2023

LED Sequence V3.0

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EMBEDDED SYSTEMS - LEVEL 1

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LED Sequence V3.0

System Requirements Specifications

Brief

Develop a system that controls 4 LEDs lighting sequence according to button pressing.

Hardware Requirements

- Four LEDs (LED0, LED1, LED2, LED3)
- Two buttons (BUTTON0, BUTTON1)

Software Requirements

1. Initially, all LEDs are OFF
2. Once **BUTTON0** is pressed, **LED0** will blink with **BLINK_1** mode
3. Each press further will make another LED blinks **BLINK_1** mode
4. At the **fifth press**, **LED0** will changed to be **OFF**
5. Each **press further** will make only one LED is **OFF**
6. This will be repeated forever
7. The sequence is described below
    1. Initially (OFF, OFF, OFF, OFF)
    2. Press 1 (BLINK_1, OFF, OFF, OFF)
    3. Press 2 (BLINK_1, BLINK_1, OFF, OFF)
    4. Press 3 (BLINK_1, BLINK_1, BLINK_1, OFF)
    5. Press 4 (BLINK_1, BLINK_1, BLINK_1, BLINK_1)
    6. Press 5 (OFF, BLINK_1, BLINK_1, BLINK_1)
    7. Press 6 (OFF, OFF, BLINK_1, BLINK_1)
    8. Press 7 (OFF, OFF, OFF, BLINK_1)
    9. Press 8 (OFF, OFF, OFF, OFF)
    10. Press 9 (BLINK_1, OFF, OFF, OFF)

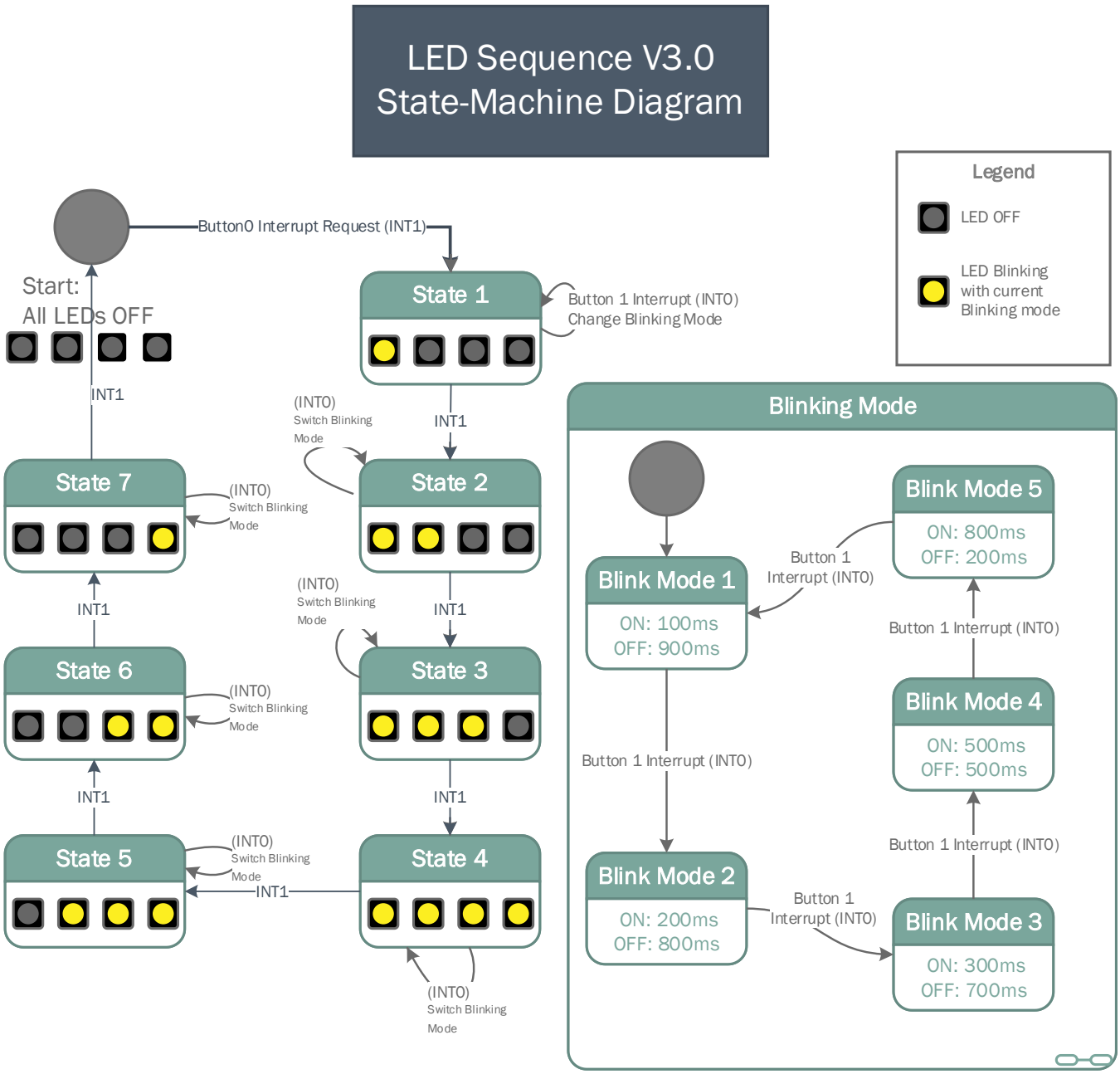
8. When BUTTON1 has pressed the blinking on and off durations will be changed
    1. No press → **BLINK_1** mode (**ON**: 100ms, **OFF**: 900ms)
    2. First press → **BLINK_2** mode (**ON**: 200ms, **OFF**: 800ms)
    3. Second press → **BLINK_3** mode (**ON**: 300ms, **OFF**: 700ms)
    4. Third press → **BLINK_4** mode (**ON**: 500ms, **OFF**: 500ms)
    5. Fourth press → **BLINK_5** mode (**ON**: 800ms, **OFF**: 200ms)
    6. Fifth press → **BLINK_1** mode

9. **USE EXTERNAL INTERRUPTS**

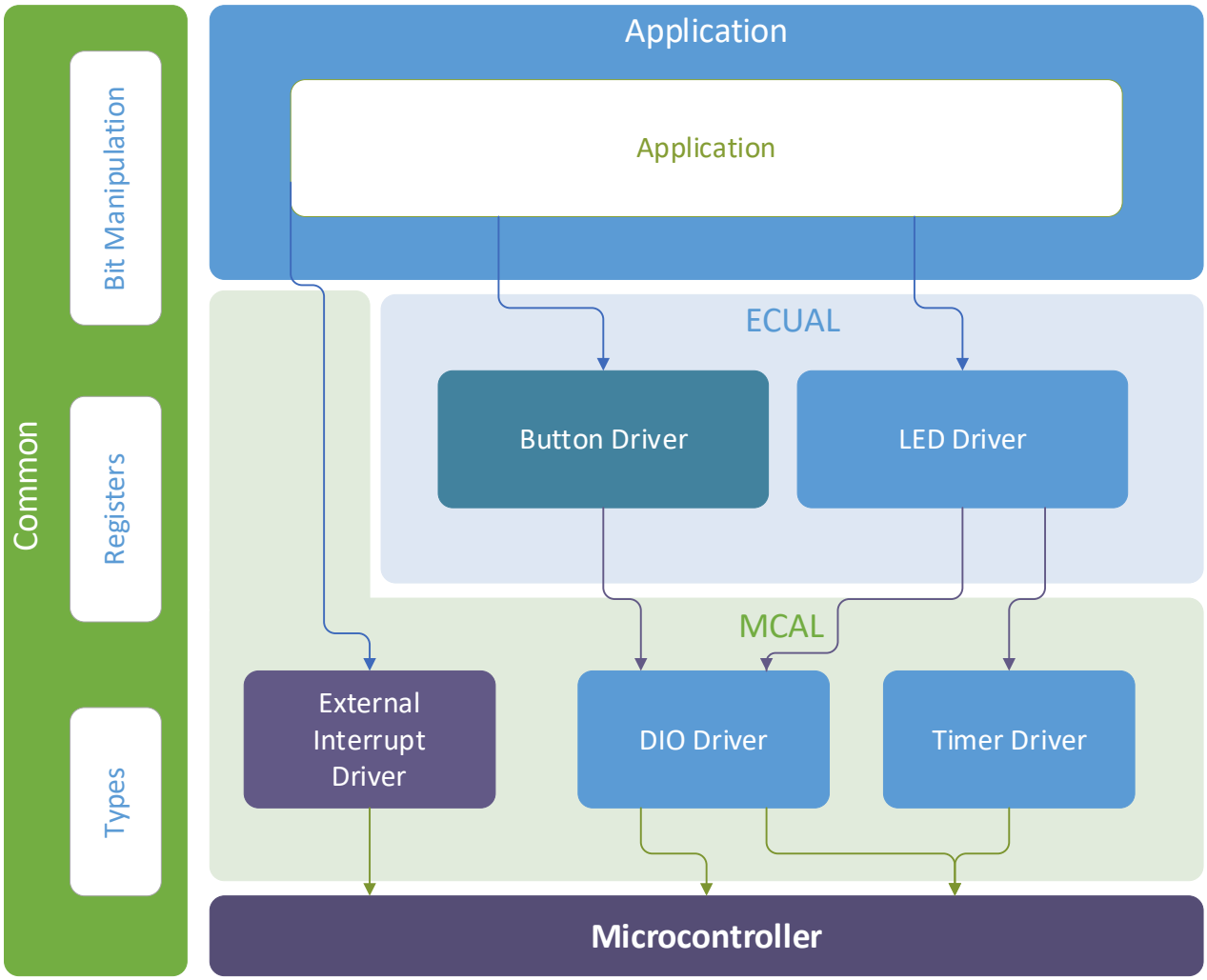
System Design

State Machine Diagram

Software used: Microsoft Visio



LED Sequence V3.0 Layered Architecture



Project Modules APIs

DIO Driver

DIO Macros/Enums:

Type	Name	Values	Desc
`#define`	LOW HIGH	LOW = 0 HIGH = 1	**Macro for digital levels**
`typedef enum`	EN_DIO_PORT_T	• A, B, C, D	**Defines available DIO ports**
`typedef enum`	EN_DIO_DIRECTION_T	• In = 0 • Out = 1	**Defines DIO pin direction**
`typedef enum`	EN_DIO_Error_T	• DIO_OK • DIO_Error	**Defines DIO return error**

DIO Functions:

```
/**
 * Configures pin at given portNumber as input/output
 * @param pinNumber [in] pin number
 * @param portNumber [in] Port to configure
 * @param direction [in] direction for pin enum (IN, OUT)
 */
EN_DIO_Error_T DIO_init(uint8_t pinNumber, EN_DIO_PORT_T portNumber, EN_DIO_DIRECTION_T direction);
```

```
/**
 * Writes pin value for the given port/pin
 * @param pinNumber [in] pin number
 * @param portNumber [in] Port to use
 * @param value [in] value to write
 */
EN_DIO_Error_T DIO_write(uint8_t pinNumber, EN_DIO_PORT_T portNumber, uint8_t value);
```

```
/**
 * Toggles pin value for the given port/pin
 * @param pinNumber [in] pin number
 * @param portNumber [in] Port to use
 */
EN_DIO_Error_T DIO_toggle(uint8_t pinNumber, EN_DIO_PORT_T portNumber);
```

```
/**
 * Reads pin value for the given port/pin and stores it in *value
 * @param pinNumber [in] pin number
 * @param portNumber [in] Port to use
 * @param *value [out] pointer to output pin value into
 */
EN_DIO_Error_T DIO_read(uint8_t pinNumber, EN_DIO_PORT_T portNumber, uint8_t *value);
```

```c
/**
 * Writes a byte to a given PORT
 * @param portNumber [in] Port to use
 * @param byte [in] value to write
 */
EN_DIO_Error_T DIO_port_write(EN_DIO_PORT_T portNumber, uint8_t byte, uint8_t mask);
```

```c
/**
 * Toggles a given PORT
 * @param portNumber [in] Port to use
 * @param mask [in] (optional, 0 to disable)
 */
EN_DIO_Error_T DIO_port_toggle(EN_DIO_PORT_T portNumber, uint8_t mask);
```

```c
/**
 * Toggles pin value for the given port/pin
 * @param pinNumber [in] pin number
 * @param portNumber [in] Port to use
 */
EN_DIO_Error_T DIO_toggle(uint8_t pinNumber, EN_DIO_PORT_T portNumber);
```

EXI (External Interrupt) Driver

EXI Macros/Enums:

Type	Name/Value	Desc
#define	EXT_INT_0 __vector_1	Interrupt vector naming
#define	EXT_INT_1 __vector_2	Interrupt vector naming
#define	EXT_INT_2 __vector_3	Interrupt vector naming
#define	sei() __asm__ __volatile__ ("sei" ::: "memory")	Enables global interrupt
#define	cli() __asm__ __volatile__ ("cli" ::: "memory")	Disables global interrupt
#define	ISR(INT_VECT) void INT_VECT(void) __attribute__ ((signal,used));\ void INT_VECT(void)	ISR definition
typedef enum	typedef enum EN_EXI_INT_t { INT0, INT1 } EN_EXI_INT_t;	Defines Interrupt port names

typedef enum	typedef enum EN_EXI_SENSE_t {
	// Interrupts on low level
	LOW_LEVEL = 0xFC,
	// Interrupts on any logical change
	ANY_LEVEL = 0x01,
	// Interrupts on Falling edge
	FALLING_EDGE = 0x02,
	// Interrupts on Rising edge
	RISING_EDGE = 0x03
	} EN_EXI_SENSE_t;
		Enum for ATmega32 interrupt sense modes

typedef enum	typedef enum EN_EXI_ERROR_t { EXI_OK, EXI_ERROR } EN_EXI_ERROR_t;	Error return type for EXI API

EXI Functions:

```
/**
 * Sets and enables an external interrupt pin with given mode
 * @param interrupt [in] Interrupt number (INT0, INT1)
 * @param interruptSenseMode [in] sense mode enum
 */
EN_EXI_ERROR_t EXI_enableInterrupt(EN_EXI_INT_t interrupt, EN_EXI_SENSE_t interruptSenseMode);
```

```
/**
 * Disables a given interrupt pin
 * @param interrupt [in] enum (INT0, INT1)
 */
EN_EXI_ERROR_t EXI_disableInterrupt(EN_EXI_INT_t interrupt);
```

```
/**
* Disables global interrupts
*  sets I-(7th) bit in SREG to 0
*/
void EXI_disableAll(void); // no return needed
```

LED Driver

LED Macros/Enums:

Type	Name/Value	Desc
typedef enum	typedef enum EN_LED_ERROR_t { LED_OK, LED_ERROR }EN_LED_ERROR_t;	Enum for LED error return

LED Functions:

```
/**
 * Initializes LED on given port & pin
 * @param ledPort [in] LED Port
 * @param ledPin [in] LED Pin number in ledPort
 */
EN_LED_ERROR_t LED_init(EN_DIO_PORT_T ledPort, uint8_t ledPin);
```

```
/**
 * Turns on LED at given port/pin
 * @param ledPort [in] LED Port
 * @param ledPin [in] LED Pin number in ledPort
 */
EN_LED_ERROR_t LED_on(EN_DIO_PORT_T ledPort, uint8_t ledPin);
```

```
/**
 * Turns off LED at given port/pin
 * @param ledPort [in] LED Port
 * @param ledPin [in] LED Pin number in ledPort
 */
EN_LED_ERROR_t LED_off(EN_DIO_PORT_T ledPort, uint8_t ledPin);
```

```
/**
 * Toggles LED at given port/pin
 * @param ledPort [in] LED Port
 * @param ledPin [in] LED Pin number in ledPort
 */
EN_LED_ERROR_t LED_toggle(EN_DIO_PORT_T ledPort, uint8_t ledPin);
```

LED ARRAYS Functions

```
/**
 * Turns on a LED Array at given PORT
 * @param ledPort [in] LED Port
 * @param mask [in] (optional, 0 to disable)
 * \n mask to turn on specific LEDs only | e.g. to only turn on the first LED use 0x01 (0b0000 0001)
 */
EN_LED_ERROR_t LED_array_on(EN_DIO_PORT_T ledPort, uint8_t mask);
```

```
/**
 * Turns off a LED Array at given PORT
 * @param ledPort [in] LED Port
 * @param mask [in] (optional, 0 to disable)
 * \n mask to turn off specific LEDs only | e.g. to only turn off the first LED use 0x01 (0b0000 0001)
 */
EN_LED_ERROR_t LED_array_off(EN_DIO_PORT_T ledPort, uint8_t mask);
```

```
/**
 * Toggles a LED Array at given PORT
 * @param ledPort [in] LED Port
 * @param mask [in] (optional, 0 to disable)
 * \n mask to turn off specific LEDs only | e.g. to only turn off the first LED use 0x01 (0b0000 0001)
 */
EN_LED_ERROR_t LED_array_toggle(EN_DIO_PORT_T ledPort, uint8_t mask);
```

```
/**
 * Blinks LED array once at given port
 * @param ledPort [in] LED Port
 * @param ledPin [in] LED Pin number in ledPort
 * @param onTime [in] Time in which LED will be on (milliseconds)
 * @param offTime [in] Time in which LED will be off (milliseconds)
  * @param mask [in] optional, 0 to disable i.e. blinks all LEDs
 * \n mask to blink specific LEDs only | e.g. to only blink the first LED use 0x01 (0b0000 0001)
 */
void LED_array_blink(EN_DIO_PORT_T ledPort, uint16_t onTime, uint16_t offTime, uint8_t mask);
```

Button Driver

Button Macros/Enums:

Type	Name/Value	Desc
typedef enum	typedef enum EN_ButtonError_t { BUTTON_OK, BUTTON_ERROR }EN_ButtonError_t;	**Button Error Types**

Button Functions:

```
/**
 * Initializes port and pin as button
 * @param buttonPort [in] Port to use
 * @param buttonPin [in] Pin number in port
 */
EN_ButtonError_t BUTTON_init(EN_DIO_PORT_T buttonPort, uint8_t buttonPin);
```

```
// Read Button State
/**
 * Reads button state and stores value in buttonState
 * @param buttonPort [in] Port to use
 * @param buttonPin [in] Pin number in port
 * @param buttonState [out] Store Button State (1:High / 0:Low)
 */
EN_ButtonError_t BUTTON_read(EN_DIO_PORT_T buttonPort, uint8_t buttonPin, uint8_t *
buttonState);
```

Timer Driver

Timer Macros/Enums:

Type	Name/Value	Desc

#define(s)	`/* Microcontroller Related Macros */`
	`#define timerNBits 8`
	`#define SystemClockInMhz 1`
	
	`/* Clears mode bits in timer */`
	`#define TimerClearModes() TCCR0 &= 0xB7`
	
	`/* Clears Clock selection bits */`
	`#define TimerClearClockSelection() TCCR0 &= 0xF8`	

typdef enum	`typedef enum EN_TimerMode_t`
	`{`
	`NORMAL = 0xB7,`
	`CTC = 0x08,`
	`FAST_PWM = 0x48,`
	`PWM_PHASE_CORRECT = 0x40`
	`}EN_TimerMode_t;`
		ATmega32 Timer Modes

typedef enum	`typedef enum EN_ClockSelection_t`
	`{`
	`NoClock = 0xF8, // stops clock - no clock is set`
	`NoPrescaling = 0x01, // clock matches internal clock with no prescaling`
	`Prescale8 = 0x02, // prescale clock /8`
	`Prescale64 = 0x03, // prescale clock /64`
	`Prescale256 = 0x04, // prescale clock /256`
	`Prescale1024 = 0x05, // prescale clock /1024`
	
	`/* External Clock on T0 pin with falling edge */`
	`ExternalFallingEdge = 0x06,`
	
	`/* External Clock on T0 pin with rising edge */`
	`ExternalRisingEdge = 0x07,`
	`}EN_ClockSelection_t; // 1 byte`
		ATmega32 Timer/Counter clock selections

typdef enum	`typedef enum EN_timerError_t`
	`{`
	`OK,`
	`Error`
	`}EN_timerError_t;`
		Error return type for timer driver

Timer Functions:

```c
/**
 * Initialize timer-0 with given operating mode
 *  and automatically calculates init start value and overflow count to achieve the
 *  desiredDelayMs (ms)
 * @param operatingMode one of (Normal, CTC, FAST_PWM, PWM_PHASE_CORRECT)
 * @param desiredDelayMs desired delay in milliseconds
 */
EN_timerError_t timer_init(EN_TimerMode_t operatingMode);
```

```c
/**
 * blocks for a given delay time before returning
 * @param desiredDelay [in] (ms) delay to wait for - Range 2ms upto 60 seconds, sensitivity ~1.2 ms
 * @return Error if any
 */
void timer_delay(uint16_t desiredDelay);
```

```c
/**
 * sets given Prescaler for timer0
 * @param enClockPrescaleSelection [in] prescaler enum
 * @return
 */
static EN_timerError_t timer_start(EN_ClockSelection_t enClockPrescaleSelection);
```

```c
/*
*//**
 * Manually set initial timer start value
 * @param timerInitValue [in] value (0 -> 255)
 */
static void timer_setTimerValue(uint8_t timerInitValue);
```

```c
/**
 * Resets the timer
 */
void timer_reset();
```

Application

Application Includes:

```
#include "../ECUAL/LED Driver/led.h"
#include "../ECUAL/Button Driver/button.h"
#include "../MCAL/EXI Driver/interrupts.h"
```

Application Functions:

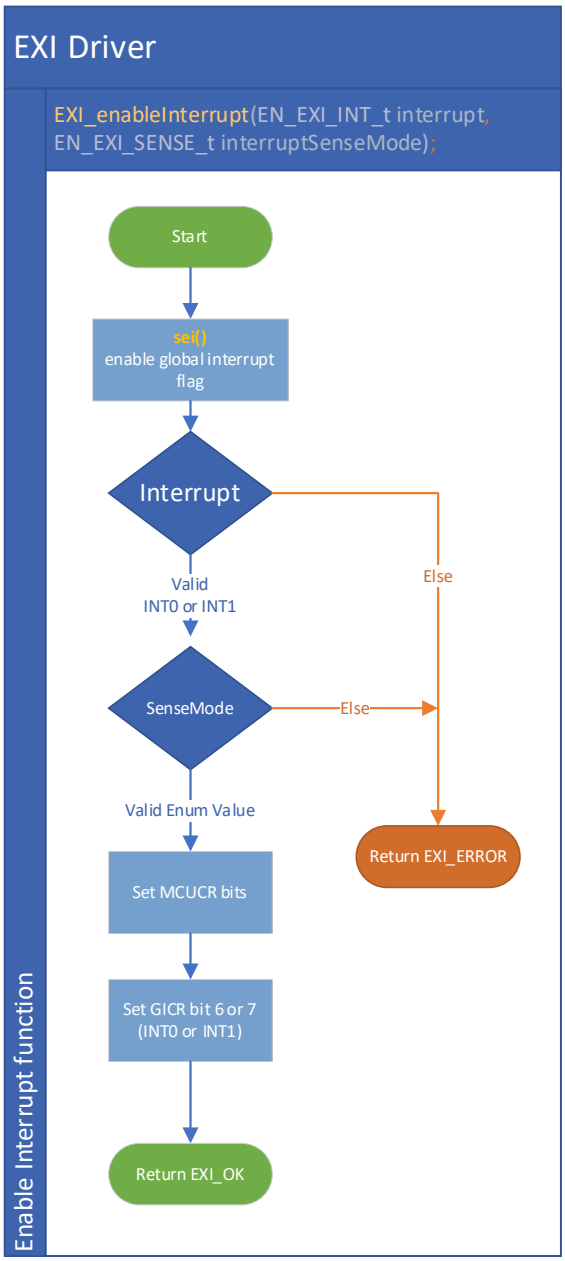
```
/// Application initialization
void App_init();
```

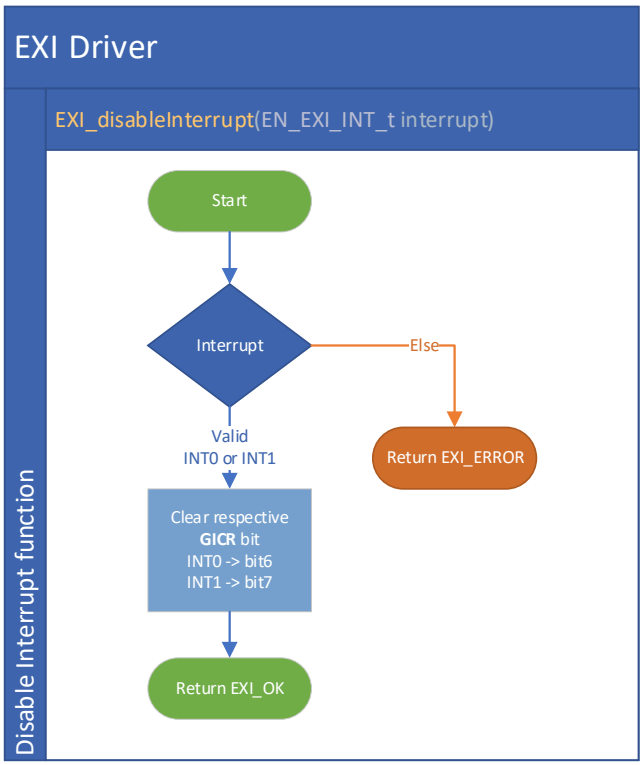
```
/// Start Application routine
void App_Start();
```

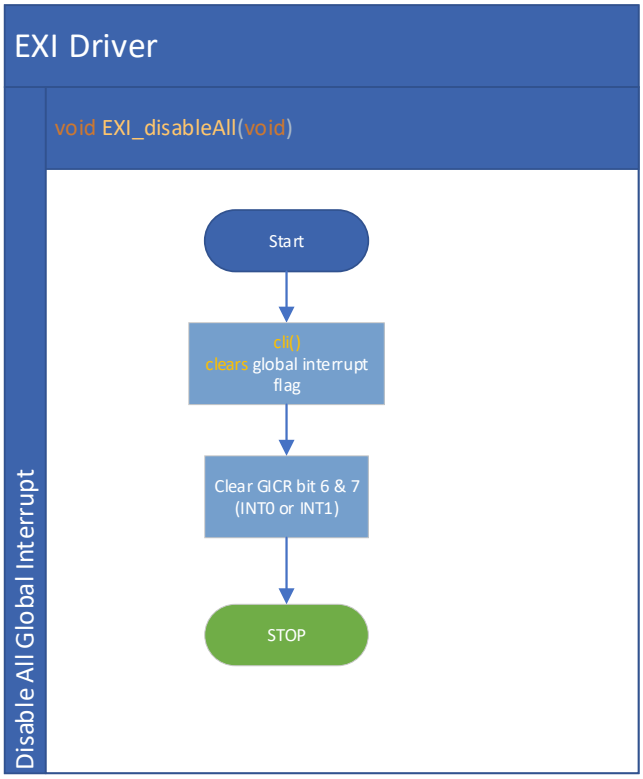
Project Tree

```
D:.
    .gitignore
    main.c
    main.h
    README.md

---Application
        application.c
        application.h

---Common
        bit_manipulation.h
        types.h

---Docs
    ---Visio Diagrams
                *.visio
    ---LED Sequence V3.0 - Design.pdf

---ECUAL
    ---Button Driver
            button.c
            button.h

    ---LED Driver
            led.c
            led.h

---MCAL
    |   registers.h
    |
    ---DIO Driver
    |       dio.c
    |       dio.h
    |
    ---Timer Driver
    |       timer.c
    |       timer.h
    |
    ---EXI Driver
            interrupts.c
            interrupts.h

---Proteus
        Proteus_LED_Sequence_V3.0.pdsprj
```

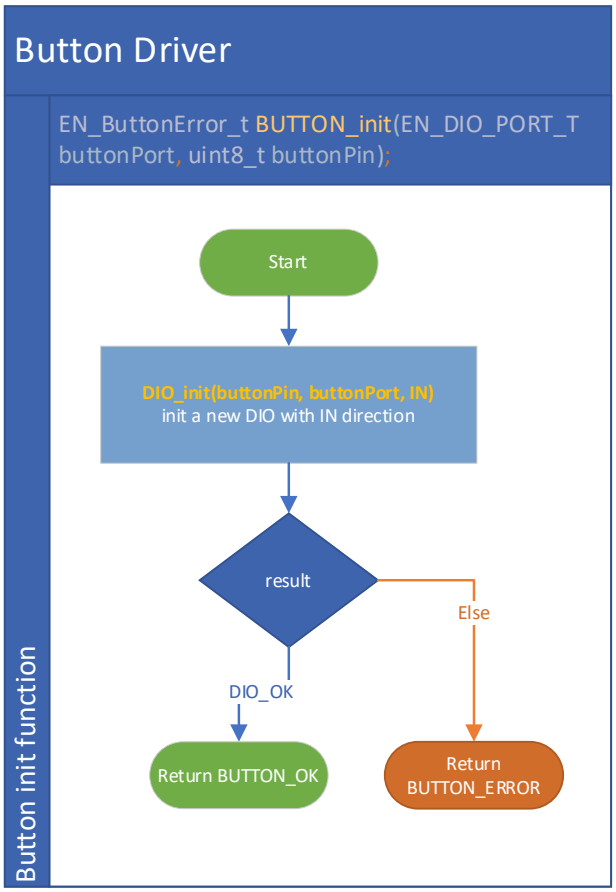
EXI Flowcharts

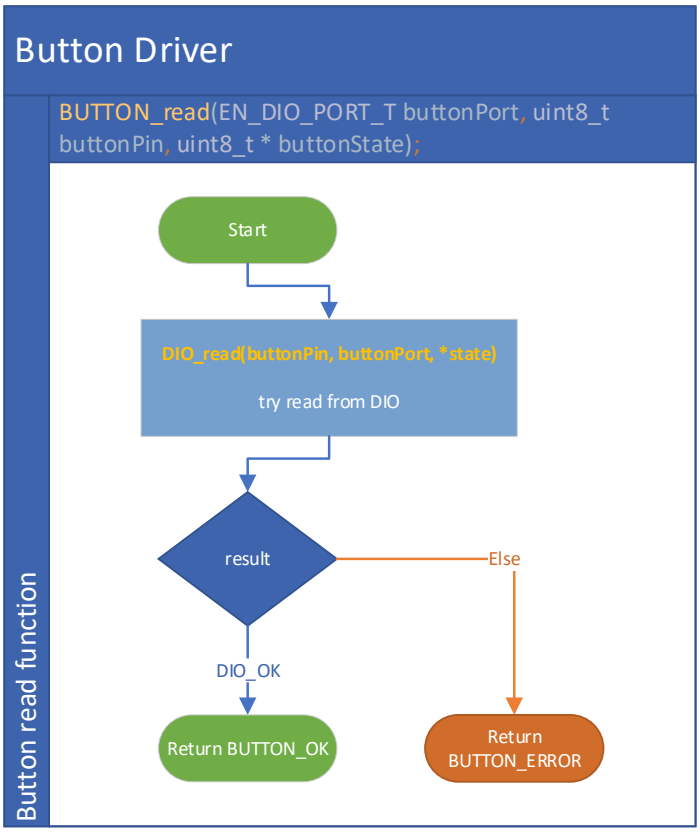




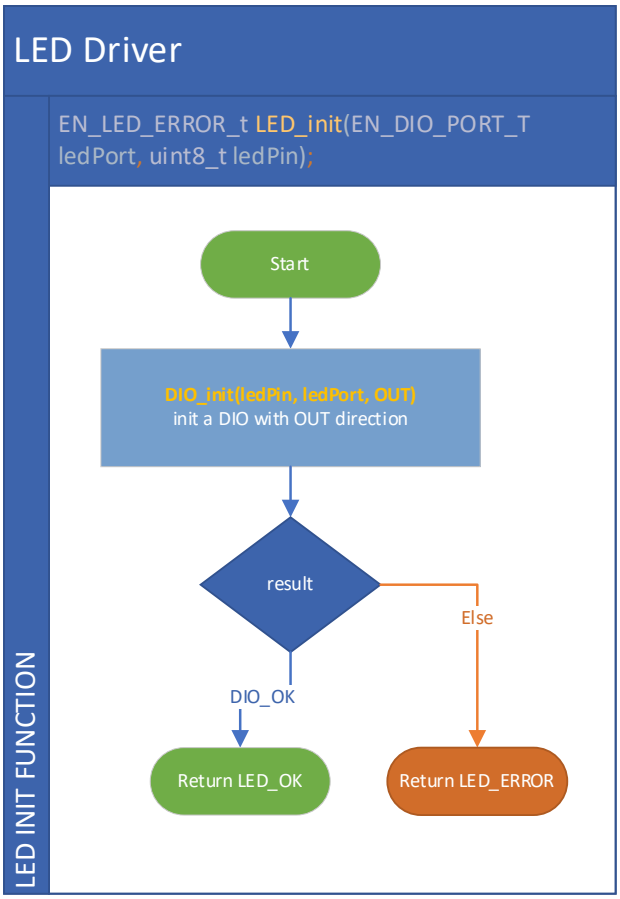


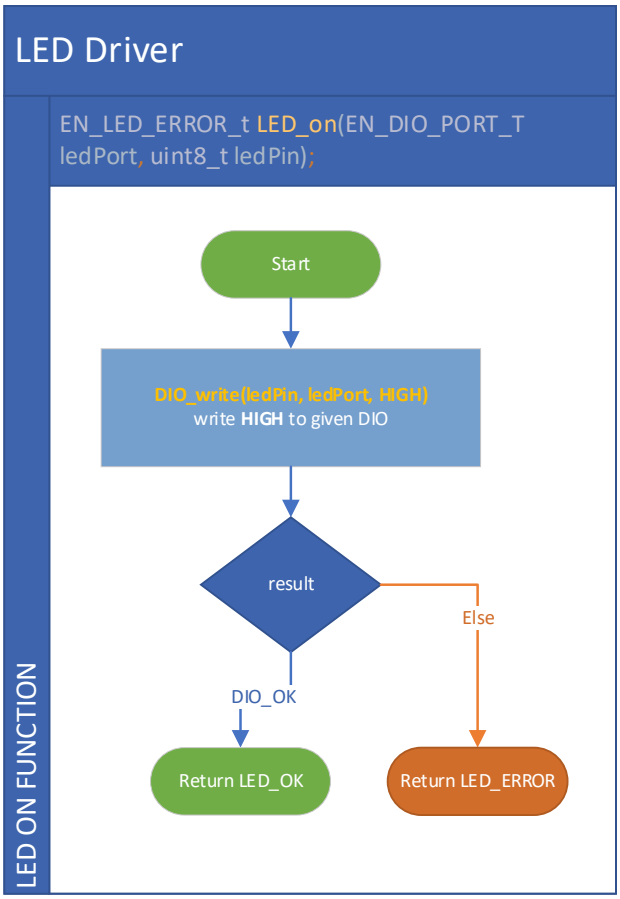
Button API Flowcharts

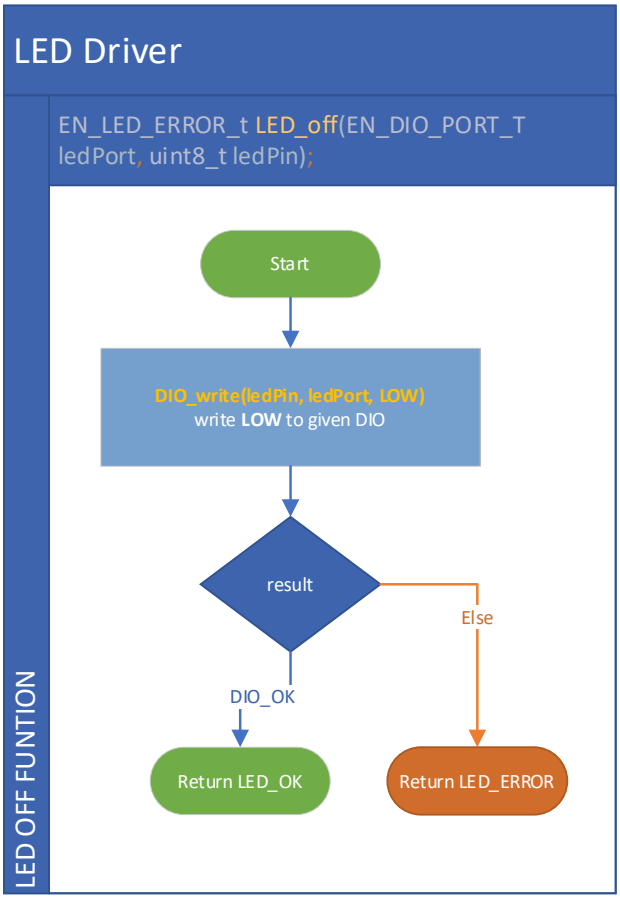


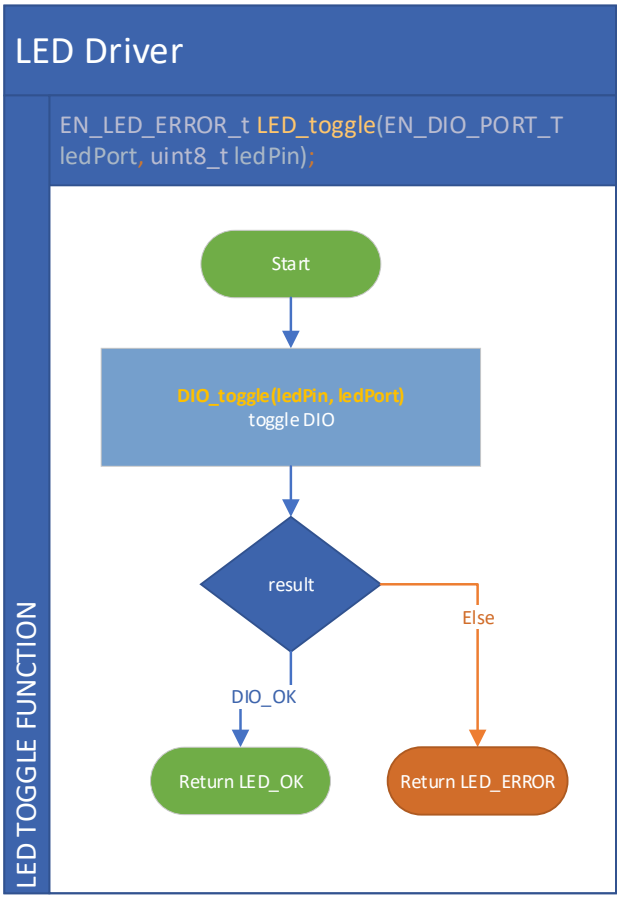


LED API Flowcharts





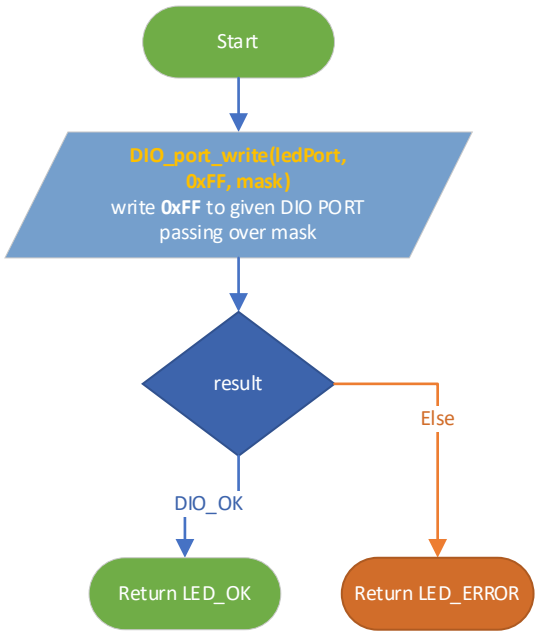




LED Driver

EN_LED_ERROR_t LED_array_on(EN_DIO_PORT_T ledPort, uint8_t mask)

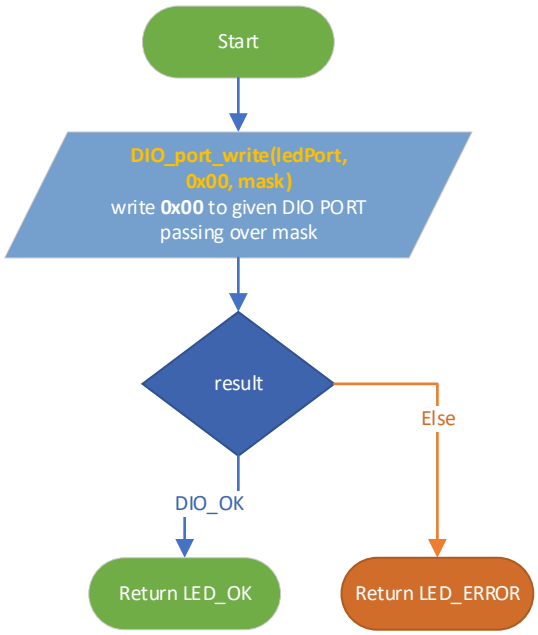
Led Array ON Function



LED Driver

EN_LED_ERROR_t LED_array_off(EN_DIO_PORT_T ledPort, uint8_t mask)

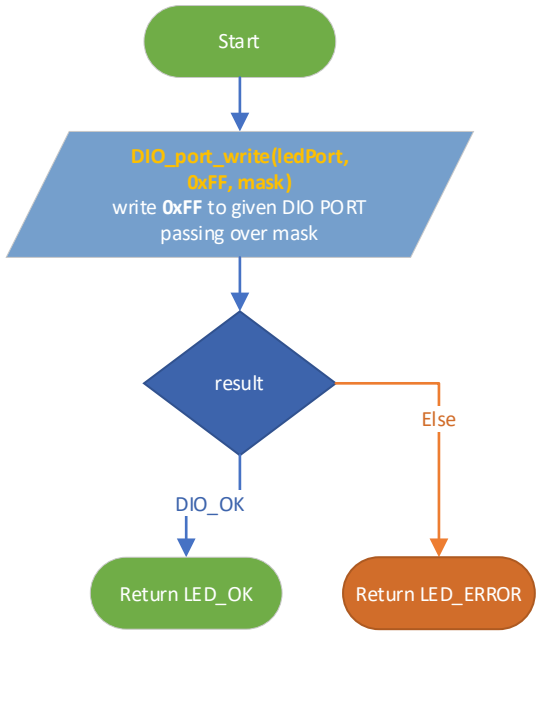
Led Array OFF Function



LED Driver

EN_LED_ERROR_t LED_array_toggle(EN_DIO_PORT_T ledPort, uint8_t mask)

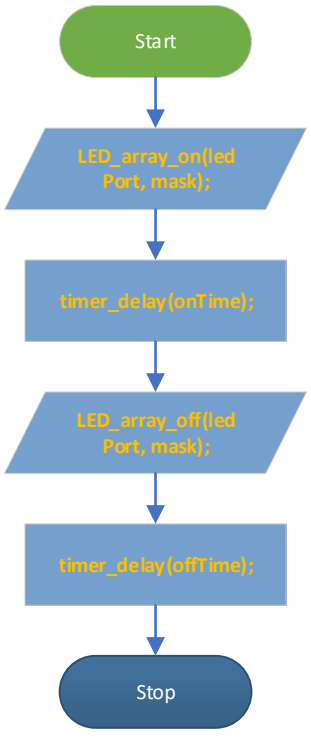
LED Array Toggle Function



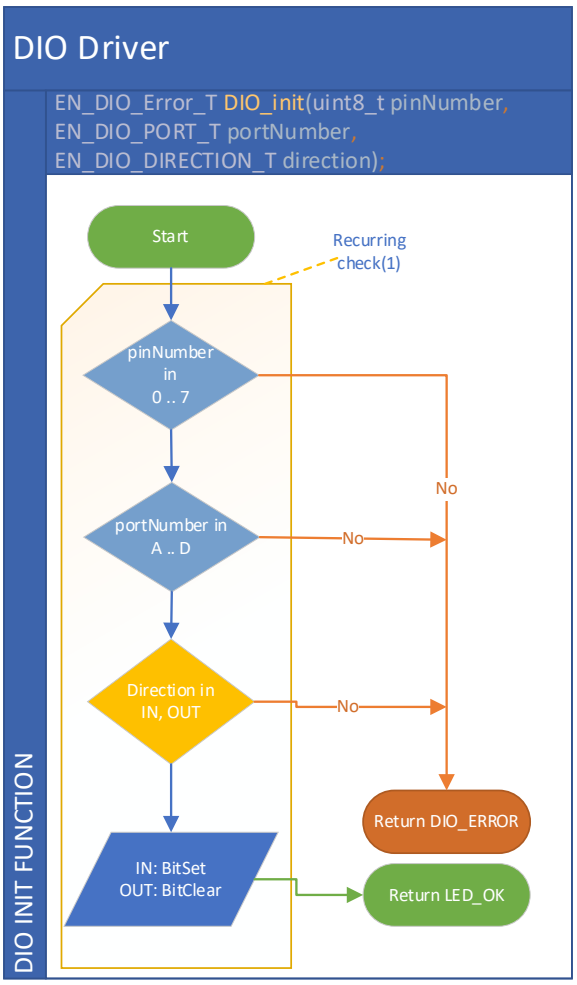
LED Driver

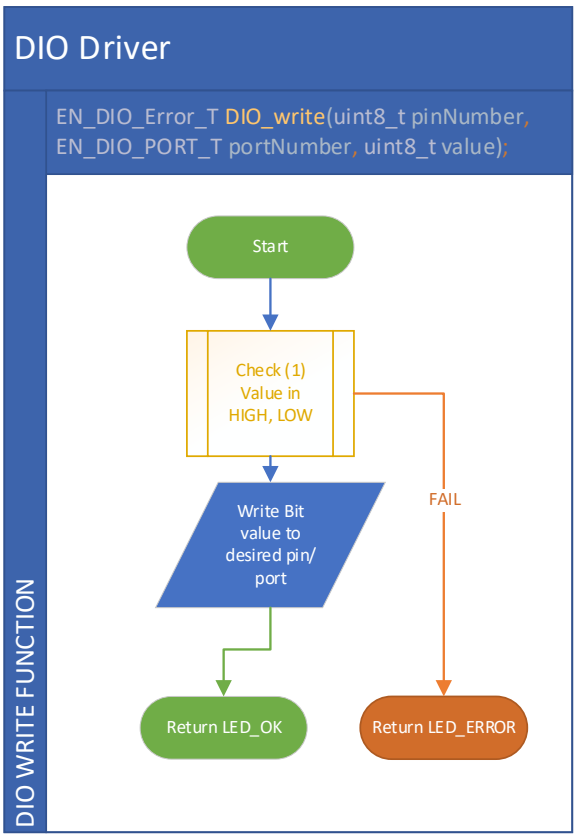
void LED_array_blink(EN_DIO_PORT_T ledPort, uint16_t onTime, uint16_t offTime, uint8_t mask)

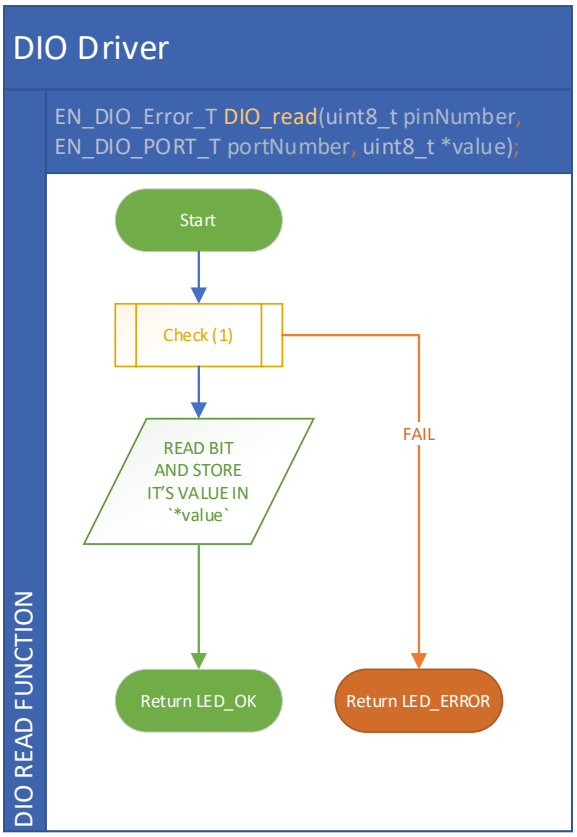
LED Array Toggle Function

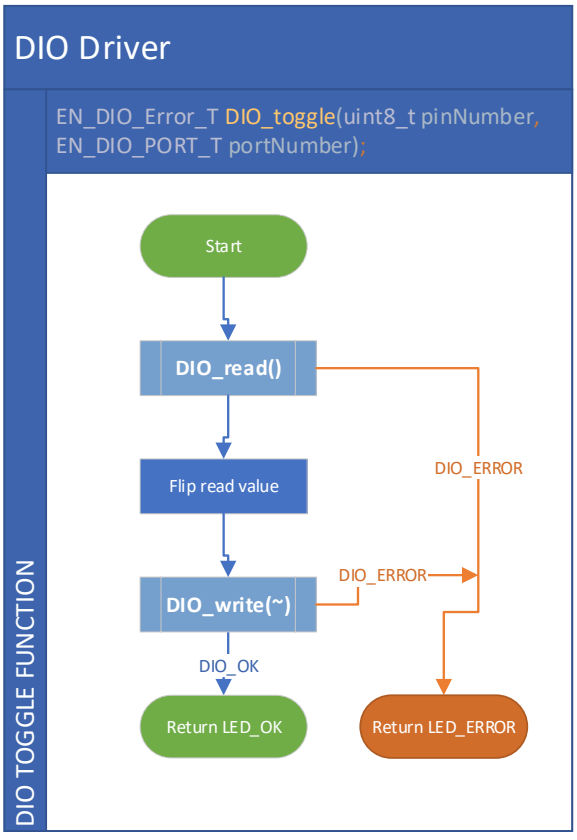


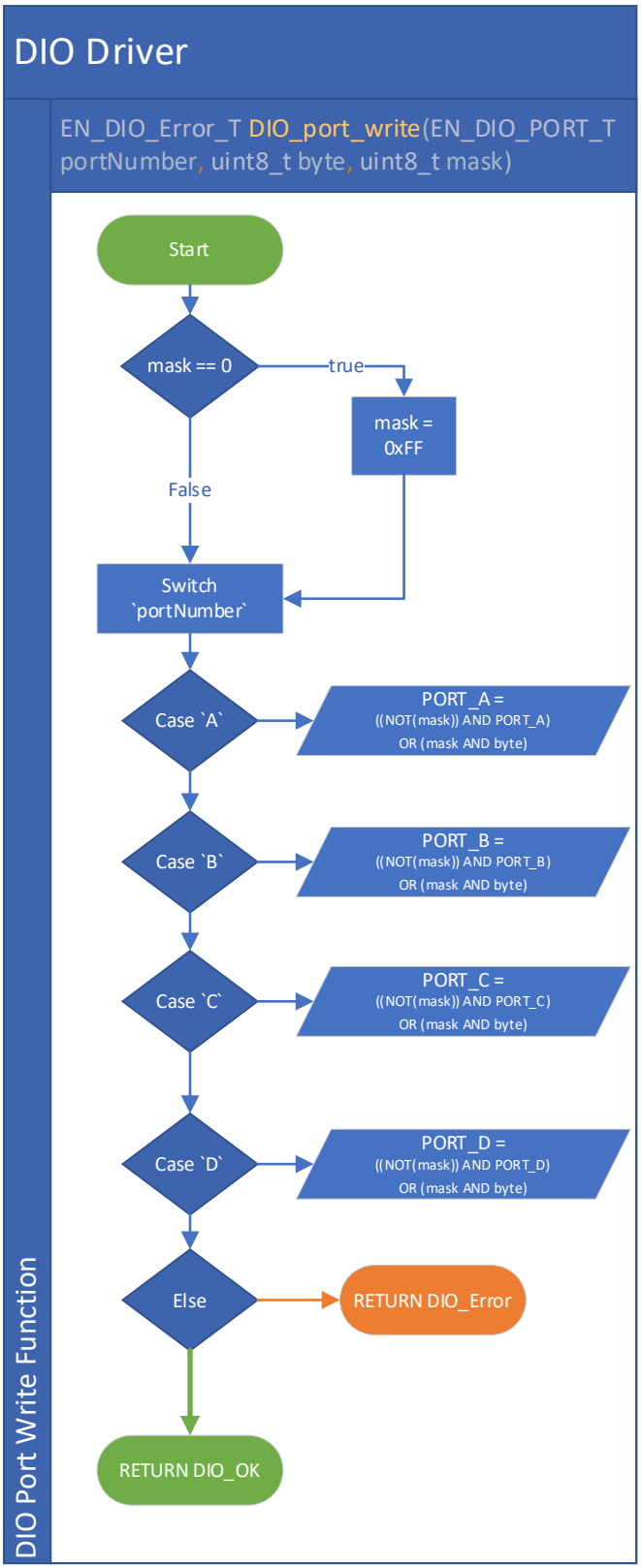
DIO API Flowcharts

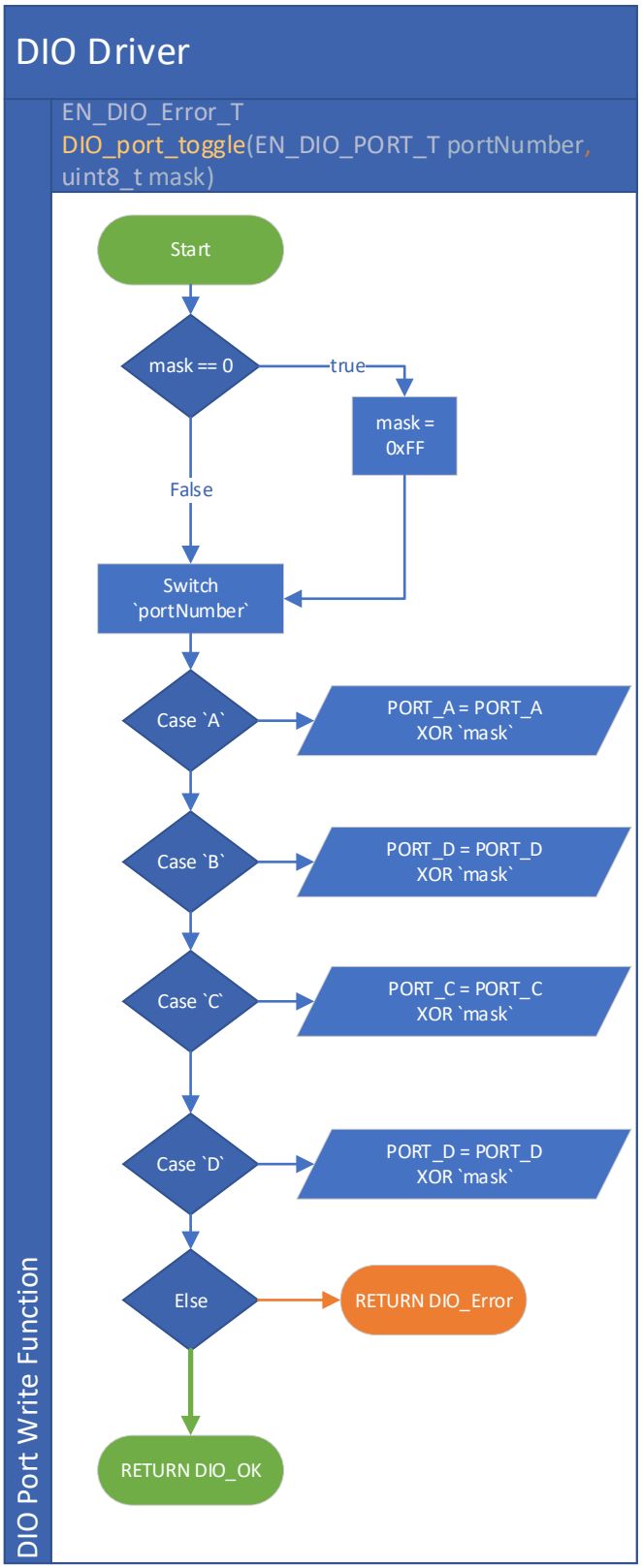




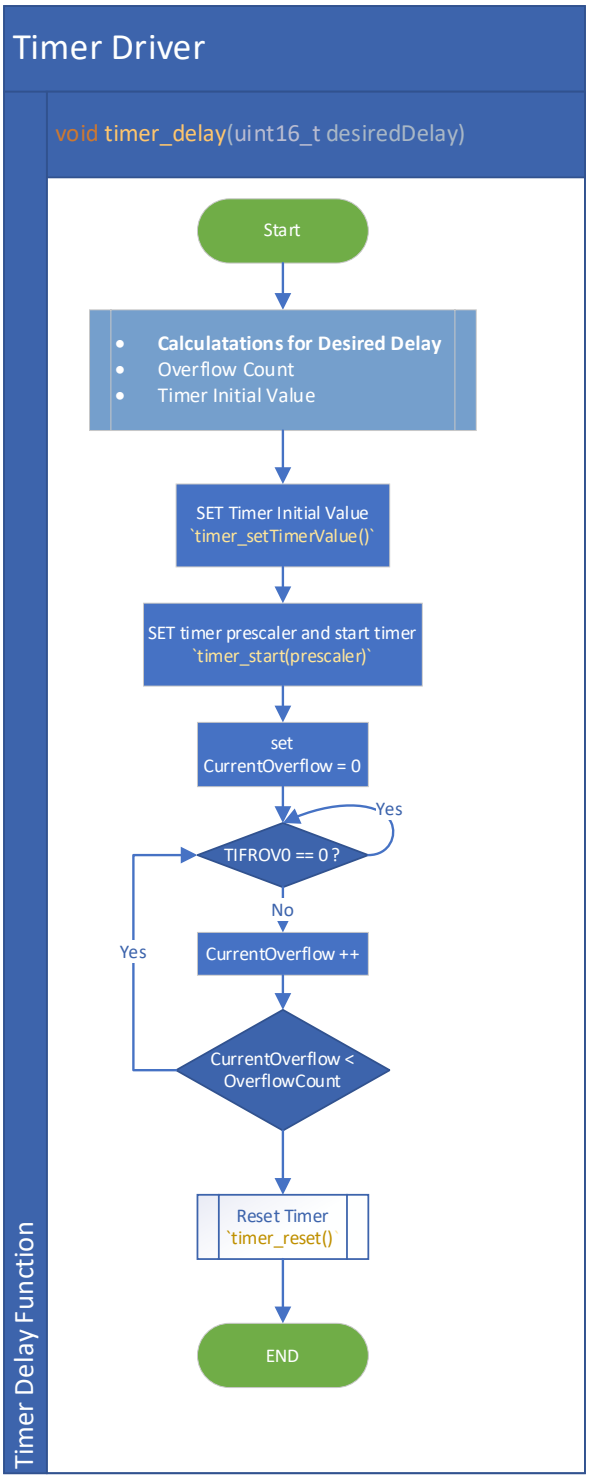


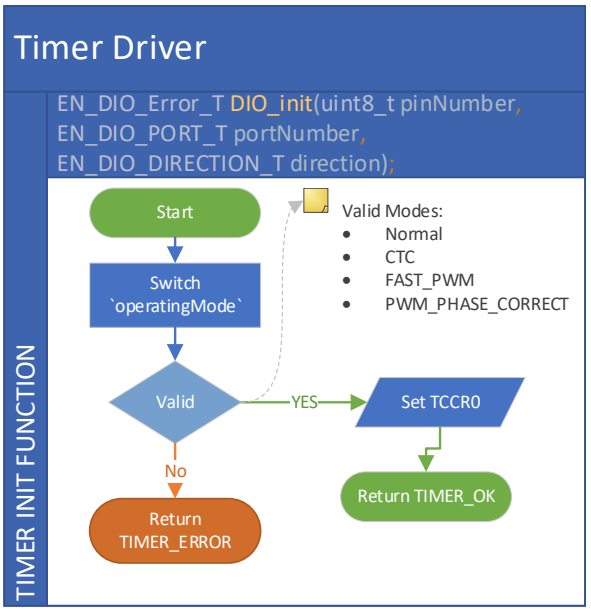


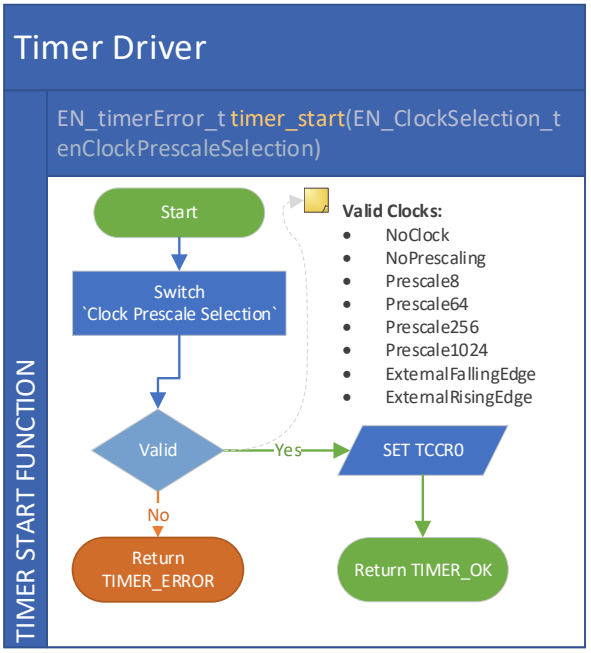

DIO Driver
EN_DIO_Error_T DIO_port_write(EN_DIO_PORT_T portNumber, uint8_t byte, uint8_t mask)
DIO Port Write Function
Start
mask == 0
true
mask = 0xFF
False
Switch `portNumber`
Case `A`
PORT_A = ((NOT(mask)) AND PORT_A) OR (mask AND byte)
Case `B`
PORT_B = ((NOT(mask)) AND PORT_B) OR (mask AND byte)
Case `C`
PORT_C = ((NOT(mask)) AND PORT_C) OR (mask AND byte)
Case `D`
PORT_D = ((NOT(mask)) AND PORT_D) OR (mask AND byte)
Else
RETURN DIO_Error
RETURN DIO_OK

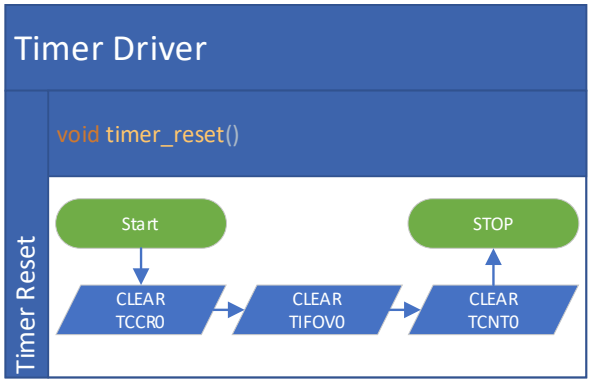

DIO Driver
EN_DIO_Error_T DIO_port_toggle(EN_DIO_PORT_T portNumber, uint8_t mask)
DIO Port Write Function
Start
mask == 0
true
mask = 0xFF
False
Switch `portNumber`
Case `A`
PORT_A = PORT_A XOR `mask`
Case `B`
PORT_D = PORT_D XOR `mask`
Case `C`
PORT_C = PORT_C XOR `mask`
Case `D`
PORT_D = PORT_D XOR `mask`
Else
RETURN DIO_Error
RETURN DIO_OK

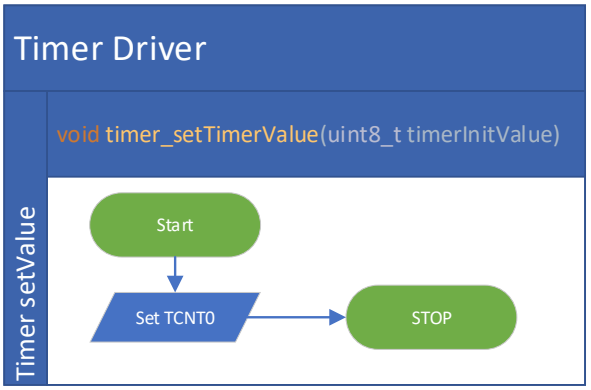
Timer API Flowcharts











Application API Flowcharts

Application

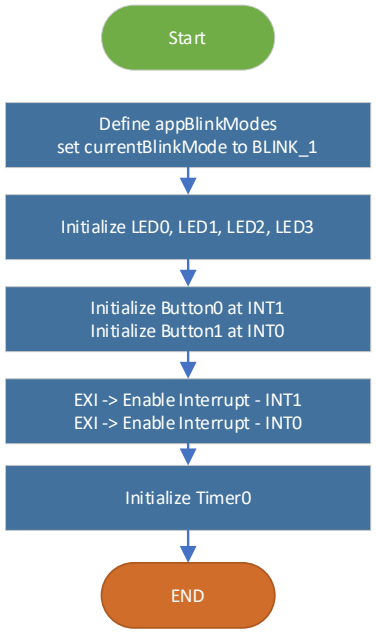
Globals

```
/* LEDs */
#define LED_0_PORT C
#define LED_0_PIN 0
#define LED_1_PORT C
#define LED_1_PIN 1
#define LED_2_PORT C
#define LED_2_PIN 2
#define LED_3_PORT C
#define LED_3_PIN 3

/* Buttons */
#define BUTTON_0_port D
#define BUTTON_0_PIN 3   // INT0
#define BUTTON_1_port D
#define BUTTON_1_PIN 2   // INT1

/* Magic Numbers */
#define NUMBER_OF_LED_STATES 7

/* Global Variables */
uint8_t state_number = 0;
uint8_t current_blink_mode_index = 1;

/* App Blink Modes */
ST_APP_BLINK_MODES_t appBlinkModes;
ST_APP_BLINK_MODE_t
currentBlinkMode;
```

Globals

Application

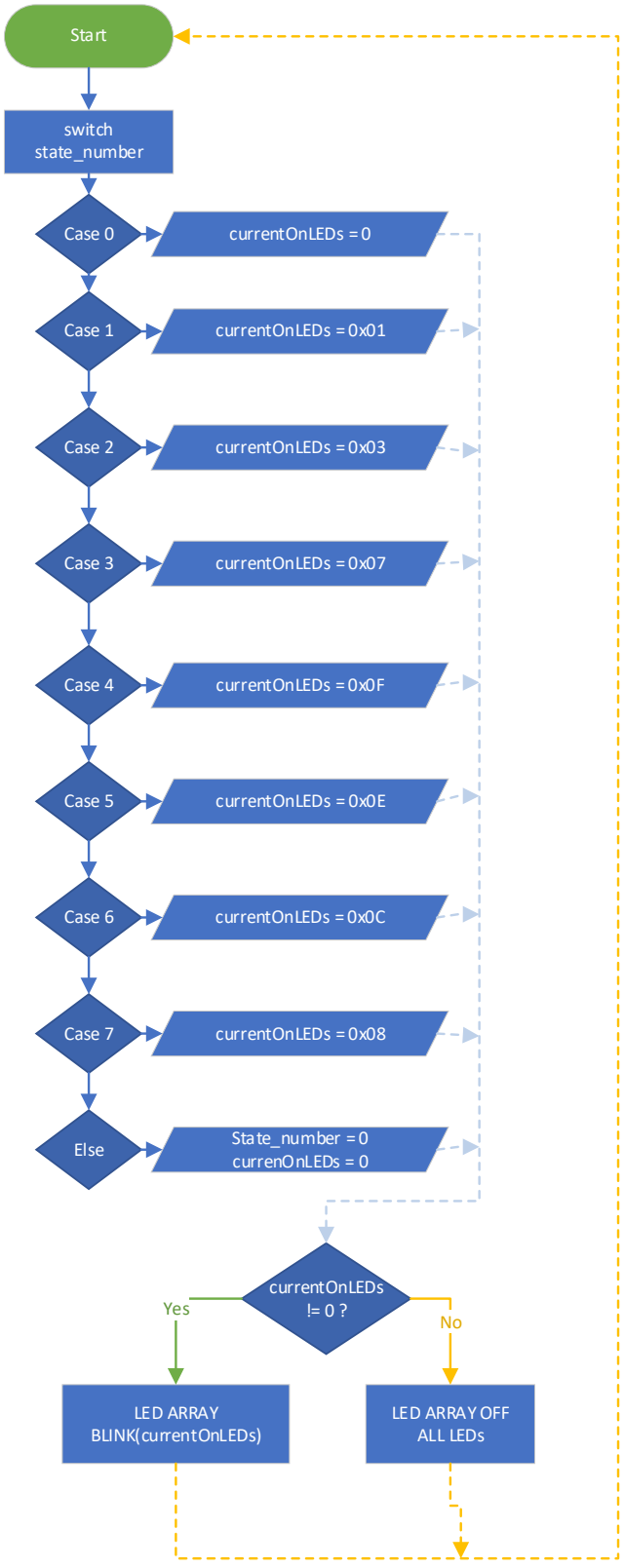
void App_init();



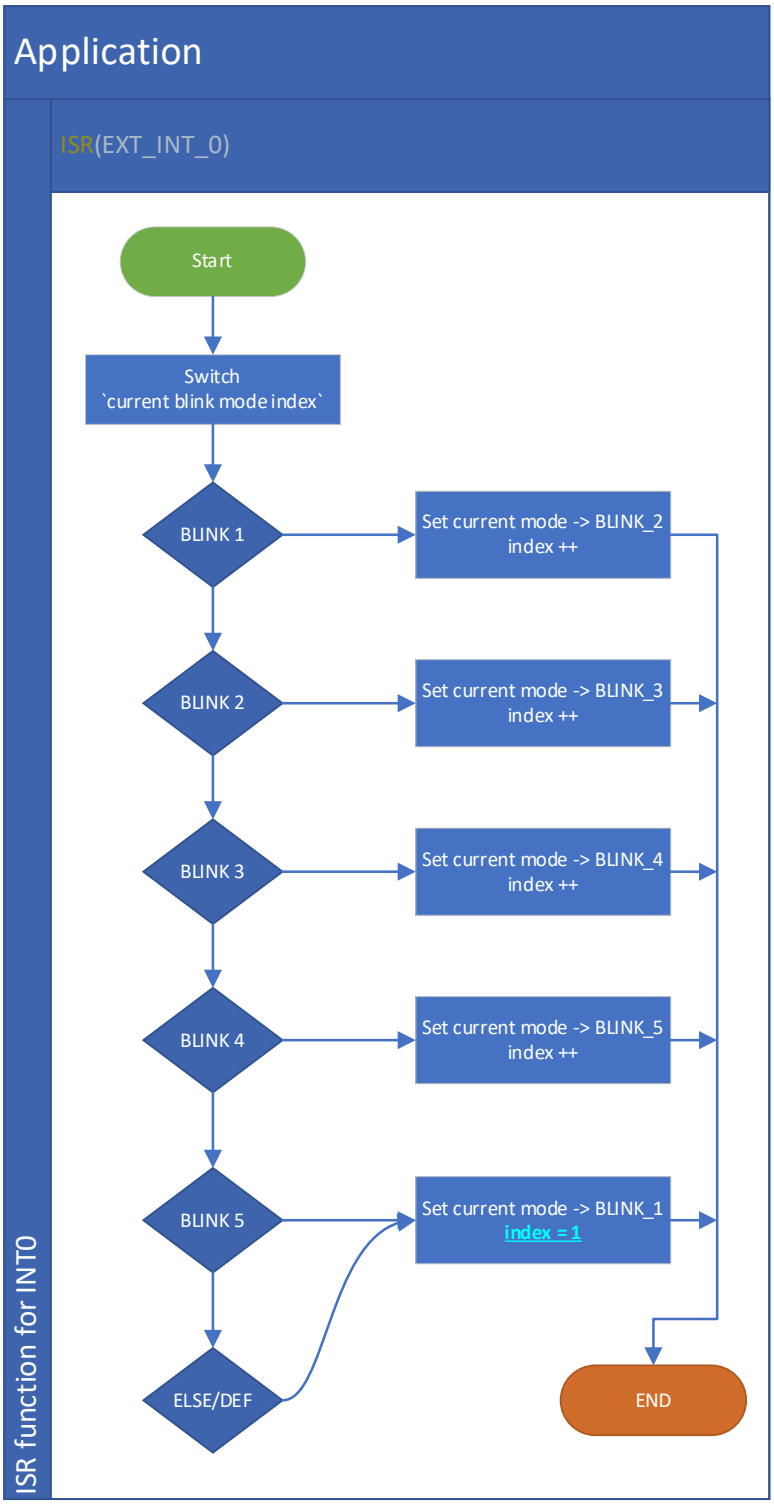
Application init function

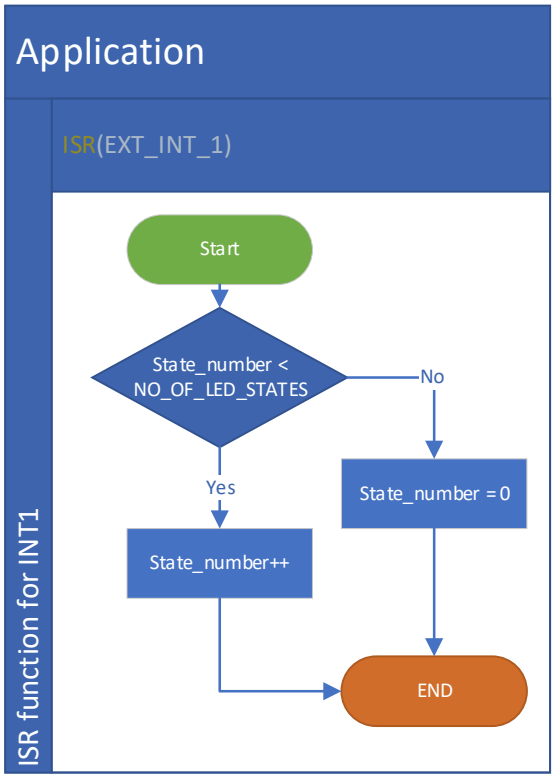
Application

void App_Start();



Application Start Function


Application
ISR(EXT_INT_0)
Start
Switch
`current blink mode index`
BLINK 1
Set current mode -> BLINK_2
index ++
BLINK 2
Set current mode -> BLINK_3
index ++
BLINK 3
Set current mode -> BLINK_4
index ++
BLINK 4
Set current mode -> BLINK_5
index ++
BLINK 5
Set current mode -> BLINK_1
index = 1
ELSE/DEF
END
ISR function for INT0


Application
ISR(EXT_INT_1)
Start
State_number <
NO_OF_LED_STATES
No
Yes
State_number = 0
State_number++
END
ISR function for INT1