Introduction to Digital Peripherals

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WW 20 17



Objective

- By the end of this training, you will

✓ Learn the digital peripherals available in Cypress' PSoC 6

✓ Understand their basic functions

✓ Learn how to use them in an application using ModusToolbox

Hardware:
PSoC6 BLE Pioneer Kit
PSoC6 WIFI-BT Pioneer Kit
CY8CPROTO-062-4343W PSoC6 Prototyping Kit

Software:
ModusToolbox 2.1

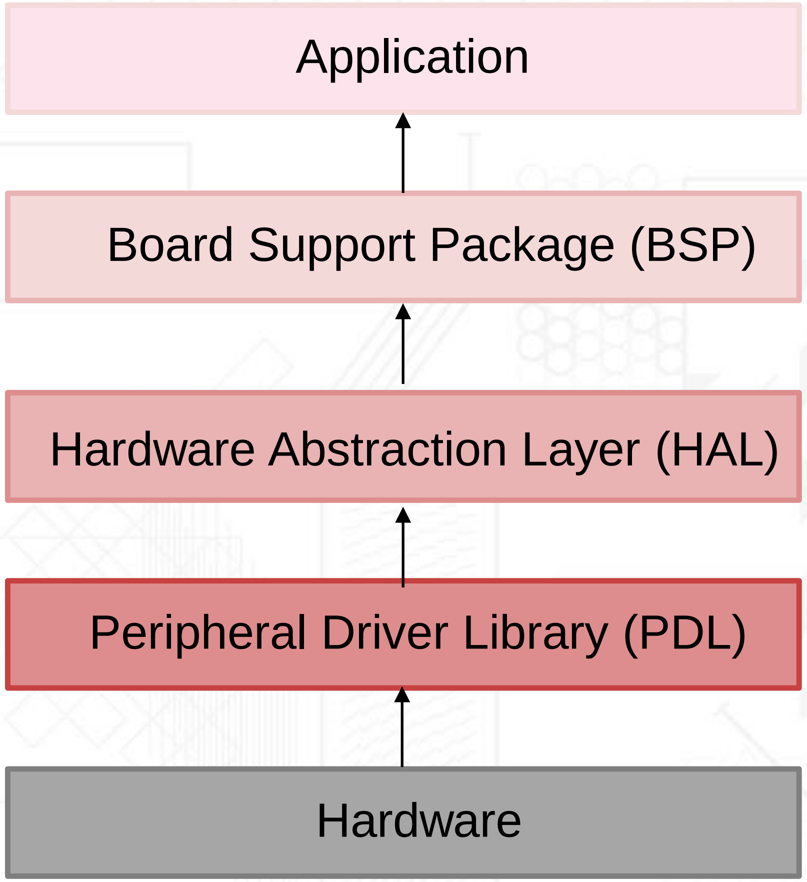
Agenda

- Recap
- Quick overview: ModusToolbox 2.1
- Introduction
  - Digital Architecture
- Smart-IO
- TCPWM
- SCBs
- Exercises

Recap

In the previous training we understood:

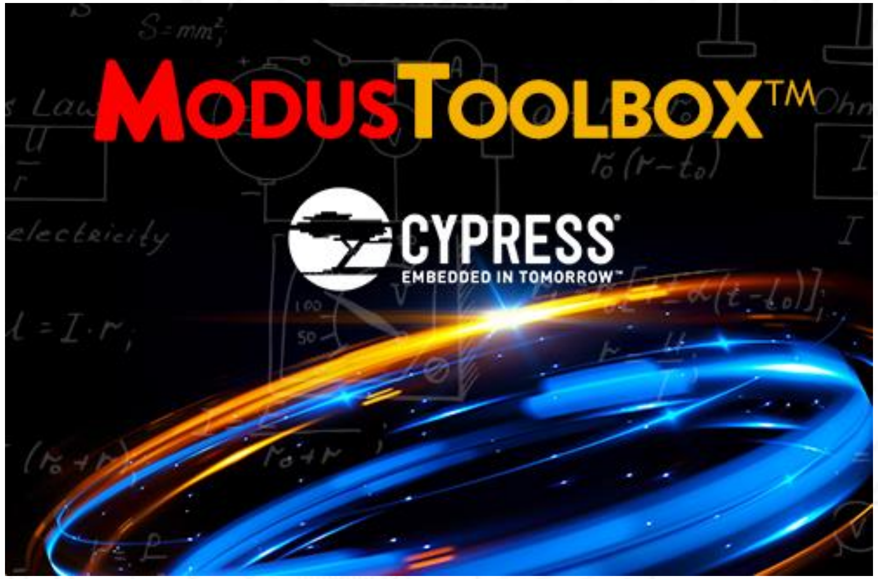
- ✓ what ModusToolbox is
- ✓ what it comprises
- ✓ How to create a project
- ✓ the directory structure
- ✓ different tools and configurators
- ✓ terminologies like HAL, BSP, PDL
- ✓ different ecosystems supported by ModusToolbox



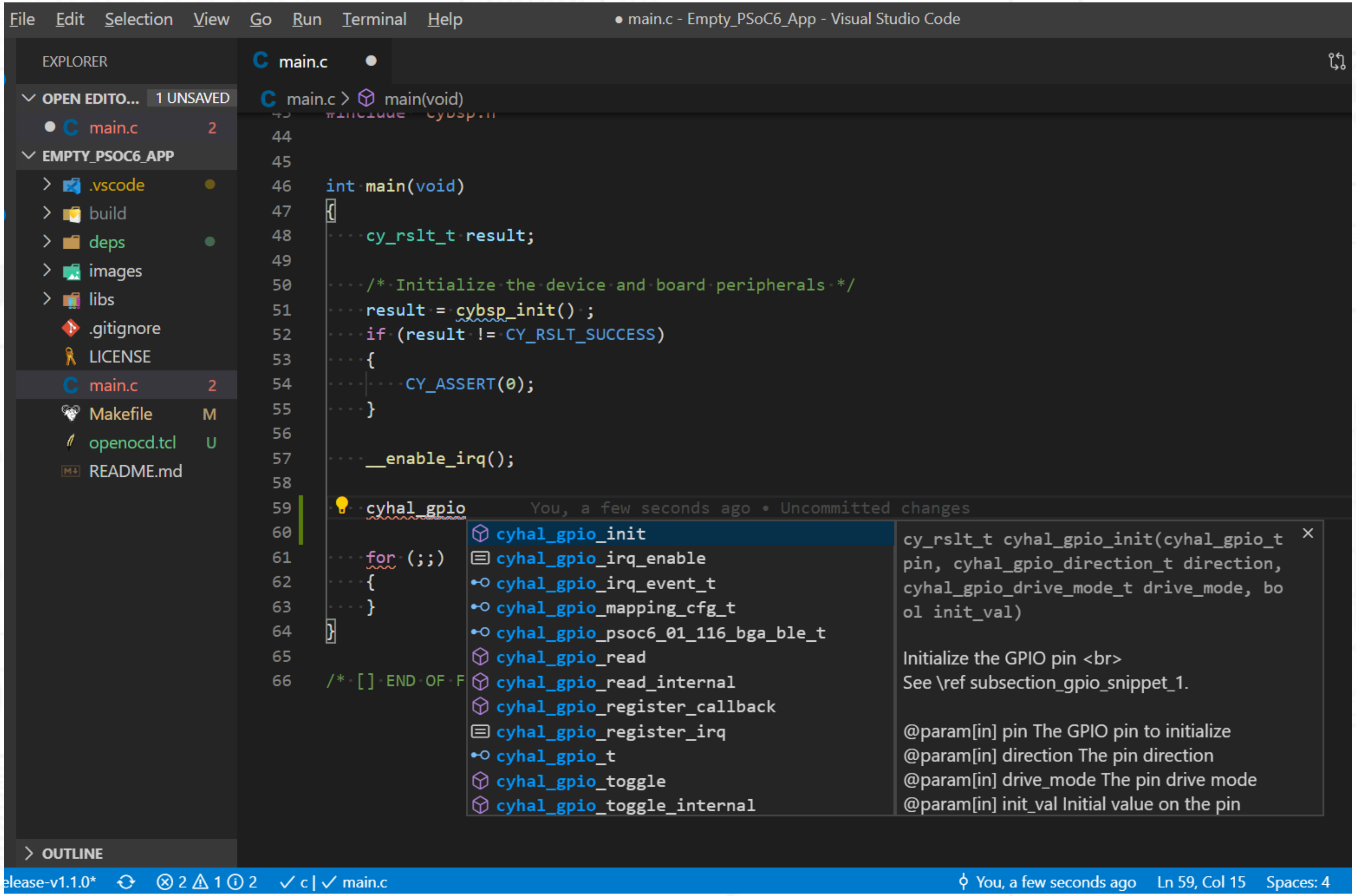
ModusToolbox 2.1

What's new?

- No longer called ModusToolbox IDE
- Proxy Handling Improvements
- Upgrades to Tools and Configurators
- OpenOCD 3.0
- Offline Support Package
- Support for third party IDEs
  - ✓ IAR Embedded Workbench
  - ✓ Keil ARM-MDK
  - ✓ Visual Studio Code (VSCode)



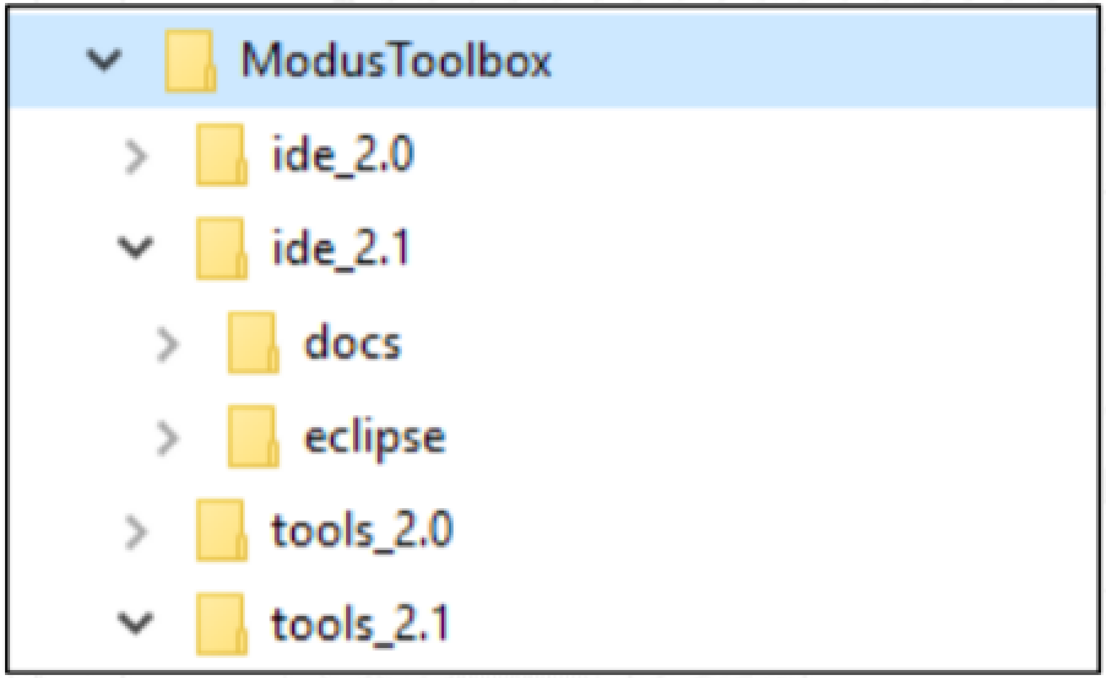
Visual Studio Code



Yes, now you can work in dark mode!!!

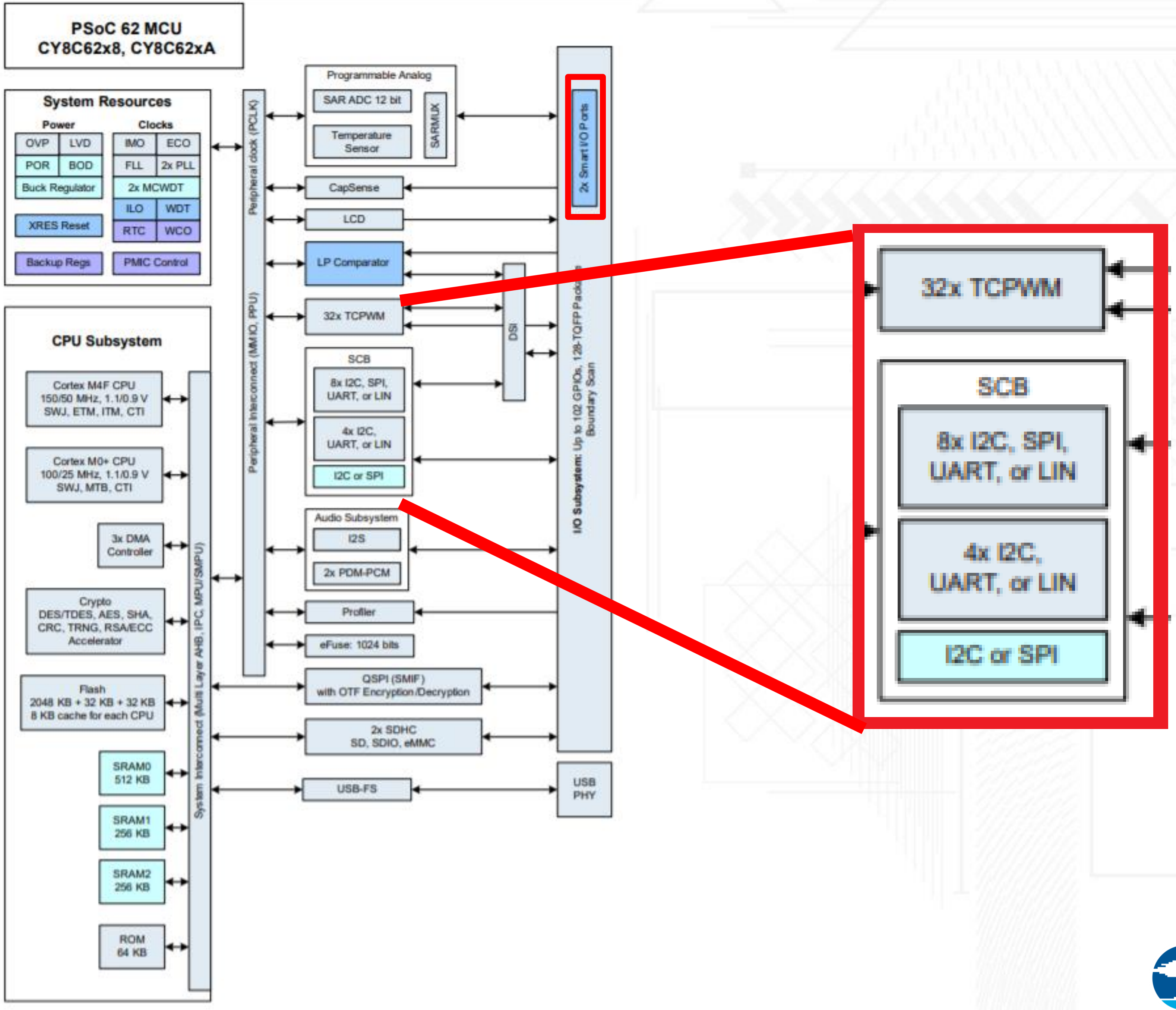
Product Versioning

- The ModusToolbox installation package is versioned as MAJOR.MINOR.PATCH. The file located at /ModusToolbox/tools_2.1/version-2.1.0.xml also indicates the build number
- Multiple versions installed in parallel in the same ModusToolbox directory
- Flexibility to use the version you want
  - ✓ Using Application Makefile
  - ✓ Set CY_TOOLS_PATH in environment variable



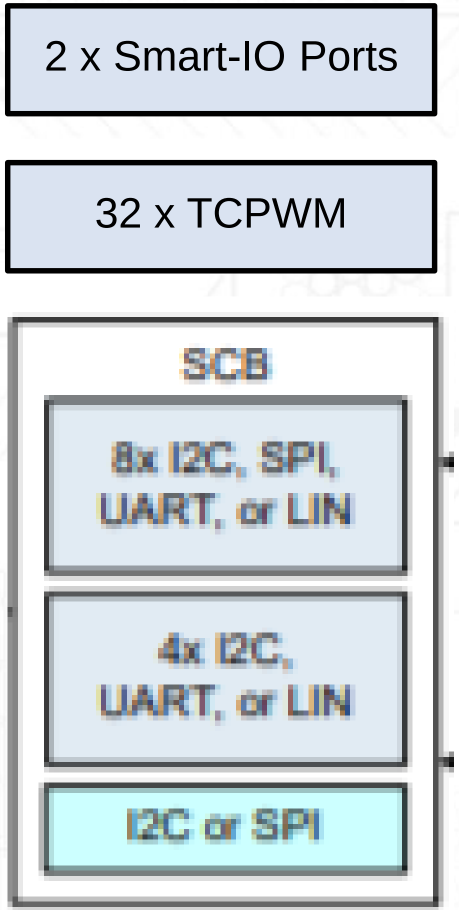
Introduction

PSoC6 Device Architecture



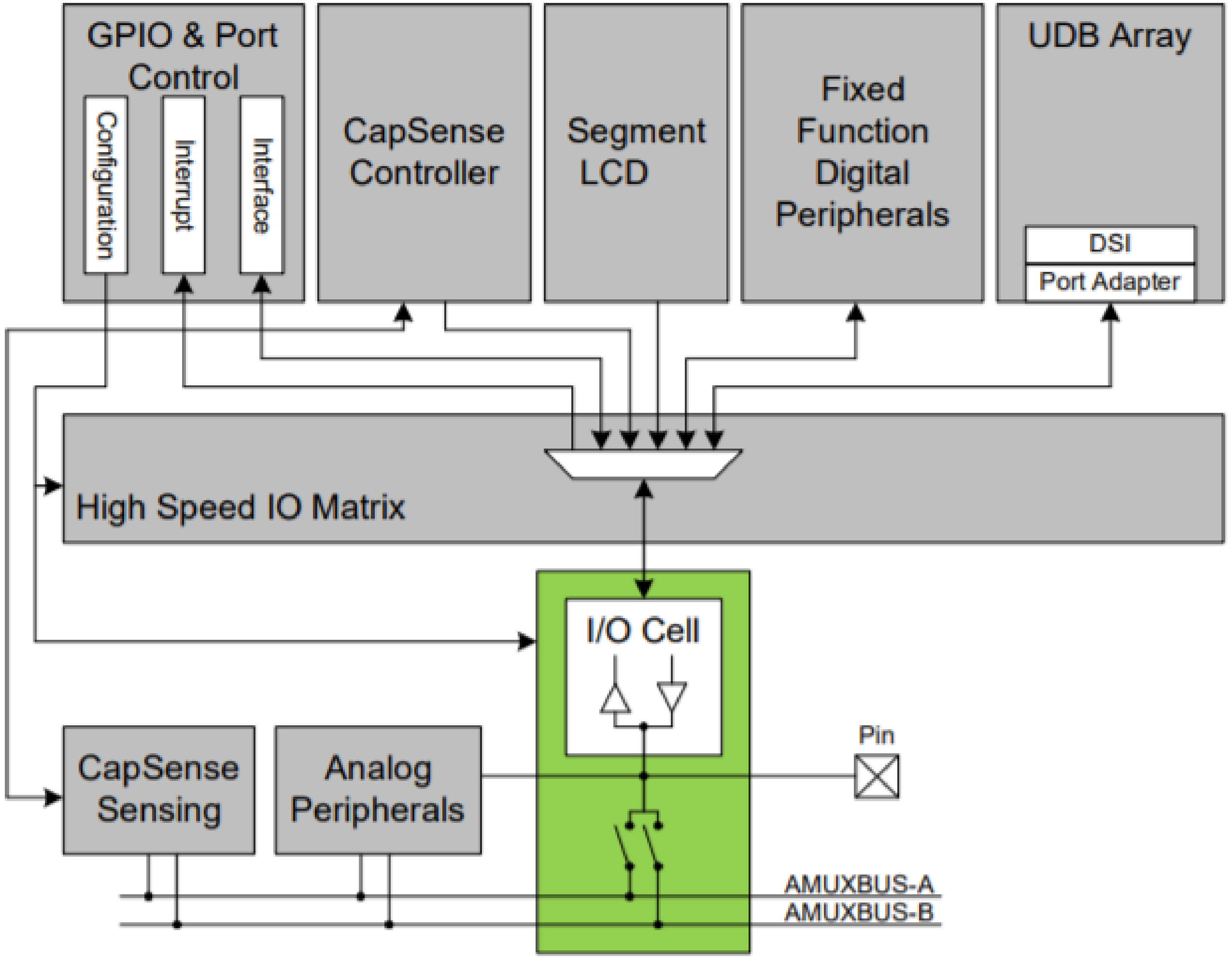
PSoC6 Digital Peripherals

- Programmable Digital
  - ✓ Smart-IO - programmable logic fabric that enables Boolean operations on signals passing through it
- Fixed-Function Digital
  - ✓ Timer/Counter/PWM Block (TCPWM) –
    - → Timer-counter with compare
    - → Timer-counter with capture
    - → Quadrature decoding
    - → Pulse width modulation (PWM)
  - ✓ Serial Communication Blocks (SCB) – digital block that is configurable as UART, I2C or SPI interfaces
  - ✓ USB, QSPI, SD Host Controller (out of scope for this training)



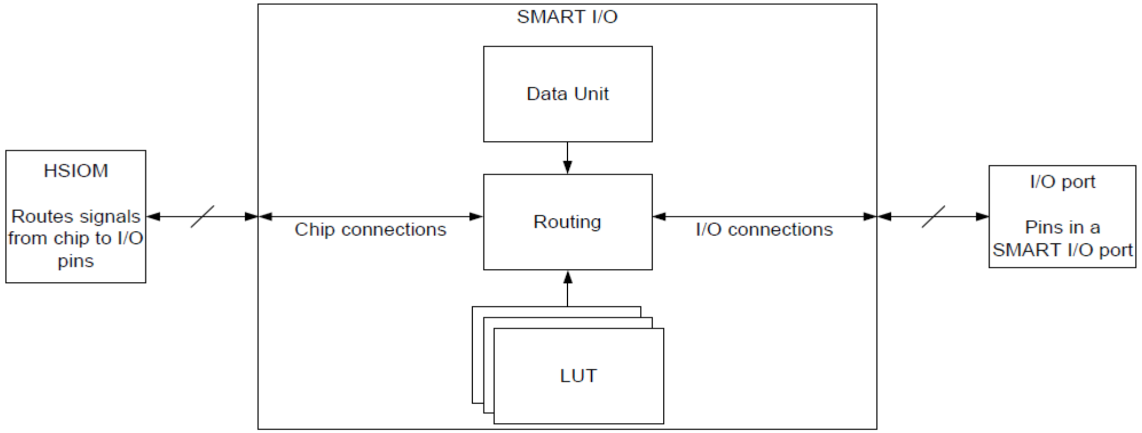
High Speed Input Output Matrix (HSIOM)

- Contains multiplexers to connect between the selected peripheral and the pin.

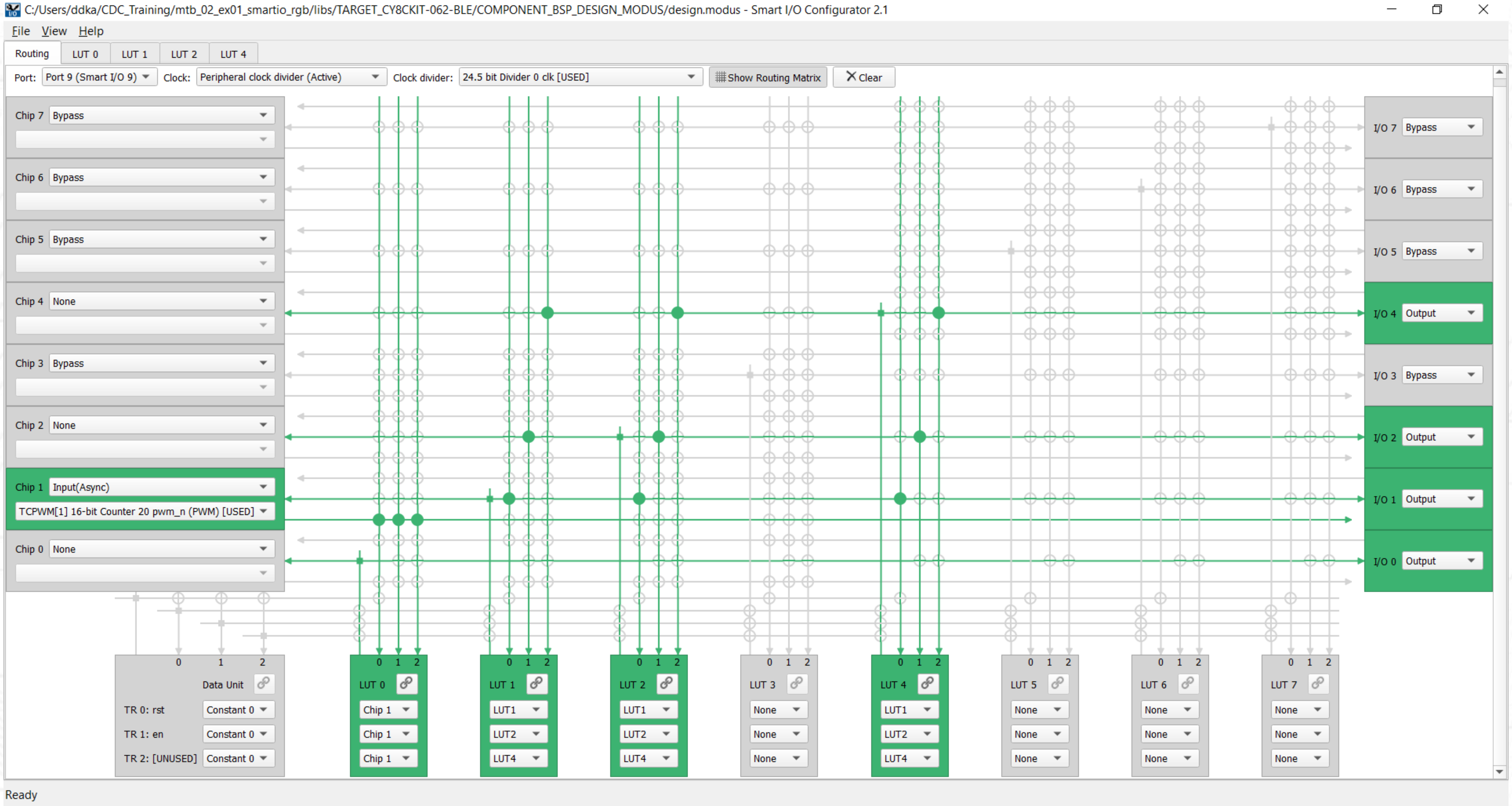


Smart-IO

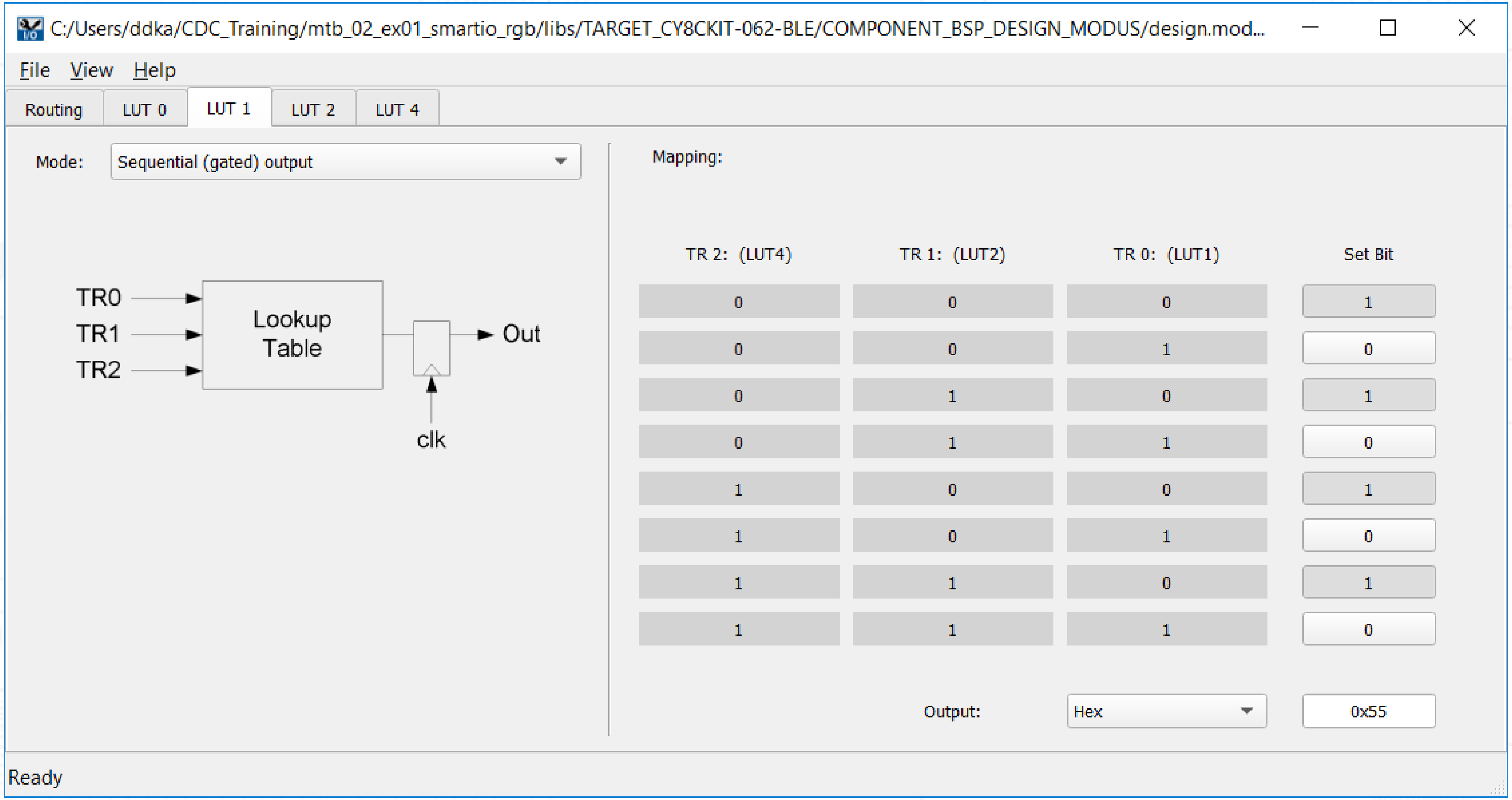
- The Smart I/O block sits between the GPIO pins and the high-speed I/O matrix (HSIOM) and is dedicated to a single port.
- Smart I/O supports:
  - ✓ Deep Sleep operation
  - ✓ Boolean operations without CPU intervention
  - ✓ Asynchronous or synchronous (clocked) operation
- Three selectable input sources
  - ✓ another LUT
  - ✓ an internal resource
  - ✓ an external signal from a GPIO pin



Smart-IO Configurator



Lookup Table (LUT)



Using Smart-IO in your Application

Steps:

- Go to design.modus file and enable Smart-IO. Use the Smart-IO configurator to define the inputs, the outputs and the logical operations to be performed.
- Make use of these APIs (basic) to start the Smart-IO block

```
Cy_SmartIO_Init(SMARTIO_HW, &SMARTIO_config);   - Initializes the SMART-IO Block
Cy_SmartIO_Enable(SMARTIO_HW);                  - Enables it
```

Refer to the code example ”*Ramping LED using Smart-IO*” for more information.

Note: No HAL yet, support only through PDL.

Smart-IO Configurator

Exercise 1:

Configure a PWM to generate a frequency of 1Hz with 50% duty cycle. Route this signal to pin 9[0] using the Smart-IO Block. In firmware read the output on pin 9[0] and write to LED9 (P13_7) and observe the LED blinking every second.

Exercise 2:

Create a LUT such that it functions as a 8-bit counter. Route the three output signals of the LUT to the RGB LEDs and observe the colors as shown in the below table.

LUT3	LUT2	LUT1	Color
0	0	0	OFF
0	0	1	RED
0	1	0	GREEN
0	1	1	YELLOW
1	0	0	BLUE
1	0	1	PINK
1	1	0	INDIGO
1	1	1	WHITE

Refer mtb_02_ex01_smartio_rgb project which implements the solution to both the exercises.

Smart-IO Configurator

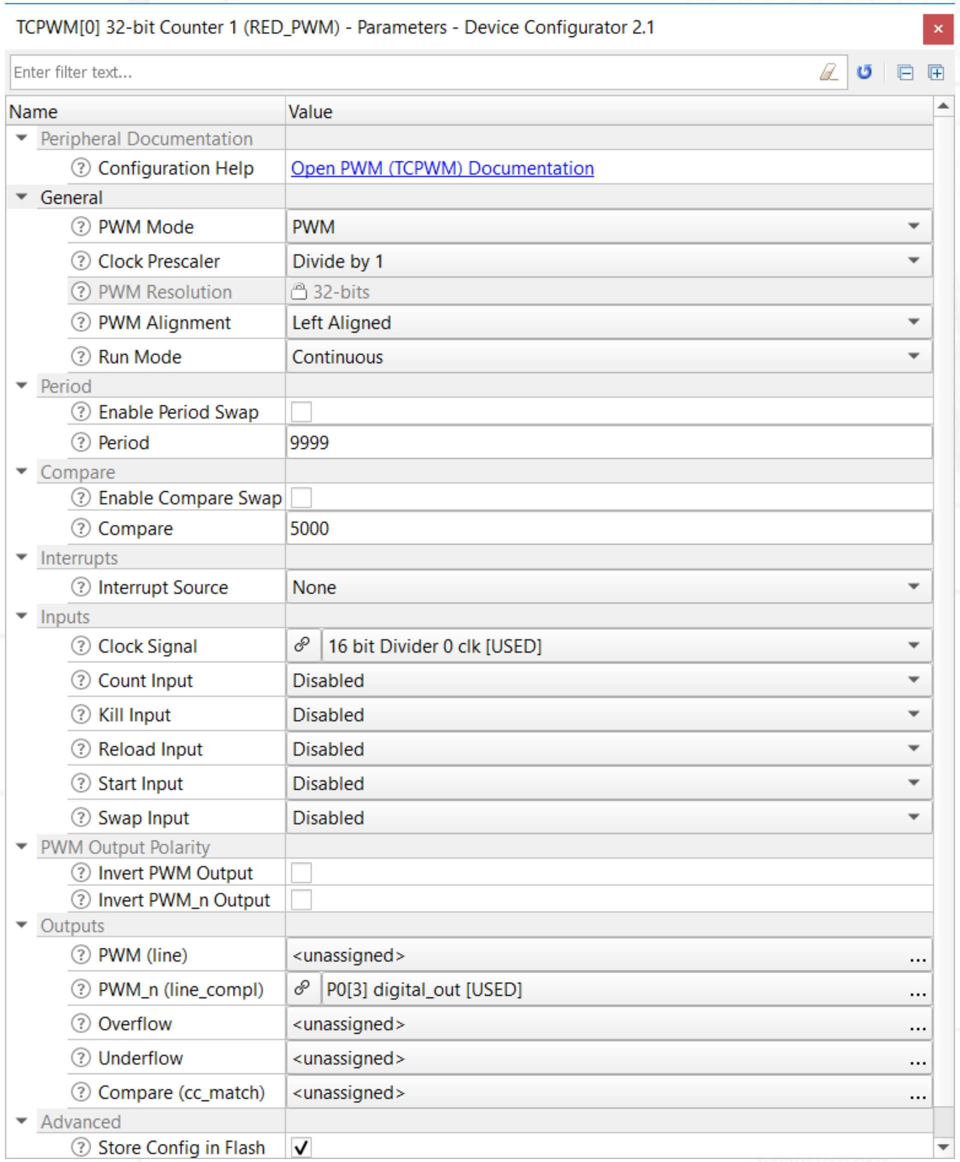
Exercise 2 LUT Logic Explained:

Present State			Next State		
LUT4	LUT2	LUT1	LUT4	LUT2	LUT1
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	1	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	0

Refer mtb_02_ex01_smartio_rgb project which implements the solution to both the exercises.

Timer Counter Pulse Width Modulation

- Multi-functional, configurable digital block containing 32 counters. Each can be 16 or 32-bit wide.
- Modes:
  - ✓ Counter – counts events, for e.g., number of pulse edges
  - ✓ Timer – sets up a counter to generate time intervals
  - ✓ PWM – Generates pulses based on the duty cycle, period and compare values
- Up, Down, and Up/Down counting modes
- Clock prescaling (division by 1, 2, 4, ... 64, 128)



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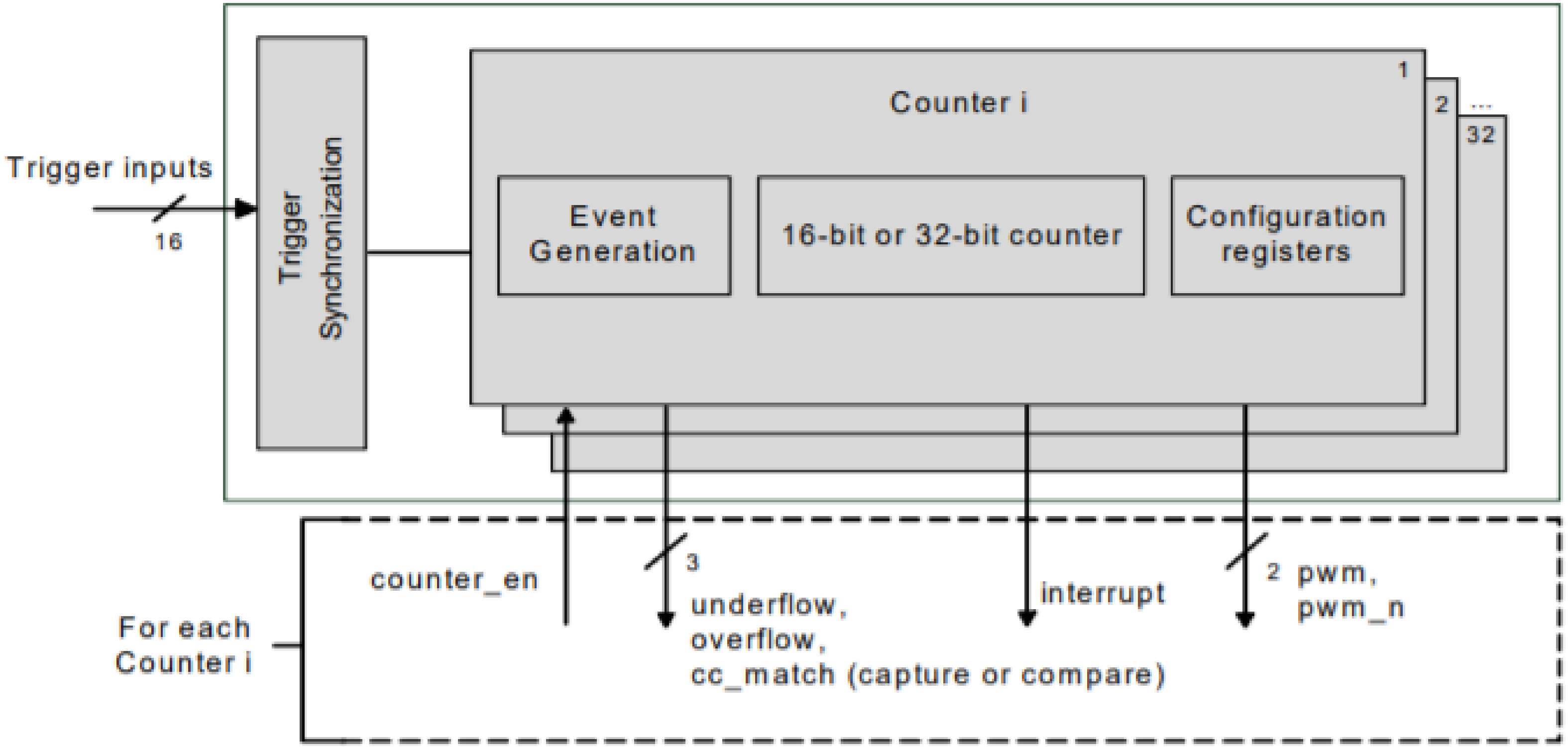
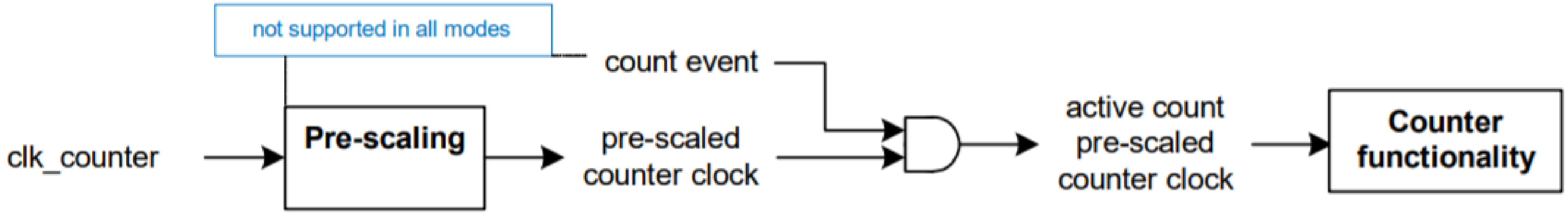
Timer Counter Pulse Width Modulation

Provides two interfaces:

- I/O signal interface:
  - Consists of input triggers:
    - ✓ Reload
    - ✓ Start
    - ✓ Stop
    - ✓ Count
    - ✓ Capture
  - Output signals:
    - ✓ pwm
    - ✓ pwm_n
    - ✓ overflow (OV)
    - ✓ underflow (UN)
    - ✓ capture/compare (CC)).
- Interrupts: Provides interrupt request signals from each counter, based on TC or CC conditions



Counter Functionality



Configurable Modes

Mode	MODE Field [26:24]	Description
Timer	000	The counter increments or decrements by '1' at every clk_counter cycle in which a count event is detected. The Compare/Capture register is used to compare the count.
Capture	010	The counter increments or decrements by '1' at every clk_counter cycle in which a count event is detected. A capture event copies the counter value into the capture register.
Quadrature	011	Quadrature decoding. The counter is decremented or incremented based on two phase inputs according to an X1, X2, or X4 decoding scheme.
PWM	100	Pulse width modulation.

Understanding HAL

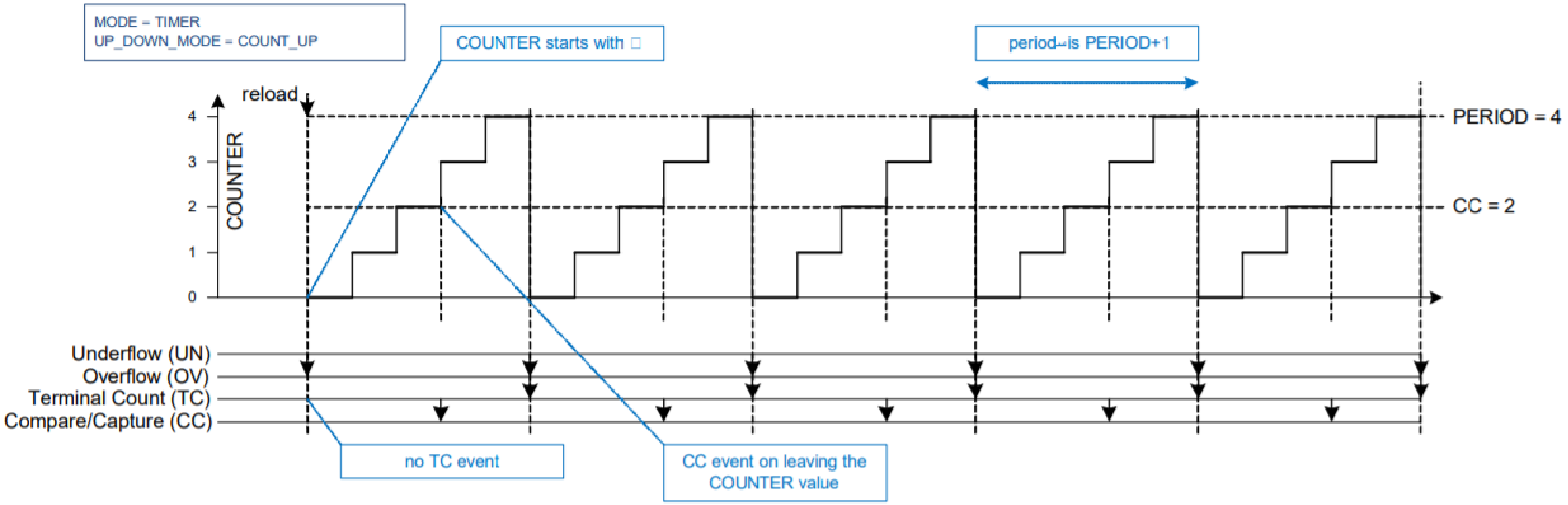
- It is a generic interface that can be used across multiple product families
- The focus is on ease-of-use and portability

API Structure

- `_init` function – Allocates a block, configures it and enables it.
- `_free` function – Disables a block, releases resources
- Other functions – provide block specific functionality

Timer

- Increments/decrements a counter between 0 and the value stored in the PERIOD register.
- Used for:
  - ✓ Timing a specific delay
  - ✓ Counting the occurrence of a specific event



Using Timer in your Application

Steps:

Using HAL APIs:

First configure the timer parameters using cyhal_timer_cfg_t and then initialize and enable it as shown:

```
const cyhal_timer_cfg_t led_blink_timer_cfg =
{
.compare_value = 0,                 /* Timer compare value, not used */
.period = LED_BLINK_TIMER_PERIOD,   /* Defines the timer period */
.direction = CYHAL_TIMER_DIR_UP,    /* Timer counts up */
.is_compare = false,                /* Don't use compare mode */
.is_continuous = true,              /* Run timer indefinitely */
.value = 0                          /* Initial value of counter */
};
cyhal_timer_init(&led_blink_timer, NC, NULL);
cyhal_timer_configure(&led_blink_timer, &led_blink_timer_cfg);
cyhal_timer_set_frequency(&led_blink_timer, LED_BLINK_TIMER_CLOCK_HZ);
```

Using Timer in your Application

Additionally you can register the callback functions to be triggered when a specific event occurs using the following APIs:

```
/* Assign the ISR to execute on timer interrupt */
cyhal_timer_register_callback(&led_blink_timer, isr_timer, NULL);


/* Set the event on which timer interrupt occurs and enable it */
cyhal_timer_enable_event(&led_blink_timer, CYHAL_TIMER_IRQ_TERMINAL_COUNT,
7, true);
```

Then you can go ahead and start the timer!

```
/* Start the timer with the configured settings */
cyhal_timer_start(&led_blink_timer);
```

Using Timer in your Application

Steps:

Using PDL APIs:

First configure the timer parameters using the design.modus file and then use the following APIs to start the timer:

```
/* Initialize the interrupt */
Cy_SysInt_Init(&timer_isr_config, timer_isr);
NVIC_EnableIRQ(timer_isr_config.intrSrc);


/* Start the timer */
Cy_TCPWM_Counter_Init(TIMER_HW, TIMER_NUM, &TIMER_config);
Cy_TCPWM_Counter_Enable(TIMER_HW, TIMER_NUM);
Cy_TCPWM_TriggerStart(TIMER_HW, TIMER_MASK);
```

Counter

- The capture functionality increments and decrements a counter between 0 and PERIOD. When the capture event is activated the counter value COUNTER is copied to CC.
- Used for:
  - ✓ Measuring the width of a pulse
  - ✓ Measuring the frequency of a signal

Using Counter in your Application

Steps:

Using PDL APIs (HAL not supported):

First configure the timer parameters using the design.modus file and then use the following APIs to start the timer:

```
/* Start the timer */
Cy_TCPWM_Counter_Init(COUNTER_HW, COUNTER_NUM, &COUNTER_config);
Cy_TCPWM_Counter_Enable(COUNTER_HW, COUNTER_NUM);
Cy_TCPWM_TriggerStart(COUNTER_HW, COUNTER_MASK);
```

To read the captured values use:

```
Cy_TCPWM_Counter_GetCapture()
```

Timer/Counter

Exercise 3:

Configure a timer to generate an interrupt every 1s and toggle the LED. Use only HAL APIs.

Refer mtb_02_ex04_timer_hal project which implements the solution to this exercise.

Exercise 4:

Configure a timer to generate an interrupt every 1s and toggle the LED. Use only PDL APIs.

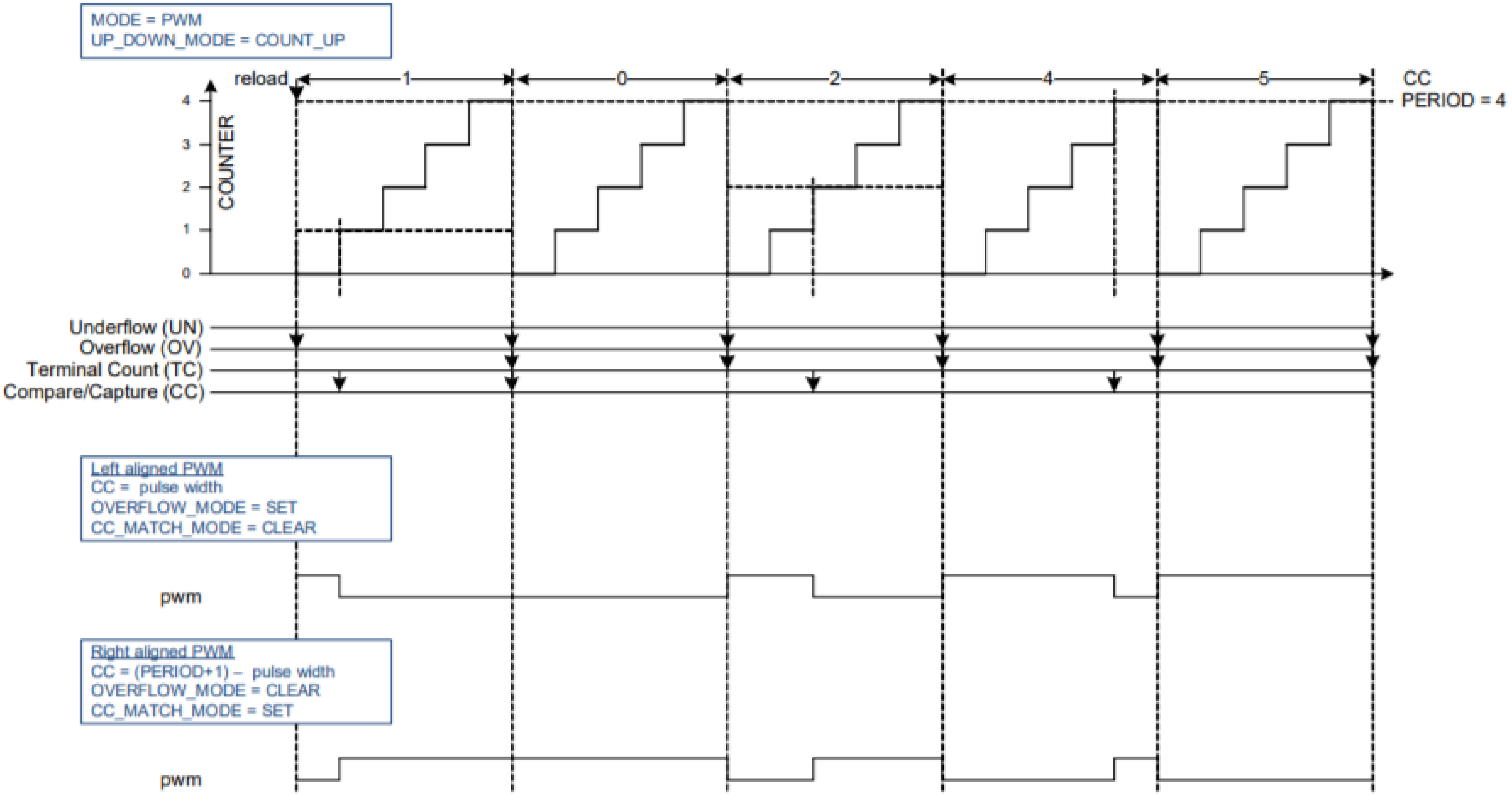
Refer mtb_02_ex05_timer_pdl project which implements the solution to this exercise. Compare this with the previous exercise. Which do you think was easier?

Exercise 5:

- Generate a 250 Hz signal with any duty cycle using PWM
- Use a Counter to measure counts between PWM pulses
- Print measured frequency to serial terminal using UART

Refer mtb_02_ex06_counter_dutycycle project which implements the solution to this exercise.

PWM


MODE = PWM
UP_DOWN_MODE = COUNT_UP
reload
1
0
2
4
5
CC
PERIOD = 4
COUNTER
4
3
2
1
0
Underflow (UN)
Overflow (OV)
Terminal Count (TC)
Compare/Capture (CC)
Left aligned PWM
CC = pulse width
OVERFLOW_MODE = SET
CC_MATCH_MODE = CLEAR
pwm
Right aligned PWM
CC = (PERIOD+1) – pulse width
OVERFLOW_MODE = CLEAR
CC_MATCH_MODE = SET
pwm

Using PWM in your Application

Steps:

Using HAL APIs:

Add the following code directly in main.c to interact with the PWM block

```
cyhal_pwm_init(&pwm_obj, CYBSP_USER_LED, NULL);

cyhal_pwm_set_duty_cycle(&pwm_obj, 50, 1);

cyhal_pwm_start(&pwm_obj);
```

Using PDL APIs:

Configure a PWM in design.modus file with the required parameters and then call the following APIs:

```
Cy_TCPWM_PWM_Init(PWM_HW, PWM_NUM, &PWM_config);

Cy_TCPWM_PWM_Enable(PWM_HW, PWM_NUM);

Cy_TCPWM_TriggerStart(PWM_HW, PWM_MASK);
```

PWM

Exercise 6:

Configure a PWM to generate a frequency of 1Hz with 50% duty cycle using HAL and PDL APIs. Check if there is a conflict.

Solution key: Refer mtb_02_ex02_pwm_blinkyled project for this solution.

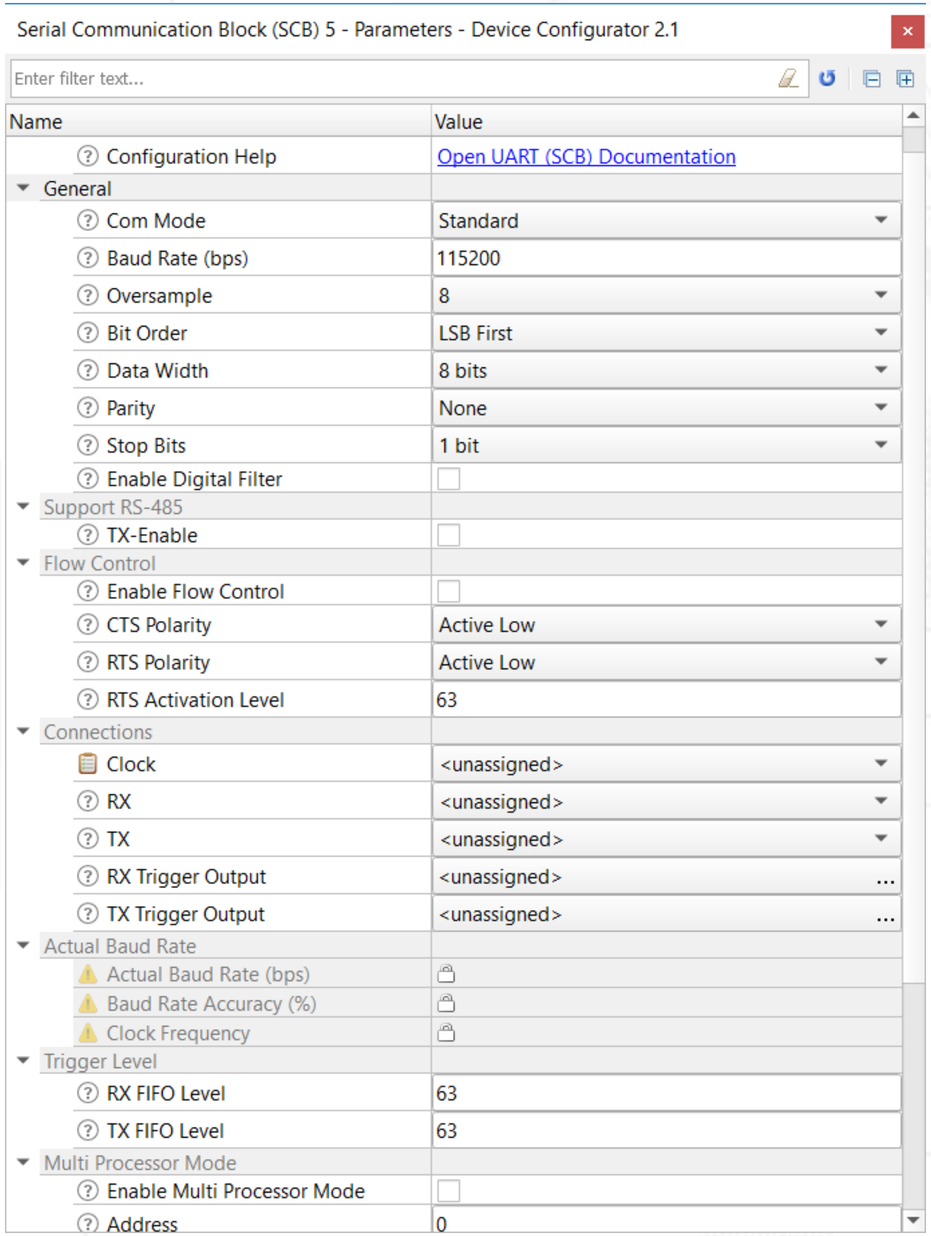
Exercise 7:

Configure a PWM to increase the brightness of the LED to its maximum and then decrement to its lowest. Hint: Vary the duty cycle every 500ms to observe the output on the LED.

Solution key: Refer mtb_02_ex03_pwm_brightness_control project for this solution.

Serial Communication Block

- Multi-functional, configurable digital communication block
- Can be made to function as communication components:
  - ✓ I2C
  - ✓ SPI
  - ✓ UART
- Standard SPI master and slave functionality with Motorola, Texas Instruments, and National Semiconductor protocols Standard
- UART functionality
- Standard I2C master and slave functionality
- Trigger outputs for connection to DMA
- Multiple interrupt sources to indicate status of FIFOs and transfers



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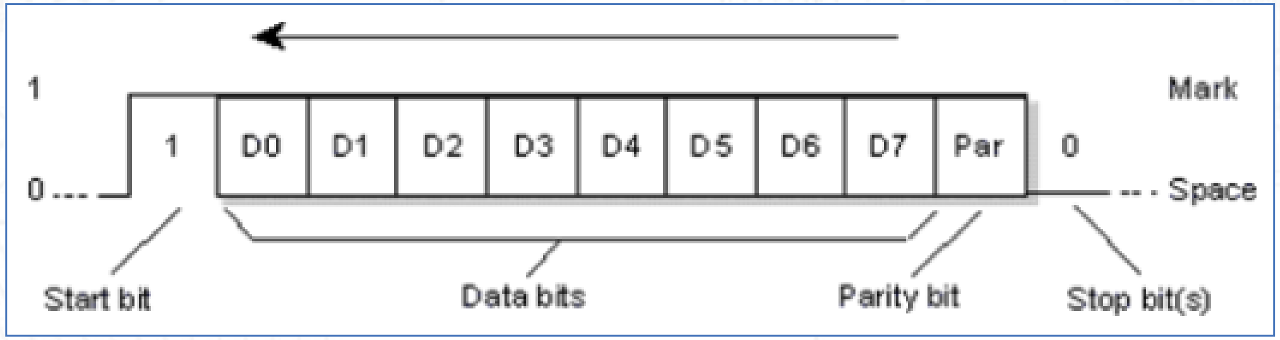
Serial Communication Block

UART

- Universal asynchronous transmitter and receiver
- Half duplex, full duplex,, only TX and only RX modes
- Two wire – Transmit (TX) and Receive (RX)
- No Clock line
- Typically used baud rates – 9600 to 115200 bps
- Additional pins – flow control functionality
- Usually between two devices



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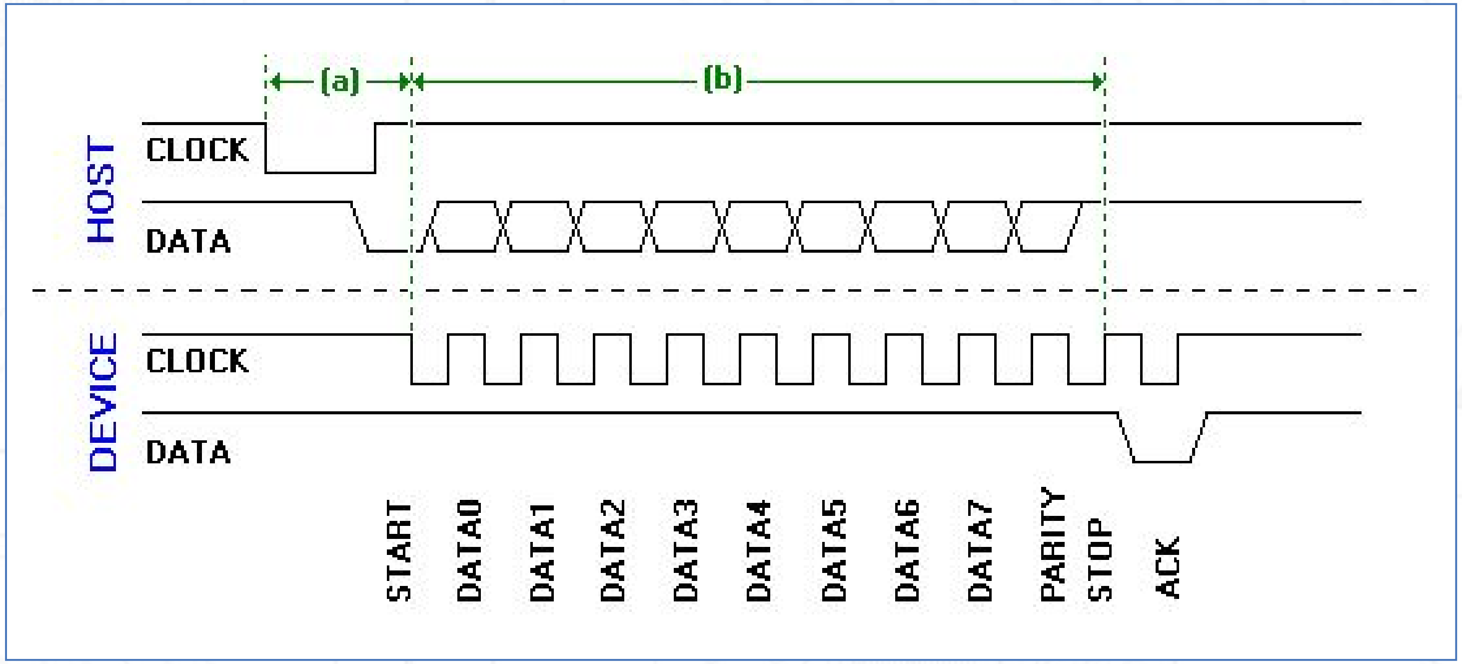

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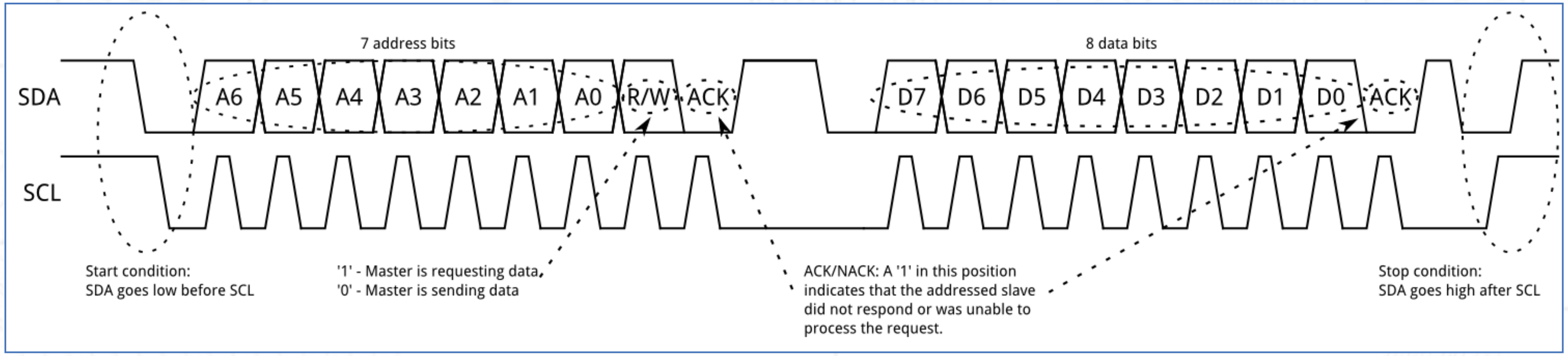
I2C

- Inter-integrated circuit (IIC / I^2C)
- Half duplex protocol
- Two wire – Serial Data (SDA) and Serial Clock (SCL)
- Typically used clock rates – 100 kHz to 400 kHz
- A master can talk to 127 slaves



Serial Communication Block

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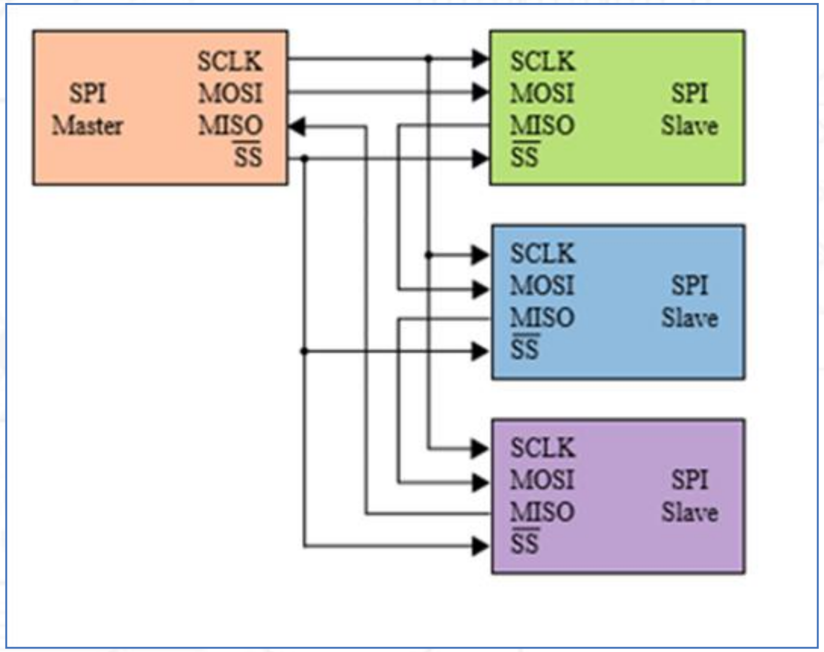
- Universal asynchronous transmitter and receiver
- Half duplex, full duplex,, only TX and only RX modes
- Two wire – Transmit (TX) and Receive (RX)
- No Clock line
- Typically used baud rates – 9600 to 115200 bps
- Additional pins – flow control functionality
- Usually between two devices

I2C

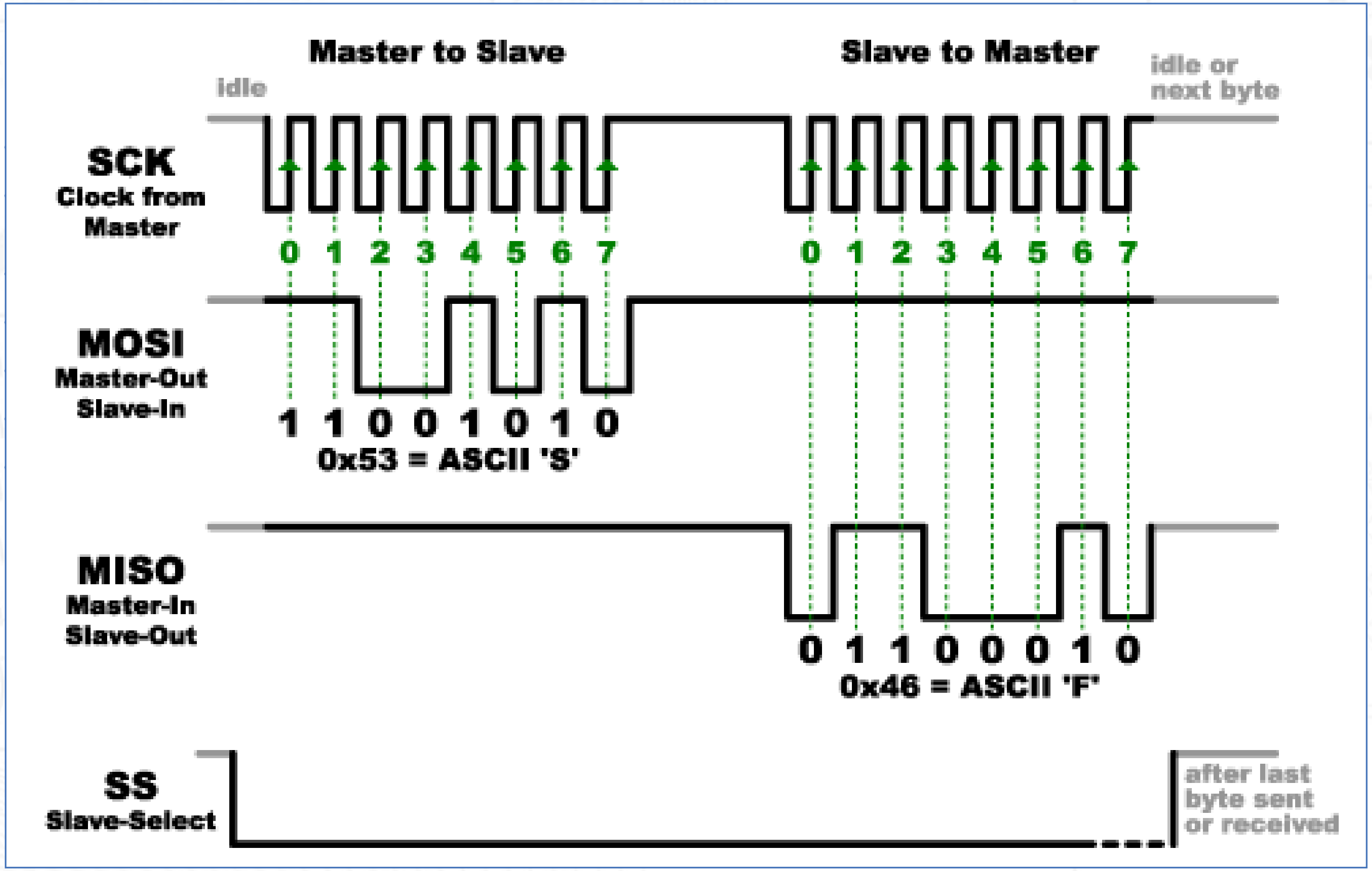
- Inter-integrated circuit (IIC / I^2C)
- Half duplex protocol
- Two wire – Serial Data (SDA) and Serial Clock (SCL)
- Data rates from 100 kbps to 1000kbps
- A master can talk to 127 slaves



SPI

- Serial peripheral interface
- Full duplex protocol
- Four wire –
  - Master Out Slave In (MOSI)
  - Master In Slave Out (MISO)
  - Serial clock (SCK)
  - Slave Select (SS)
- Typically used data rates – 1 Mbps to 8 Mbps

Serial Communication Block



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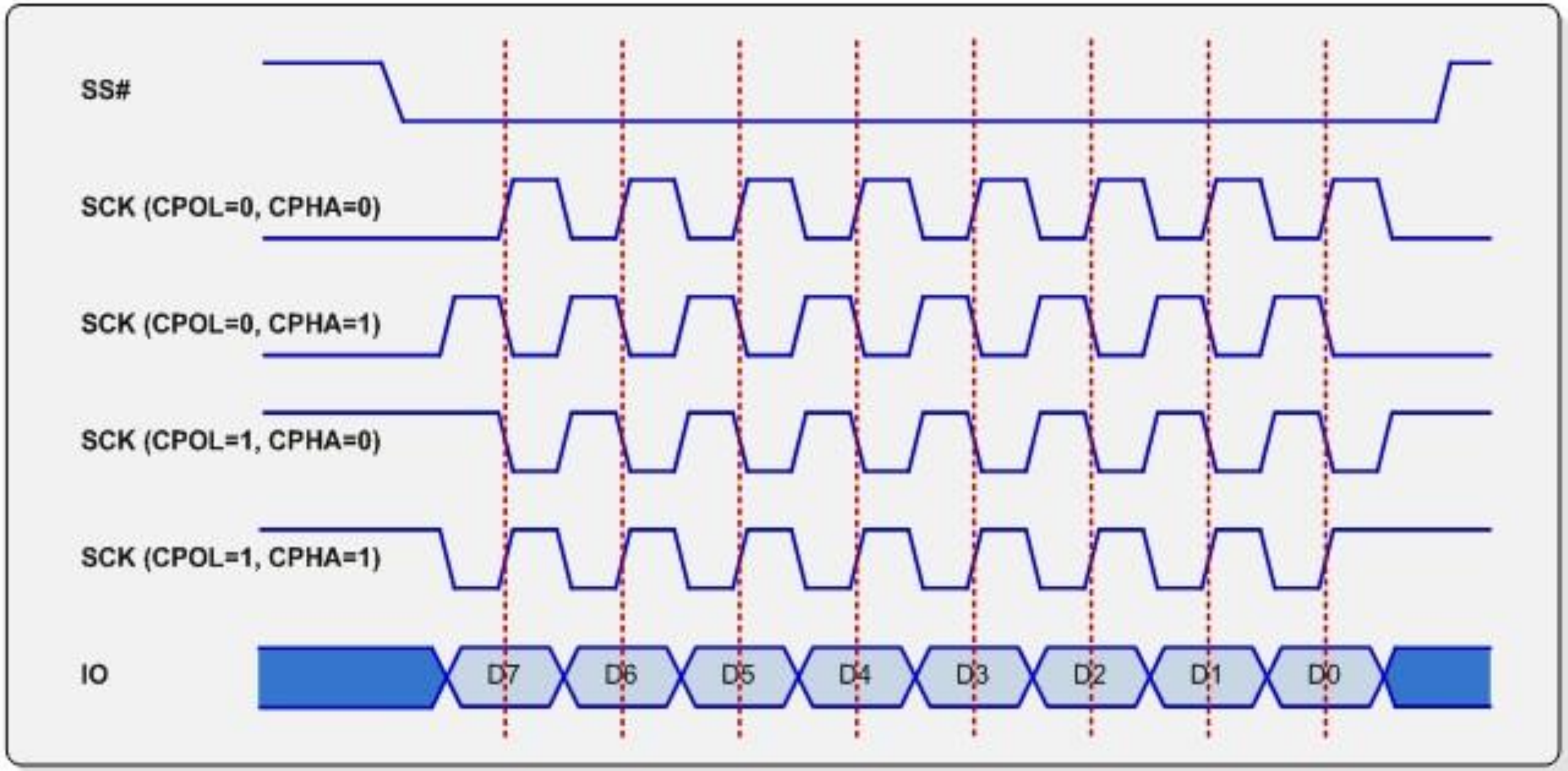
Serial Communication Block



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- Typically used data rates – 1 Mbps to 8 Mbps

UART

Exercise 8:

- Use the project from Exercise 6 (Generate PWM signal of 100 Hz frequency with 10% duty cycle)
- Print the PWM parameters (duty cycle, compare value, period) on a PC terminal using UART
- Control PWM duty cycle from the PC (increase or decrease by 10% upon two different keypresses)

Solution key: Use mtb_02_ex06_counter_dutycycle project for reference.

Useful APIs:

Retarget-IO Middleware – `cy_retarget_io_init(CYBSP_DEBUG_UART_TX, CYBSP_DEBUG_UART_RX, 115200);`

Then make use of standard IO library functions like printf, sprintf etc. to read or print something to the terminal.

I2C

Exercise 9:

Control PWM brightness by writing data from an I2C master (use KitProg3 as master; using Bridge Control panel (BCP) on PC)

Solution key: Refer mtb_02_ex07_i2c_brightness_control project for this solution.

Useful APIs:

```
/* Allocate and initialize a I2C resource and auto select a clock */
cyhal_i2c_init(&i2c_slave, CYBSP_I2C_SDA, CYBSP_I2C_SCL, NULL);
/* Configure the I2C resource to be slave */
cyhal_i2c_configure (&i2c_slave, &i2c_slave_cfg);
/* Configure I2C slave write buffer for I2C master to write into */
cyhal_i2c_slave_config_read_buff(&i2c_slave, i2c_write_buffer, SL_WR_BUFFER_SIZE);
/* Configure I2C slave read buffer for I2C master to read from */
cyhal_i2c_slave_config_write_buff(&i2c_slave, i2c_read_buffer, SL_RD_BUFFER_SIZE);
```

SPI

Exercise 10:

Setup PSoC as both an SPI master and slave. SPI master sends a command every second to a SPI slave to toggle the LED. Use HAL APIs.

Solution key: Refer mtb_02_ex08_spi_master project for this solution.

Useful APIs:

`cyhal_spi_init()` – Initializes the SPI block and configures it as slave or master.

`cyhal_spi_set_frequency()` – set the SPI baud rate

`cyhal_spi_send()` – Sends the command

`cyhal_spi_recv()` – Receives the command

Resources

- ModusToolbox User Guide
- Cypress Github Landing Page
- PSoC6 Architecture TRM

Contact Information

- https://community.cypress.com/welcome
- Send your queries to ddka@cypress.com

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