN_INT_LEVEL_HIGH       = GPIO_INTERRUPT_ENABLE | GPIO_LEVEL_TRIGGER, /**< Interrupt on level HIGH */
GPIO_EN_INT_LEVEL_LOW        = GPIO_INTERRUPT_ENABLE | GPIO_LEVEL_TRIGGER | GPIO_TRIGGER_NEG, /**< Interrupt on level LOW */
GPIO_EN_INT_RISING_EDGE      = GPIO_INTERRUPT_ENABLE | GPIO_EDGE_TRIGGER, /**< Interrupt on rising edge */
GPIO_EN_INT_FALLING_EDGE     = GPIO_INTERRUPT_ENABLE | GPIO_EDGE_TRIGGER | GPIO_TRIGGER_NEG, /**< Interrupt on falling edge */
GPIO_EN_INT_BOTH_EDGE        = GPIO_INTERRUPT_ENABLE | GPIO_EDGE_TRIGGER | GPIO_EDGE_TRIGGER_BOTH, /**< Interrupt on both edges */

/* GPIO Output Buffer Control and Output Value Multiplexing Control
 * GPIO configuration bit 4:5, and 14 output enable control and
 * muxing control
 */
GPIO_INPUT_ENABLE            = 0x0000, /**< Input enable */
GPIO_OUTPUT_DISABLE          = 0x0000, /**< Output disable */
GPIO_OUTPUT_ENABLE           = 0x4000, /**< Output enable */
GPIO_KS_OUTPUT_ENABLE        = 0x0001, /**< Keyscan output enable*/
GPIO_OUTPUT_FN_SEL_MASK      = 0x0000, /**< Output function select mask*/
GPIO_OUTPUT_FN_SEL_SHIFT     = 0,


/* Global Input Disable
 * GPIO configuration bit 6, "Global_input_disable" Disable bit
 * This bit when set to "1" , P0 input_disable signal will control
 * ALL GPIOs. Default value (after power up or a reset event) is "0".
 */
GPIO_GLOBAL_INPUT_ENABLE     = 0x0000, /**< Global input enable */
GPIO_GLOBAL_INPUT_DISABLE    = 0x0040, /**< Global input disable */

/* Pull-up/Pull-down
 * GPIO configuration bit 9 and bit 10, pull-up and pull-down enable
 * Default value is [0,0]--means no pull resistor.
 */
GPIO_PULL_UP_DOWN_NONE       = 0x0000, /**< No pull [0,0] */
GPIO_PULL_UP                 = 0x0400, /**< Pull up [1,0] */
GPIO_PULL_DOWN               = 0x0200, /**< Pull down [0,1] */
GPIO_INPUT_DISABLE           = 0x0600, /**< Input disable [1,1] (input disabled the GPIO) */
```

For example:

An input pin with an active-low button would typically have the config set to:

`GPIO_INPUT_ENABLE | GPIO_PULL_UP`

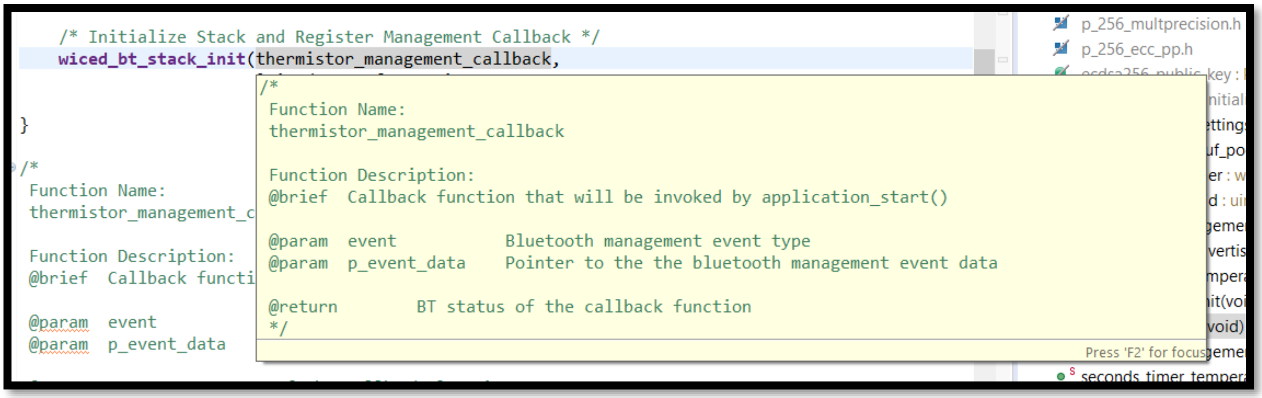
An output pin driving an active-low LED would typically have the config set to:

`GPIO_OUTPUT_ENABLE | GPIO_PULL_UP`

2.3.1 Context Sensitive Help

Right-clicking and selecting "Open Declaration" on function names and data-types inside ModusToolbox IDE is often very useful in finding information on how to use functions and what values are allowed for parameters.

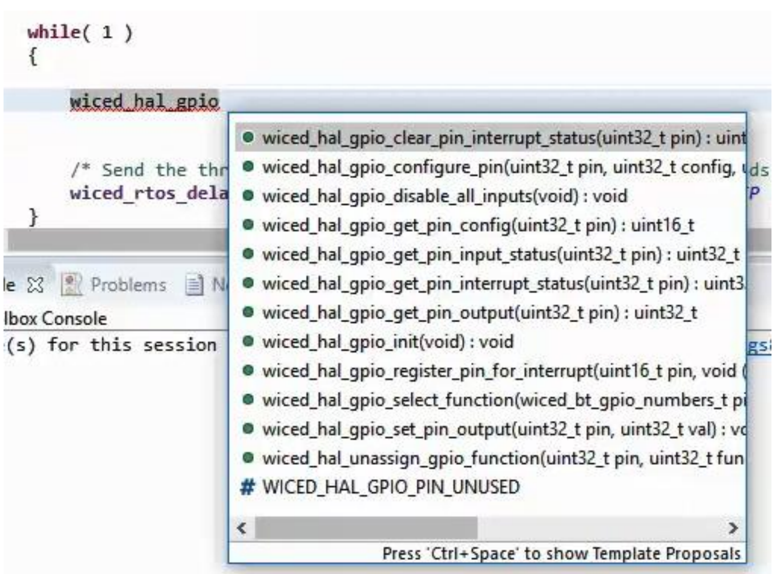
You can also just hover over a function name and get information like this:



2.3.2 Intellisense

Another very useful tool is to type Control-Space when you are in the code editor. This will fill in possible completions for whatever you have already typed so that you can select what you want from the list. You can type the start of a function name, the start of a macro, the start of a variable, etc.

For example, if you type "wiced_hal_gpio" and press Control-Space, you will get this list of all the matching items that the tool can find:



2.4 Peripherals

2.4.1 GPIO

You will use this in Exercise - 2.1, Exercise - 2.3, and Exercise - 2.4.

As explained previously, GPIOs must be configured using the function *wiced_hal_gpio_configure_pin()*. The IOs on the kit that are connected to specific peripherals such as LEDs and buttons are usually configured for you as part of the platform files, so you don't need to configure them explicitly in your projects unless you want to change a setting (for example to enable an interrupt on a button pin).

Once configured, input pins can be read using *wiced_hal_gpio_get_pin_input_status()* and outputs can be driven using *wiced_hal_gpio_set_pin_output()*. You can also get the state that an output pin is set to (not necessarily the actual value on the pin) using *wiced_hal_gpio_get_pin_output().* The parameter for these functions is the WICED pin name such as WICED_P01 or a peripheral name from your BSP such as WICED_GPIO_PIN_LED_1.

For example:

```
btnState = wiced_hal_gpio_get_pin_input_status( WICED_GPIO_PIN_BUTTON_1 ); /* Get pin state */

wiced_hal_gpio_set_pin_output(WICED_GPIO_PIN_LED_2, 0); /* Set pin low */

wiced_hal_gpio_set_pin_output(WICED_GPIO_PIN_LED_2,
      !wiced_hal_gpio_get_pin_output(WICED_GPIO_PIN_LED_2) );  /* Invert desired pin state */
```

You will use code like this in exercise 1.

GPIO interrupts are enabled or disabled during pin configuration. For pins with interrupts enabled, the interrupt callback function (i.e. interrupt service routine or interrupt handler) is registered using *wiced_hal_gpio_register_pin_for_interrupt()*. For example, the following would enable a falling edge interrupt on BUTTON1 with a callback function called *my_interrupt_callback*.

```
wiced_hal_gpio_register_pin_for_interrupt( WICED_GPIO_PIN_BUTTON_1,
      my_interrupt_callback, NULL);

wiced_hal_gpio_configure_pin( WICED_GPIO_PIN_BUTTON_1,
      ( GPIO_INPUT_ENABLE | GPIO_PULL_UP | GPIO_EN_INT_FALLING_EDGE),
      GPIO_PIN_OUTPUT_HIGH );
```

The interrupt callback function is passed user data (optional) and the pin number. The callback function should clear the interrupt using *wiced_hal_gpio_clear_pin_interrupt_status*. For example:

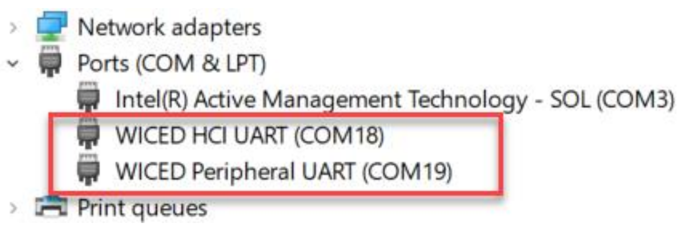
```
void gpio_interrupt_callback(void *data, uint8_t port_pin)
{
   /* Clear the gpio interrupt */
   wiced_hal_gpio_clear_pin_interrupt_status( port_pin );

   /* Add other interrupt functionality here */
}
```

Note: The call to *wiced_hal_gpio_clear_pin_interrupt_status()* is shown in the code above for completeness. For most peripherals it is necessary to clear the interrupt in the callback function. However, for GPIOs this is done automatically before the callback is executed and so it is not strictly necessary.

2.4.2 Debug Printing

You will use this in Exercise - 2.2.

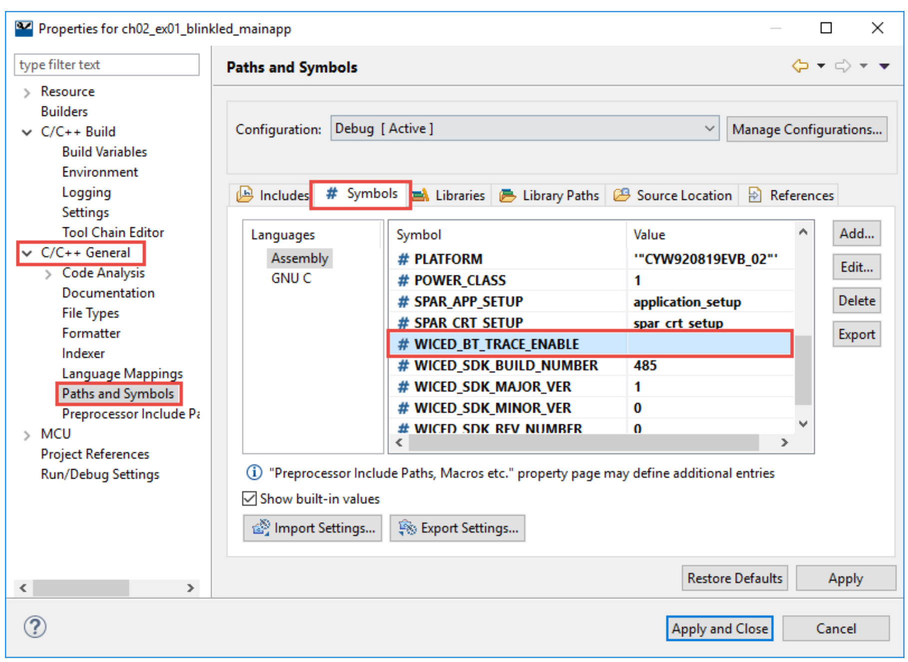
The kit has two separate UART interfaces –the HCI UART (Host Controller Interface UART) and the PUART (peripheral UART). The HCI UART interface is used for programming the kit and often is used by a host microcontroller to communicate with the BLE device. It will be discussed in more detail in a later chapter. The PUART is not used for any other specific functions so it is useful for general debug messages. When you plug a kit into your USB port both UART channels appear as COM ports. If you attach a kit to a Windows machine, the Device Manager will display entries that look something like this.



There are 3 things required to allow debug print messages:

1. Make sure that the symbol WICED_BT_TRACE_ENABLE is defined in the project Properties in the *Symbols* tab under *C/C++ General->Paths and Symbols*.

   Note: to get to the window, first select the project that you want to modify in the project explorer, then either click "Project Build Settings" in the Quick Panel or use the menu item *Project->Properties*.



The provided starter templates all set this up automatically so editing the properties is not usually necessary.

2. Include the following header in the top-level C file:

```
#include "wiced_bt_trace.h"
```

3. Indicate which interface you want to use by choosing one of the following:

```
wiced_set_debug_uart( WICED_ROUTE_DEBUG_NONE);
wiced_set_debug_uart( WICED_ROUTE_DEBUG_TO_PUART );
wiced_set_debug_uart( WICED_ROUTE_DEBUG_TO_HCI_UART );
wiced_set_debug_uart( WICED_ROUTE_DEBUG_TO_WICED_UART);
```

The last of these is used for sending formatted debug strings over the HCI interface specifically for use with the BTSpy application. The BTSpy application will be discussed in detail in the debugging chapter.

Once the appropriate debug UART is selected, messages can be sent using sprintf-type formatting using the WICED_BT_TRACE function. For example:

```
WICED_BT_TRACE( "Hello - this is a debug message \n");
WICED_BT_TRACE("The value of X is: %d\n", x);
```

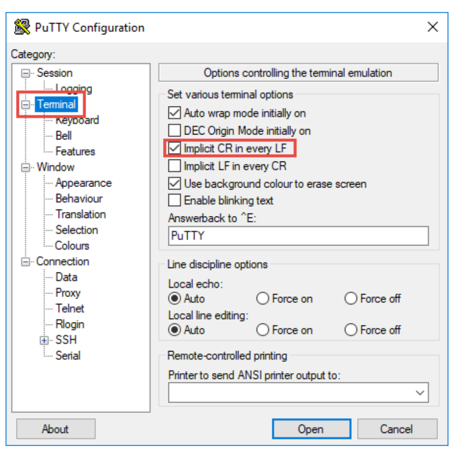
<u>Note: this function does NOT support floating point values (i.e. %f).</u>

You can easily print arrays using WICED_BT_TRACE_ARRAY. The usage is:

```
WICED_BT_TRACE_ARRAY(arrayName, arrayLength, "String to be printed before the
array data: ");
```

The WICED_BT_TRACE_ARRAY function automatically adds a newline (\n) to the end of the printed string.

Note that we typically put "\n" at the end of strings to be printed but not "\r" to save flash/ram. Typically, you will want to setup your terminal window to automatically generate a carriage return for every line feed so that each debug message will start at the beginning of the line. In putty, the setting is under "Terminal -> Implicit CR in every LF". You can save this to the default settings with if you want it to be on by default (you can also save the default speed to be 115200).



2.4.3 PUART (Peripheral UART)

You will use this in Exercise - 2.11 and Exercise - 2.12.

In addition to the debug printing functions, the PUART can also be used as a generic Tx/Rx UART block. To use it, first include the header file in your top level C file:

```
#include "wiced_hal_puart.h"
```

Next, initialize the block and setup the flow control and baud rate. For example:

```
wiced_hal_puart_init( );
wiced_hal_puart_flow_off( );
wiced_hal_puart_set_baudrate( 115200 );
```

For transmitting data, enable Tx, and then use the desired functions for sending strings (print), single bytes (write), or an array of bytes (synchronous_write).

```
wiced_hal_puart_enable_tx( );
wiced_hal_puart_print("Hello World!\n");
/* Print value to the screen */
wiced_hal_puart_print("Value = ");
/* Add '0' to the value to get the ASCII equivalent of the number */
wiced_hal_puart_write(value+'0');
wiced_hal_puart_print("\n");
```

For receiving data, register an interrupt callback function, set the watermark to determine how many bytes should be received before an interrupt is triggered, and enable Rx.

```
wiced_hal_puart_register_interrupt(rx_interrupt_callback);
/* Set watermark level to 1 to receive interrupt up on receiving each byte */
wiced_hal_puart_set_watermark_level(1);
wiced_hal_puart_enable_rx();
```

The Rx processing is done inside the interrupt callback function. You must clear the interrupt inside the callback function so that additional characters can be received.

```
void rx_interrupt_callback(void* unused)
{
    uint8_t  readbyte;

    /* Read one byte from the buffer and then clear the interrupt */
    wiced_hal_puart_read( &readbyte );
    wiced_hal_puart_reset_puart_interrupt();

    /* Add your processing here */
}
```

2.4.4 Timers

You will use this in Exercise - 2.5.

A timer allows you to schedule a function to run at a specified interval - e.g. send data every 10 seconds.

First, you initialize the timer using wiced_init_timer, you give it a pointer to a timer structure, specify the function want run, provide an argument to the function (or NULL if you don't need it), and the timer type. There are four types of timer. The first two are one-shot timers while the last two will repeat:

```
WICED_SECONDS_TIMER
WICED_MILLI_SECONDS_TIMER
WICED_SECONDS_PERIODIC_TIMER
WICED_MILLI_SECONDS_PERIODIC_TIMER
```

The function that you specify takes a single argument of u*int32_t arg*. If the function doesn't require any arguments you can specify 0 in the timer initialization function, but the function itself must still have the u*int32_t arg* argument in its definition.

Once you initialize the timer, you then start it using wiced_start_timer. This function takes a pointer to the timer structure and the actual time interval for the timer (either in seconds or milliseconds depending on the timer chosen).

Note that this is an interrupt function for when the timer expires rather than a continually executing thread so the function should NOT have a while(1) loop – it should just run and exit each time the timer calls it.

For example, to setup a timer that runs a function called myTimer every 100ms, you would do something like this:

```
wiced_timer_t my_timer_handle; /* Typically defined as a global */
.
.
.
.
/* Typically inside the BTM_ENABLED_EVT */
wiced_init_timer(&my_timer_handle, myTimer, 0,
WICED_MILLI_SECONDS_PERIODIC_TIMER);
wiced_start_timer(&my_timer_handle, 100);
.
.
.
.
/* The timer function */
void myTimer( uint32_t arg )
{
    /* Put timer code here */
}
```

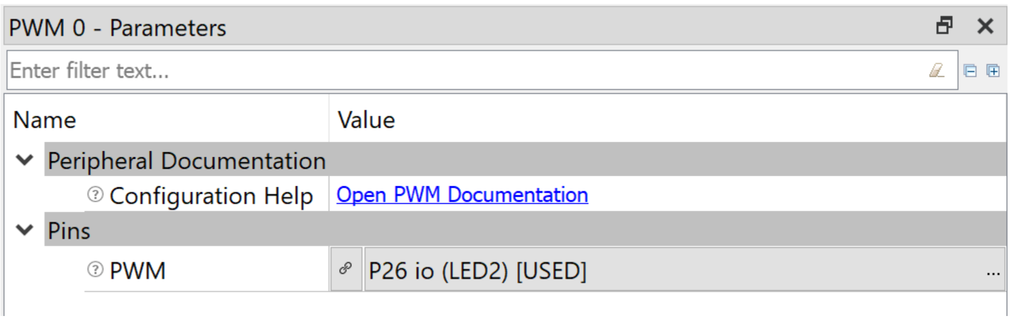
2.4.5 PWM

You will use this in Exercise - 2.6 and Exercise - 2.7.

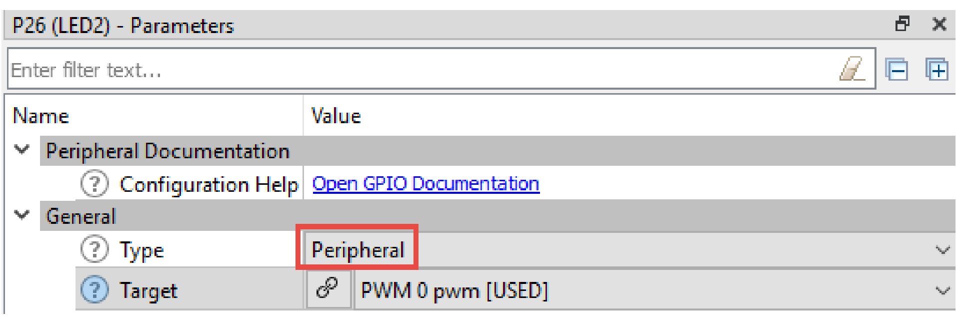
There are 6 PWM blocks (PWM0 – PWM5) on the device each of which can be routed to any GPIO pin. The PWMs are 16 bits (i.e. they count from 0 to 0xFFFF).

The PWMs can use either the LHL_CLK (which is 32 kHz) or PMU_CLK (aka ACLK1) which is configurable.

You use the Device Configurator to enable the PWM and assign its output to one of the LED pins.



You also need to change the pin configuration from LED to Peripheral:



You can jump back and forth from the PWM to its associated pin using the button that looks like 2 links in a chain.

Note: The configurator currently only does pin routing – in the future it will provide more functionality like selecting clock sources, setting period and compare, etc. If you don't want to use the configurator for pin routing, you can instead use a line of code during initialization like this:

```
wiced_hal_gpio_select_function(WICED_GPIO_PIN_LED_2, WICED_PWM0);
```

The pin name used above is defined in wiced_platform.h and the peripheral name is defined in wiced_hal_gpio.h.

The solution projects and templates generally use code instead of the configurators because it makes the new application creation simpler.

Whether you use the configurator or manual pin routing from the code, you must include the PWM header file to use the PWM API functions:

```
#include "wiced_hal_pwm.h"
```

When you want to start the PWM, just call the start function like this:

```
wiced_hal_pwm_start( PWM0, LHL_CLK, toggleCount, initCount, 0 );
```

The initCount parameter is the value that the PWM will reset to each time it wraps around. For example, if you set initCount to (0xFFFF – 99) then the PWM will provide a period of 100 counts.

The toggleCount parameter is the value at which the PWM will switch its output from high to low. That is, it will be high when the count is less than the toggleCount and will be low when the count is greater than the toggleCount. For example, if you set the toggleCount to (0xFFFF-50) with the period set as above, then you will get a duty cycle of 50%.

You can invert the PWM output (i.e. it will start low and then transition high at the toggleCount) by setting the last parameter to 1 instead of 0.

If you want a specific clock frequency for the PWM, you must first configure the PMU_CLK clock and then specify it in the PWM start function.

First, you have to include an additional header file:

```
#include "wiced_hal_aclk.h"
```

Then, if you (for example) want a 1 kHz clock for the PWM, you could do the following:

```
#define CLK_FREQ   (1000)

wiced_hal_aclk_enable(CLK_FREQ, ACLK1, ACLK_FREQ_24_MHZ );
wiced_hal_pwm_start(PWM0, PMU_CLK, toggleCount, initCount, 0);
```

Note that there is only 1 PMU clock available so if you use it, you will get the same clock frequency for all PWMs that use it as the source.

There are additional functions to enable, disable, change values while the PWM is running, get the init value, and get the toggle count. There is even a helper function called *wiced_hal_pwm_params()* which will calculate the parameters you need given the clock frequency, the desired output frequency, and desired duty cycle. See the documentation for details on each of these functions.

2.4.6 NVRAM

You will use this in Exercise - 2.9.

There are many situations in a Bluetooth system where a non-volatile memory is required. One example of that is Bonding – which we will discuss in detail later - where you are required to save the Link Keys for future use. The BT_20819 SDK provides an abstraction called the "NVRAM" (it is really just an area of flash memory that is set aside) for this purpose. The BSP typically allocates 4 kB to 8 kB for the NVRAM, but it is user-modifiable. The API and programming model remain the same regardless of the total NVRAM size.

The NVRAM is broken into multiple sections that are up to 512 bytes long (on the 20819 device), of which 500 are available for user data. To use the NVRAM, the application developer writes/reads to/from a number called the VSID (Virtual System Identifier). This number is not an offset or a block number within the memory. Rather, it is an ID that the API uses to locate the actual memory.

Physical addresses are not used because the NVRAM has a wear leveling scheme built in that moves the data around to avoid wearing out the memory. By using the VSID the user does not need to concern themselves with the (moving) physical location of their data. The only cost of this implementation is that reads and writes to NVRAM take a variable amount of time. Note that the scheme also has a "defragmentation" algorithm that runs during chip boot-up.

As the developer, you are responsible for managing what the VSIDs are used for in your application.

The API can be included in your project with #include "wiced_hal_nvram.h" which also #defines the first VSID to be WICED_NVRAM_VSID_START and last VSID to be WICED_NVRAM_VSID_END.

The write function for the NVRAM is:

```
uint16_t wiced_hal_write_nvram( uint16_t vs_id, uint16_t data_length, uint8_t *p_data,
                                wiced_result_t * p_status);
```

The return value is the number of bytes written. You need to pass a pointer to a wiced_result which will give you the success or failure of the write operation.

The read function for the NVRAM looks just like the write function:

```
uint16_t wiced_hal_read_nvram( uint16_t vs_id,uint16_t data_length, uint8_t * p_data,
                               wiced_result_t * p_status);
```

The return value is the number of bytes read into your buffer, and p_status tells you if the read succeeded.

Note that if you read from a VSID that has not been written to (since the device was programmed) the read will return with a failing error code. This is useful to determine if a device already has information (such as bonding information) stored.

2.4.7 I2C

You will use this in Exercise - 2.8.

There is an I2C master on the device which is routed by default to the Arduino header dedicated I2C pins. It is also connected to an LSM9DS1 motion sensor on the CYW920819EVB-02 kit.

Initialization

You must include the I2C header file to use the I2C functions:

```
#include "wiced_hal_i2c.h"
```

To initialize the I2C block you need to call the initialization function. If you want a speed other than the default of 100 kHz then you have to call the set_speed function after the block is initialized:

```
wiced_hal_i2c_init();
wiced_hal_i2c_set_speed(I2CM_SPEED_400KHZ);
```

Read and Write Functions

There are two ways to read/write data from/to the slave. There is a dedicated read function called *wiced_hal_i2c_read()* and a dedicated write function called *wiced_hal_i2c_write()*. There is also a function called wiced_hal_i2c_combined_read() which will do a write followed by a read with a repeated start between them. These functions are all blocking.

The separate read/write functions require a pointer to the buffer to read/write, the number of bytes to read/write, and the 7-bit slave address. The LSM9DS1 is at address 0xD4 (write) / 0xD5 (read) and so, to generate the 7-bit address, shift 0xD4 right by 1 bit (0x6A).

For example, to write 2 bytes followed by a read of 10 bytes:

```
#define I2C_ADDRESS (0x6A)
uint8_t TxData[2] = {0x55, 0xAA};
uint8_t RxData[10];
wiced_hal_i2c_write( TxData, sizeof(TxData), I2C_ADDRESS );
wiced_hal_i2c_read( RxData, sizeof(RxData), I2C_ADDRESS );
```

If you need to write a value (e.g. a register offset value) followed by a read, you can use the *wiced_hal_i2c_combined_read()* function to do both in one function call. The function takes a pointer to the write data buffer, the number of bytes to write, a pointer to the read data buffer, the number of bytes to read, and finally, the 7-bit slave address.

For example, the same operation shown above could be:

```
#define I2C_ADDRESS (0x6A)
uint8_t TxData[2] = {0x55, 0xAA};
uint8_t RxData[10];
wiced_hal_i2c_combined_read( TxData, sizeof(TxData), RxData, sizeof(RxData),
I2C_ADDRESS );
```

Read/Write Buffer

For the buffer containing the data that you want to read/write, you may want to setup a structure to map the I2C registers in the slave that you are addressing. In that case, if the structure elements are not all 32-bit quantities, you must use the packed attribute so that the non-32-bit quantities are not padded, which would lead to incorrect data. For example, if you have a structure with 3-axis 16-bit acceleration values, you could set up a buffer like this:

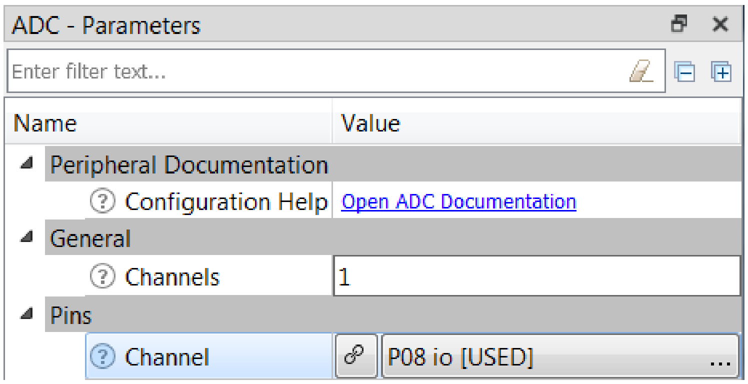
```
struct {
        int16_t ax;
        int16_t ay;
        int16_t az;
} __attribute__((packed)) accel_data;
```

There are two underscores before and after the word "attribute" and there are two sets of parentheses around the word "packed".

2.4.8 ADC

You will use this in Exercise - 2.10.

The device contains a 16-bit signed ADC (-32768 to +32767). The ADC has 32 input channels, all of which have fixed connections to pins or on-chip voltages such as Vddio. When setting up the ADC in the Device Configurator you choose the number of channels and assign each one to the desired physical pin (note that this is not routing signals on the device, merely assigning virtual channel numbers to the pins). Note that the voltage channels, like Vddio, are configured automatically for you. The ADC is enabled and set to P08 (thermistor) by default.



You must include the ADC header file to use the ADC functions:

```
#include "wiced_hal_adc.h"
```

To initialize the ADC block you need to call the initialization function and select the input range based on your board supply. When you read a sample, you must specify which channel to read from. The BSP provides enums of the form ADC_INPUT_* for these channels in wiced_hal_adc.h. Examples of channel defines are ADC_INPUT_P8 (ADC channel 9 is connected to pin P08 on the device) and ADC_INPUT_VDDIO.

There is one function that will return a count value and another function that will return a voltage value in millivolts. For example, to read the count and voltage from a sensor which is connected to GPIO WICED_P10, you would do the following:

```
#define ADC_CHANNEL     (ADC_INPUT_P10)
wiced_hal_adc_init();
wiced_hal_adc_set_input_range( ADC_RANGE_0_3P6V );
raw_val = wiced_hal_adc_read_raw_sample( ADC_CHANNEL, 0 );
voltage_val = wiced_hal_adc_read_voltage( ADC_CHANNEL );
```

2.4.9 RTC (Real Time Clock)

You will use this in Exercise - 2.13.

The CYW20819 supports a 48-bit RTC timer referenced to a 32-kHz crystal (XTAL32K) LPO (low power oscillator). The LPO can be either external or internal. If an external LPO is not connected to the CYW20819, the firmware takes the clock input from the internal LPO for the RTC. The CYW20819 supports both 32-kHz and 128-kHz LPOs, but the internal defaults to 32-kHz.

The BT_20819A1 SDK provides API functions to set the current time, get the current time, and convert the current time value to a string. By default, the date and time are set to January 1, 2010 with a time of 00:00:00 denoting HH:MM:SS.

You must include "wiced_rtc.h" and the following code to initialize the RTC for use:

```
wiced_rtc_init();

wiced_rtc_time_t newTime = { 0, 30, 12, 30, 11, 1999 }; // s,m,h,d,m,y

rtc_setRTCTime( &newTime );
```

Note that the day and month are 0-based and so, for example, January is 0 and December is 11. Likewise, the first day of the month is 0.

After the RTC is initialized, you can use wiced_rtc_get_time() to get the time and wiced_rtc_ctime() to convert the result into a printable string.

2.5 WICED_RESULT_T

Throughout the SDK, a value from many of the functions is returned telling you what happened. The return value is of the type "wiced_result_t" which is a giant enumeration. If you right-click on wiced_result_t from a variable declaration, select "Open Declaration", and choose wiced_result.h you will see this:

```
/** WICED result */
typedef enum
{
    WICED_RESULT_LIST(WICED_)
    BT_RESULT_LIST      (  WICED_BT_       )  /**< 8000 - 8999 */
} wiced_result_t;
```

To see standard return codes (WICED_*), right click and choose Open Declaration on WICED_RESULT_LIST. For Bluetooth specific return codes (WICED_BT_*), right click and choose Open Declaration on BT_RESULT_LIST. The lists look like this:

WICED_* :

```
/** WICED result list */
#define WICED_RESULT_LIST( prefix ) \
    RESULT_ENUM( prefix, SUCCESS,                       0x00 ),   /**< Success */
    RESULT_ENUM( prefix, DELETED                       ,0x01 ),   \
    RESULT_ENUM( prefix, NO_MEMORY                     ,0x10 ),   \
    RESULT_ENUM( prefix, POOL_ERROR                    ,0x02 ),   \
    RESULT_ENUM( prefix, PTR_ERROR                     ,0x03 ),   \
    RESULT_ENUM( prefix, WAIT_ERROR                    ,0x04 ),   \
    RESULT_ENUM( prefix, SIZE_ERROR                    ,0x05 ),   \
    RESULT_ENUM( prefix, GROUP_ERROR                   ,0x06 ),   \
    RESULT_ENUM( prefix, NO_EVENTS                     ,0x07 ),   \
    RESULT_ENUM( prefix, OPTION_ERROR                  ,0x08 ),   \
    RESULT_ENUM( prefix, QUEUE_ERROR                   ,0x09 ),   \
    RESULT_ENUM( prefix, QUEUE_EMPTY                   ,0x0A ),   \
    RESULT_ENUM( prefix, QUEUE_FULL                    ,0x0B ),   \
    RESULT_ENUM( prefix, SEMAPHORE_ERROR               ,0x0C ),   \
    RESULT_ENUM( prefix, NO_INSTANCE                   ,0x0D ),   \
    RESULT_ENUM( prefix, THREAD_ERROR                  ,0x0E ),   \
    RESULT_ENUM( prefix, PRIORITY_ERROR                ,0x0F ),   \
    RESULT_ENUM( prefix, START_ERROR                   ,0x10 ),   \
    RESULT_ENUM( prefix, DELETE_ERROR                  ,0x11 ),   \
    RESULT_ENUM( prefix, RESUME_ERROR                  ,0x12 ),   \
    RESULT_ENUM( prefix, CALLER_ERROR                  ,0x13 ),   \
    RESULT_ENUM( prefix, SUSPEND_ERROR                 ,0x14 ),   \
    RESULT_ENUM( prefix, TIMER_ERROR                   ,0x15 ),   \
    RESULT_ENUM( prefix, TICK_ERROR                    ,0x16 ),   \
```

WICED_BT_*:

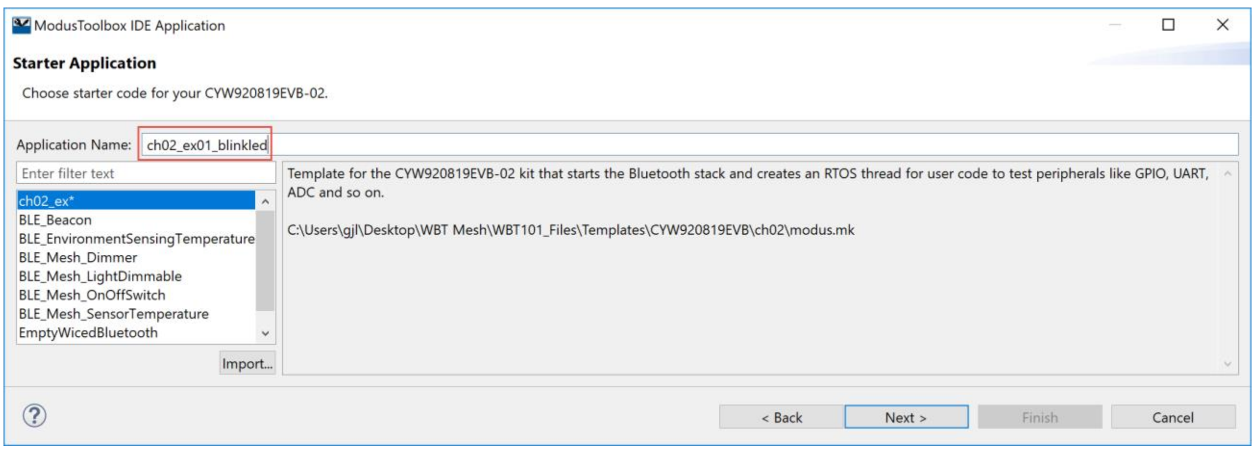
```
#define BT_RESULT_LIST( prefix ) \
        RESULT_ENUM( prefix, SUCCESS,                        0 ),   /**< Success */
        RESULT_ENUM( prefix, PARTIAL_RESULTS,                3 ),   /**< Partial results */
        RESULT_ENUM( prefix, BADARG,                         5 ),   /**< Bad Arguments */
        RESULT_ENUM( prefix, BADOPTION,                      6 ),   /**< Mode not supported */
        RESULT_ENUM( prefix, OUT_OF_HEAP_SPACE,              8 ),   /**< Dynamic memory space exhausted */
        RESULT_ENUM( prefix, UNKNOWN_EVENT,               8029 ),   /**< Unknown event is received */
        RESULT_ENUM( prefix, LIST_EMPTY,                  8010 ),   /**< List is empty */
        RESULT_ENUM( prefix, ITEM_NOT_IN_LIST,            8011 ),   /**< Item not found in the list */
        RESULT_ENUM( prefix, PACKET_DATA_OVERFLOW,        8012 ),   /**< Data overflow beyond the packet end
        RESULT_ENUM( prefix, PACKET_POOL_EXHAUSTED,       8013 ),   /**< All packets in the pool is in use *
        RESULT_ENUM( prefix, PACKET_POOL_FATAL_ERROR,     8014 ),   /**< Packet pool fatal error such as per
        RESULT_ENUM( prefix, UNKNOWN_PACKET,              8015 ),   /**< Unknown packet */
        RESULT_ENUM( prefix, PACKET_WRONG_OWNER,          8016 ),   /**< Packet is owned by another entity *
        RESULT_ENUM( prefix, BUS_UNINITIALISED,           8017 ),   /**< Bluetooth bus isn't initialised */
        RESULT_ENUM( prefix, MPAF_UNINITIALISED,          8018 ),   /**< MPAF framework isn't initialised */
        RESULT_ENUM( prefix, RFCOMM_UNINITIALISED,        8019 ),   /**< RFCOMM protocol isn't initialised *
        RESULT_ENUM( prefix, STACK_UNINITIALISED,         8020 ),   /**< SmartBridge isn't initialised */
        RESULT_ENUM( prefix, SMARTBRIDGE_UNINITIALISED, 8021 ),   /**< Bluetooth stack isn't initialised *
        RESULT_ENUM( prefix, ATT_CACHE_UNINITIALISED,     8022 ),   /**< Attribute cache isn't initialised *
        RESULT_ENUM( prefix, MAX_CONNECTIONS_REACHED,     8023 ),   /**< Maximum number of connections is re
        RESULT_ENUM( prefix, SOCKET_IN_USE,               8024 ),   /**< Socket specified is in use */
        RESULT_ENUM( prefix, SOCKET_NOT_CONNECTED,        8025 ),   /**< Socket is not connected or connecti
        RESULT_ENUM( prefix, ENCRYPTION_FAILED,           8026 ),   /**< Encryption failed */
        RESULT_ENUM( prefix, SCAN_IN_PROGRESS,            8027 ),   /**< Scan is in progress */
        RESULT_ENUM( prefix, CONNECT_IN_PROGRESS,         8028 ),   /**< Connect is in progress */
        RESULT_ENUM( prefix, DISCONNECT_IN_PROGRESS,      8029 ),   /**< Disconnect is in progress */
        RESULT_ENUM( prefix, DISCOVER_IN_PROGRESS,        8030 ),   /**< Discovery is in progress */
        RESULT_ENUM( prefix, GATT_TIMEOUT,                8031 ),   /**< GATT timeout occured*/
```

2.6 Exercises

Exercise - 2.1 (GPIO) Blink an LED

In this exercise, you will create an application to blink LED_2 on the kit at 2 Hz. This material is covered in 2.4.1

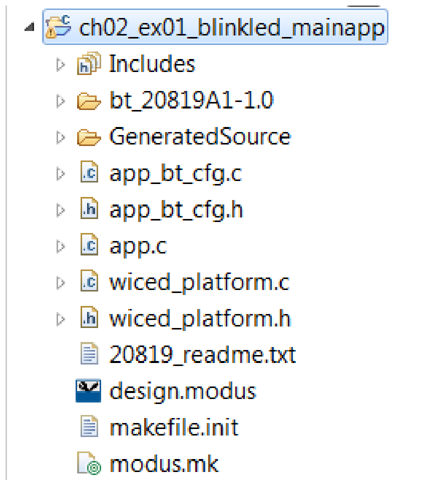
1. In the Quick Panel click "New Application".
2. Select the CYW920819EVB-02 kit and press "Next >".
3. Press the "Import…" button and navigate to the course materials "templates/CYW920819EVB/ch02" folder.
4. Double-click on the modus.mk file to import the template and return to the wizard.
5. The new template will now be selected, but you may need to wait a few seconds for the dialog to refresh.



6. Change the application name to **ch02_ex01_blinkled**.

   Note: you can call the application anything you like but it will really help if you maintain an alphabetically sortable naming scheme – you are going to create quite a few projects in this course.

7. Click "Next ". Verify the presented device, board, and example, then click "Finish". When you finish, the Project Explorer window in Eclipse should look like the following screenshot:



8. Examine app.c to make sure you understand what it does.

   All WICED BLE applications are multi-threaded (the BLE stack requires it). There is an operating system (RTOS) that gets launched from the device startup code and you can use it to create your own threads. Each thread has a function that runs almost as though it is the only software in the system – the RTOS allocates time for all threads to execute when they need to. This makes it easier to write your programs without a lot of extra code in your main loop. The details of how to use the RTOS effectively are covered in the next chapter but, in these exercises, we will show you how to create a thread and associate it with a function for the code you will write (look in app_bt_management_callback()).

9. Add code in the app_task thread function to do the following:
   a. Read the state of WICED_GPIO_PIN_LED_1
      i. Hint: Go back to the section on GPIOs if you need a reminder on using pins.
   b. Drive the state of WICED_GPIO_PIN_LED_1 to the opposite value.
10. In the Quick Panel, look in the "Launches" section and press the "ch02_ex01_blinkled Build + Program" link.

Questions

1. What is the name of the first user application function that is executed? What does it do?

2. What is the purpose of the function app_bt_management_callback? When does the BTM_ENABLED_EVT case occur?

3. What controls the rate of the LED blinking?

Exercise - 2.2 (GPIO) Add Debug Printing to the LED Blink Project

For this exercise, you will add a message that is printed to a UART terminal each time the LED changes state. This material is covered in 2.4.2

1. Repeat steps 2 through 8 from the previous exercise to create a new application called **ch02_ex02_blinkled_print**.

   Note: It is possible to copy-paste the prior project and rename it. The new application will build without error. However, Eclipse does not re-create programming or debugging configurations in a copied project and so you would need to manually configure a GDB connection to an OpenOCD server. Accordingly, we do not recommend copying whole projects unless you are an Eclipse and OpenOCD expert who can set up debugging configurations faster than it takes to create a new project!

2. Copy the app.c file from the previous application.

   Note: The safe and quick way to do this is to highlight the file you want in the Eclipse Project Explorer, copy (Control-C), select the newly created application, and paste (Control-V). Eclipse will ask if you wish to overwrite the file (if it does not, you are probably copying to the wrong location). You can also use drag & drop but be sure to press and hold the control key so that you copy, not move, the file.

3. Add WICED_BT_TRACE calls to display "LED LOW" and "LED HIGH" at the appropriate times.
   a. Hint: Go back to the section on Debug Printing if you need a refresher.
   b. Hint: Remember to set the debug UART to WICED_ROUTE_DEBUG_TO_PUART. Although you will see comments in the template code encouraging you to put initialization code in the app_bt_management_callback() function so that it runs when the BLE stack starts up, we recommend doing it in application_start() instead. This is because the PUART is a special type of peripheral and you may want to print messages before even trying to start the stack!
   c. Hint: Remember to use \n\r to create a new line so that information is printed on a new line each time the LED changes.
4. Program your application to the board.
5. Open a terminal window (e.g. PuTTY or TeraTerm) with a baud rate of 115200 and observe the messages being printed.
   a. Hint: The PUART will be the larger number of the two WICED COM ports.
   b. Hint: if you don't have terminal emulator software installed, you can use putty.exe which is included in the class files under "Software_tools". To configure putty:
      i. Go to the Serial tab, select the correct COM port (you can get this from the device manager under "Ports (COM & LPT)" as *"WICED USB Serial Port"*), and set the speed to 115200.
      ii. Go to the session tab, select the Serial button, and click on "Open".
      iii. If you want an automatic carriage return with a line feed in putty (i.e. add a \r for every \n) check the box next to "Terminal -> Implicit CR in every LF"

Exercise - 2.3 (GPIO) Read the State of a Mechanical Button

In this exercise, you will control an LED by monitoring the state of a mechanical button on the kit. This material is covered in 2.4.1

1. Create another new application called **ch02_ex03_button** with the same template.
2. Again, copy your code that toggles the LED from the **ch02_ex01_blink** application
3. In the C file:
    a. Change the thread sleep time to 100ms.
    b. In the thread function, check the state of mechanical button input (use WICED_GPIO_PIN_BUTTON_1). Turn on WICED_GPIO_PIN_LED_1 if the button is pressed and turn it off if the button is not pressed.
4. Program your project to the board and test it.

Exercise - 2.4 (GPIO) Use an Interrupt to Toggle the State of an LED

In this exercise, rather than polling the state of the button in a thread, you will use an interrupt so that your firmware is notified every time the button is pressed. In the interrupt callback function, you will toggle the state of the LED. This material is covered in 2.4.1

1. Create another new application called **ch02_ex04_interrupt** with the same template. There is no need to copy source code from another application in this exercise.
2. In the app.c file:
    a. Remove the calls to wiced_rtos_create_thread() and wiced_rtos_init_thread().
    b. Delete the thread function.
2. In the BTM_ENABLED_EVT, set up a <u>falling edge interrupt</u> for the GPIO connected to the button and register the callback function.
    a. Hint: You will need to call wiced_hal_gpio_register_pin_for_interrupt and wiced_hal_gpio_configure_pin.
3. Create the interrupt callback function so that it toggles the state of the LED each time the button is pressed.
4. Program your application to the board and test it.

Exercise - 2.5 (Timer) Use a Timer to Toggle an LED

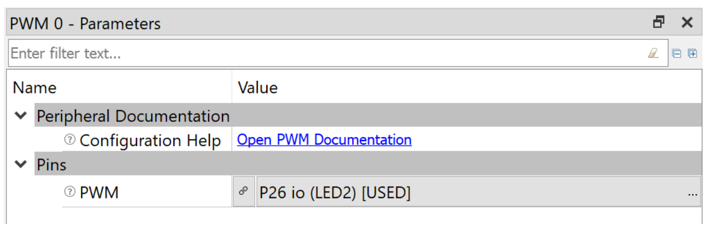
In this exercise, you will replace the thread and instead use a timer to blink an LED. This material is covered in 2.4.4

1. Create another new application called **ch02_ex05_timer** with the same template.
2. Copy app.c from **ch02_ex04_interrupt**.
3. In the C file:
    a. Add an include for wiced_timer.h.
    b. In the BTM_ENABLED_EVT, add calls to initialize and start a periodic timer with a 250ms interval.
    c. Modify the interrupt callback function to serve as the timer callback.
        i. Hint: the body of the timer function is the same as the code you wrote for the interrupt callback, but the function argument list is slightly different.
4. Program your application to the board and test it.

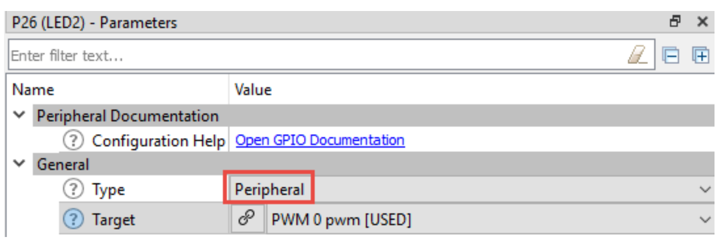
Exercise - 2.6 (PWM) LED brightness

In this exercise, you will control an LED using a PWM instead of a GPIO. The PWM will toggle the LED too fast for the eye to see, but by controlling the duty cycle you will vary the apparent brightness of the LED. This material is covered in 2.4.5

1. Create a new application called **ch02_ex06_pwm** using the modus.mk file in the original location of templates/CYW920819EVB/ch02.
2. Click Configure Device from the Quick Panel or double-click the design.modus file to open it in the Device Configurator.
    a. Find PWM0 in the list of peripherals and click the checkbox to enable it.
    b. In the Parameters panel use the PWM drop-down menu to choose P26 (LED2) for the output.
    c. Find P26 (LED2) in the list of peripherals.
    d. Hint: the PWM Parameter panel should look like this. You can jump straight to the Parameters for P26 by clicking the "link" button to the left of the drop-down menu.



    e. Change the type of the pin from LED to Peripheral.
    f. Hint: The Pin Parameter panel should look like this. Note that the PWM output is already selected.



    g. Save the changes and close the configurator.
    h. Hint: The PWM routing can be done in code rather than using the configurator. In fact, the solution project does not use the configurator method.
3. In the app.c file:
    a. Add a #include for the PWM functions - "wiced_hal_pwm.h"
    b. Configure PWM0 with an initial period of 100 and a duty cycle of 50%.
    c. Hint: Use LHL_CLK as the source clock since the exact period of the PWM doesn't matter as long as it is faster than the human eye can see (~50 Hz).
4. Update the duty cycle in the thread function so that the LED gradually cycles through intensity values from 0 to 100%.

   a. Hint: Change the delay in the thread function to 10ms so that the brightness changes relatively quickly.
5. Program the application to the board and test it.

Exercise - 2.7 (PWM) LED toggling at specific frequency and duty cycle

In this exercise, you will use a PWM with a period of 1 second and a duty cycle of 10% so that the LED will blink at a 1 Hz rate but will only be on for 100ms each second. In the prior exercise you configured the PWM and then the pin. This time do it by configuring the pin first. This material is covered in 2.4.5

1. Create a new application called **ch02_ex07_pwm_blink** using the modus.mk file in templates/CYW920819EVB/ch02.
2. Click Configure Device from the Quick Panel or double-click the design.modus file to open it in the Device Configurator.
   a. Find P27 in the list of Pins and change its type to Peripheral.
   b. Choose PWM1 from the Target drop-down menu
   c. Click the link button to jump to the PWM – notice that it is already enabled and configured.
   d. Save the file and close the Device Configurator.
3. In the app.c file:
   a. Hint: Don't forget to include the header files for the PWM and ACLK functions.
   b. Initialize the aclk with a frequency of 1 kHz.
   c. Change the PWM1 configuration to use PMU_CLK as the source. Set the period to 1000 and set the duty cycle to 10%.
4. As you did in ex05, remove or comment out the calls to wiced_rtos_create_thread(), wiced_rtos_init_thread() and the thread function because, even though it would not affect the program functionally, it is not a good practice to write to pins that are driven by a peripheral Program the application to the board and test it.

Exercise - 2.8 (I2C) Read Motion Sensor Data

In this exercise, you will use the I2C master to read 3-axis acceleration data from the LSM9DS1 motion sensor that is included on the kit. The values will be printed to the PUART. This material is covered in 2.4.7

1. Create a new application called **ch02_ex08_i2c_motion** using the modus.mk file in templates/CYW920819EVB/ch02_ex08_i2c_motion.
2. In app.c, look for TODO comments to configure the motion sensor and read values using I2C.
    a. Hint: If you use the wiced_hal_i2c_combined_read() function, which writes an offset and then reads data from that location, it expects the read arguments first and the wrote arguments second.
3. The LSM9DS1 motion sensor on the kit has the following properties:
    a. 0x6A: device I2C address
    b. 0x20: address of configuration register to enable the accelerometer
    c. 0x40: value for configuration register to provide 2g acceleration data at 50Hz
    d. 0x28: address of first acceleration data register. The values in order are:
        i. 0x28: X_LSB
        ii. 0x29: X_MSB
        iii. 0x2A Y_LSB
        iv. 0x2B Y_MSB
        v. 0x2C: Z_LSB
        vi. 0x2D: Z_MSB
    e. Hint: Search online for the LSM9DS1 datasheet if you want to explore other settings.
4. Program your application to the board and test it.

Exercise - 2.9 (Advanced) (NVRAM) Write and Read Data in the NVRAM

In this exercise, you will store a 1-byte value in the NVRAM. Mechanical button MB1 (WICED_GPIO_PIN_BUTTON_1) will increment the value each time it is pressed and print the new value. This material is covered in 2.4.6

1. Create another new application called **ch02_ex09_nvram** using the template in templates/CYW920819EVB/ch02_ex09_nvram (NOT the I2C template).
2. Add a #include for the NVRAM API functions.
3. Call wiced_set_debug_uart() to use the PUART.
4. In the interrupt callback function:
    a. Read the value from NVRAM at location WICED_NVRAM_VSID_START.
    b. Print out the value, the number of bytes read, and the status of the read operation (not the return value).
    c. Increment the value.
    d. Write the new value into NVRAM at location WICED_NVRAM_VSID_START.
    e. Print out the value, the number of bytes written, and the status of the write operation.
5. Open a terminal window and program the kit. Wait a few seconds and then press Button 1 a few times to observe the results.
6. Reset the kit. Notice that the previously stored value is retained.
7. Unplug the kit, plug it back in, and reset the terminal. Notice that the previously stored value is retained.

Questions

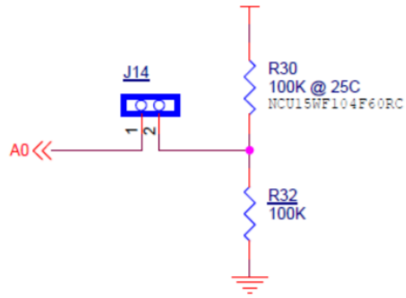
1. How many bytes does the NVRAM read function get when you press the button the first time?

2. What is the return status value when you press the button the first time?

3. What does the return value mean?

Exercise - 2.10 (Advanced) (ADC) Calculate the resistance of a thermistor

In this exercise you will measure the voltages, in millivolts, of Vddio (supply) and across the thermistor balance resistor (100kOhm). Then you will use that data to calculate the resistance of the thermistor. For reference, here is the thermistor circuit. This material is covered 2.4.8



The thermistor shares pin P08 (CYW20819EVB) or P10 (CYBT213043-MESH) with A0 on the Arduino header. You need to make sure the THERMISTOR_ENABLE jumper is attached to read the voltage.

1. Create a new application called **ch02_ex10_adc** using the modus.mk file in templates/CYW920819EVB/ch02.

   WARNING: The CYW20819EVB kit BSP only supports 8 GPIOs and adding the ADC channel causes that limit to be exceeded. Since we are not using SPI in any of these exercises disable the SPI peripheral and all four of its connected pins to avoid getting the following error:

   ../GeneratedSource/cycfg_pins.c:60:3: error: 'PLATFORM_GPIO_11' undeclared here (not in a function); did you mean 'PLATFORM_GPIO_10'?

2. Add in the include file for the ADC functions.
3. Add the call to wiced_set_debug_uart() to enable printing to the PUART.
4. In the management callback function, initialize the ADC.
5. In the application thread function, use the ADC to read Vddio and the voltages across the balance resistor.
   a. Hint: The ADC has a dedicated channel to read the supply voltage called ADC_INPUT_VDDIO.
6. Calculate and print the resistance of the thermistor periodically.
   a. Hint: The formula is as follows.

$$Rtherm = \frac{(Vddio - Vmeas) * BALANCE\_RESISTANCE}{Vmeas}$$

7. Program the board and open a terminal window with a baud rate of 115200. Alternately place and remove your finger from the thermistor (next to the THERMISTOR_ENABLE jumper) and observe the value displayed in the terminal.

Exercise - 2.11 (Advanced) (UART) Send a value using the standard UART functions

In this exercise, you will use the standard UART functions to send a value to a terminal window. The value will increment each time a mechanical button on the kit is pressed. This material is covered in 2.4.3

1. Create a new application called **ch02_ex11_uartsend** using the modus.mk file in templates/CYW920819EVB/ch02.
2. Copy the app.c file from the **ch02_ex04_interrupt** application. Remember to copy, not move!
3. In app.c, remove the call to wiced_set_debug_uart() if your interrupt exercise used the PUART.
4. Initialize the UART with Tx enabled, baud rate of 115200, and no flow control.
5. Modify the interrupt callback so that each time the button is pressed a variable is incremented and the value is sent out over the UART. For simplicity, just count from 0 to 9 and then wrap back to 0 so that you only have to send a single character each time.
    a. Hint: Use a "static" variable in the callback function to remember the last number printed.
6. Program the board and open a terminal window with a baud rate of 115200. Press the button and observe the value displayed in the terminal.

Exercise - 2.12 (Advanced) (UART) Get a value using the standard UART functions

In this exercise, you will learn how to read a value from the UART rather than sending a value like in the previous exercise. The value entered will be used to control an LED on the board (0 = OFF, 1 = ON). This material is covered in 2.4.3

1. Create a new application called **ch02_ex112_uartreceive** using the modus.mk file in templates/CYW920819EVB/ch02.
2. Copy the app.c file from the **ch02_ex11_uartsend** project. Remember to copy, not move!
3. Update the code to initialize the UART with Rx enabled, baud rate of 115200, no flow control, and an interrupt generated on every byte received.
    a. Hint: you can remove the code for the button press and its interrupt, but you will need to register a UART Rx interrupt callback instead.
4. In the interrupt callback, read the byte. If the byte is a 1, turn on LED_2. If the byte is a 0, turn off the LED. If you wish you can also print LED_ON/OFF messages. Ignore any other characters.
5. Program your application to the board.
6. Open a terminal window with a baud rate of 115200.
7. Press the 1 and 0 keys on the keyboard and observe the LED turn on/off.

Exercise - 2.13 (Advanced) (RTC) Display Time and Date Data on the UART

In this exercise you will set the time and date after reset and thereafter display a clock on the UART. This material is covered in 2.4.9

1. Create a new application called **ch02_ex13_rtc** using the modus.mk file in templates/CYW920819EVB/ch02_ex13_rtc.
2. In app.c, look for TODO comments and add code to control the RTC as follows.
    a. Initialize the RTC.
    b. Set the time and date. Make sure you understand how the getDateTimeEntry() function works and gets used.

       Hint: the template code includes ring_pop() and ring_push() functions that implement a ring buffer for the UART – the UART interrupt code pushes received characters into the buffer and the code that sets the time and date pulls characters from it.

    c. Display the clock with a precision of 1s.
3. Program your application to the board and test it.