

LED Sequence V3.0

HOSSAM ELWAHSH
EMBEDDED SYSTEMS - LEVEL 1

Table of Contents

System Requirements Specifications	2
Brief	2
Hardware Requirements.....	2
Software Requirements	2
System Design	3
State Machine Diagram.....	3
Layered Architecture	4
Project Modules APIs	5
DIO Driver	5
EXI (External Interrupt) Driver	7
LED Driver	8
Button Driver	10
Timer Driver	11
Application.....	13
Project Tree	13
Project Modules APIs Charts.....	14
EXI Flowcharts	14
Button API Flowcharts	15
LED API Flowcharts.....	16
DIO API Flowcharts	18
Timer API Flowcharts.....	20
Application API Flowcharts	21

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

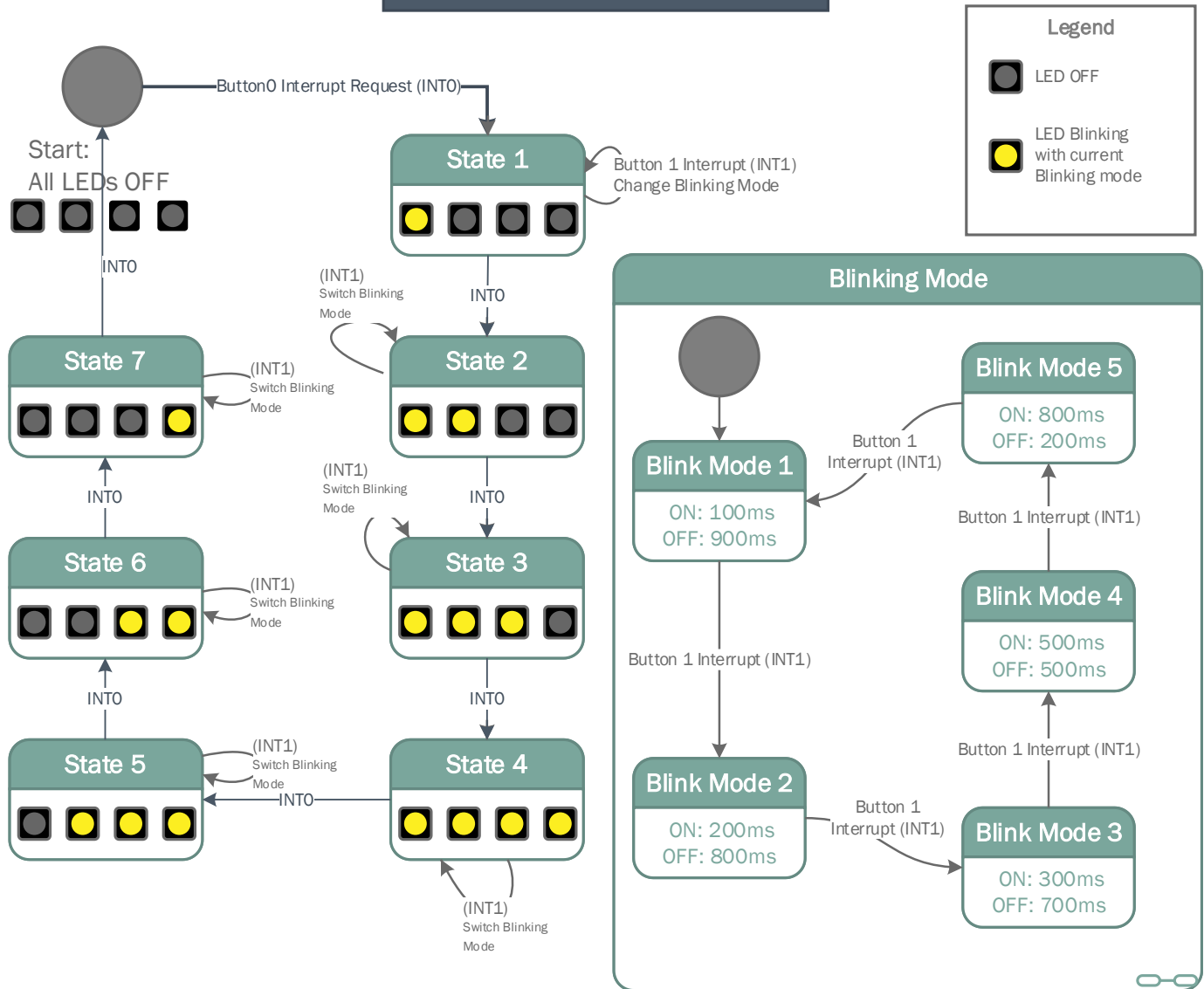
1. Initially, all LEDs are OFF
2. Once **BUTTON0** is pressed, **LED0** will blink with **BLINK_1** mode
3. Each press further will make another LED blinks **BLINK_1** mode
4. At the **fifth press**, **LED0** will be changed to be **OFF**
5. Each **press further** will make only one LED is **OFF**
6. 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

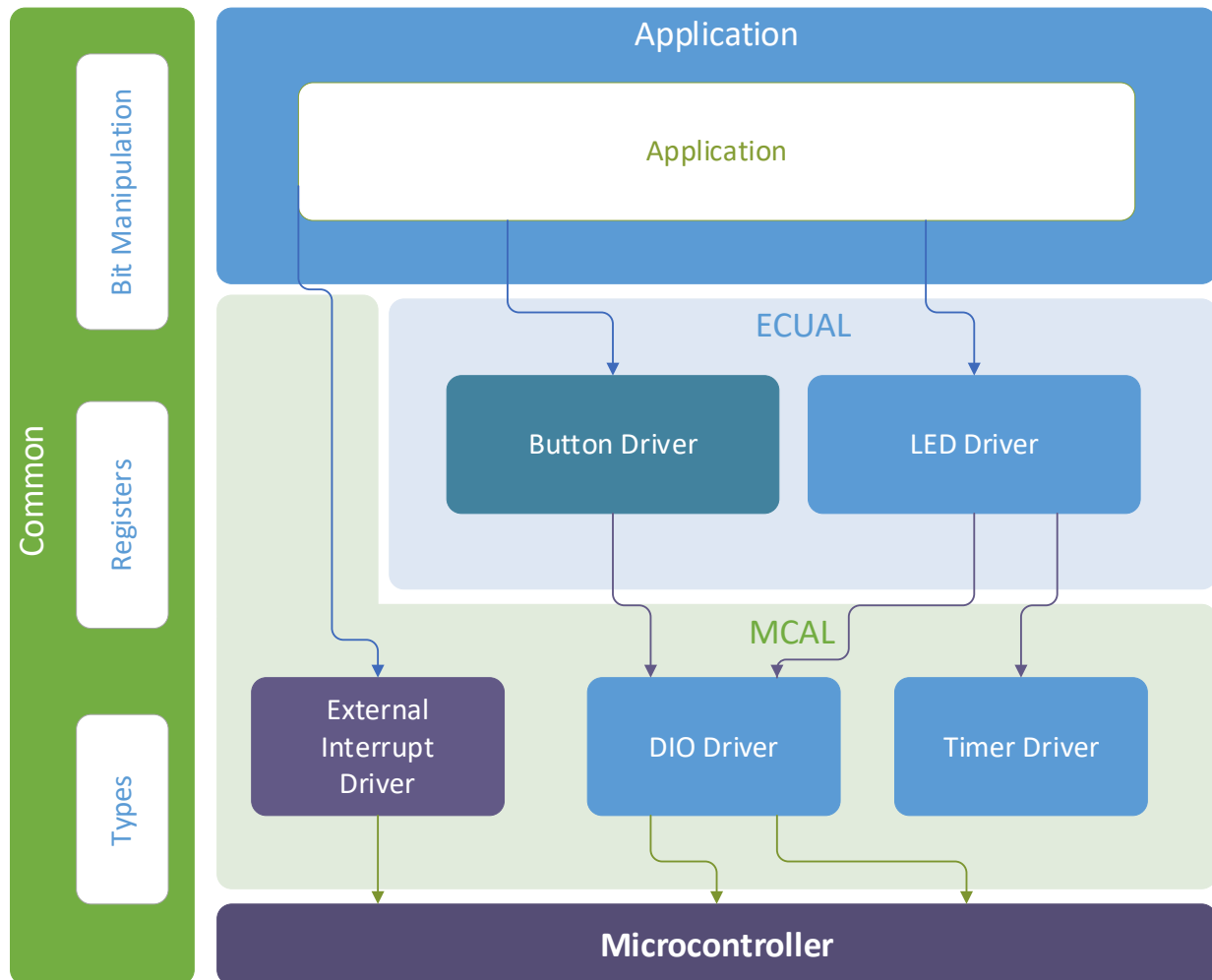
State Machine Diagram

Software used: Microsoft Visio

LED Sequence V3.0 State-Machine Diagram



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	<ul style="list-style-type: none">A, B, C, D	Defines available DIO ports
typedef enum	EN_DIO_DIRECTION_T	<ul style="list-style-type: none">In = 0Out = 1	Defines DIO pin direction
typedef enum	EN_DIO_Error_T	<ul style="list-style-type: none">DIO_OKDIO_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);
```

```
/**
 * 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);
```

```
/**
 * 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);
```

```
/**
 * 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));\nvoid INT_VECT(void)	ISR definition
typedef enum	typedef enum EN_EXI_INT_t {\n INT0, INT1\n} EN_EXI_INT_t;	Defines Interrupt port names
typedef enum	typedef enum EN_EXI_SENSE_t {\n // Interrupts on Low Level\n LOW_LEVEL = 0xFC,\n // Interrupts on any logical change\n ANY_LEVEL = 0x01,\n // Interrupts on Falling edge\n FALLING_EDGE = 0x02,\n // Interrupts on Rising edge\n RISING_EDGE = 0x03\n} EN_EXI_SENSE_t;	Enum for ATmega32 interrupt sense modes
typedef enum	typedef enum EN_EXI_ERROR_t {\n EXI_OK,\n EXI_ERROR\n} 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	<pre>typedef enum EN_LED_ERROR_t { LED_OK, LED_ERROR }EN_LED_ERROR_t;</pre>	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
<code>typedef enum</code>	<pre>typedef enum EN_ButtonError_t { BUTTON_OK, BUTTON_ERROR }EN_ButtonError_t;</pre>	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)	<pre>/* 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</pre>	
typedef enum	<pre>typedef enum EN_TimerMode_t { NORMAL = 0xB7, CTC = 0x08, FAST_PWM = 0x48, PWM_PHASE_CORRECT = 0x40 }EN_TimerMode_t;</pre>	ATmega32 Timer Modes
typedef enum	<pre>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</pre>	ATmega32 Timer/Counter clock selections
typedef enum	<pre>typedef enum EN_timerError_t { OK, Error }EN_timerError_t;</pre>	Error return type for timer driver

Timer Functions:

```
/**
 * 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);

/**
 * 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);

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

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

/**
 * 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();
```

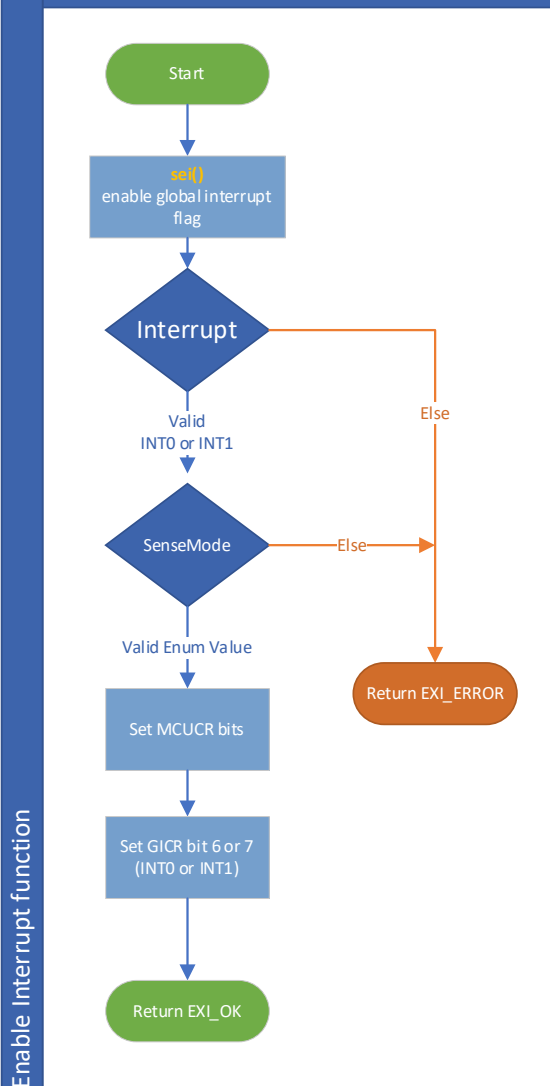
Project Tree

```
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

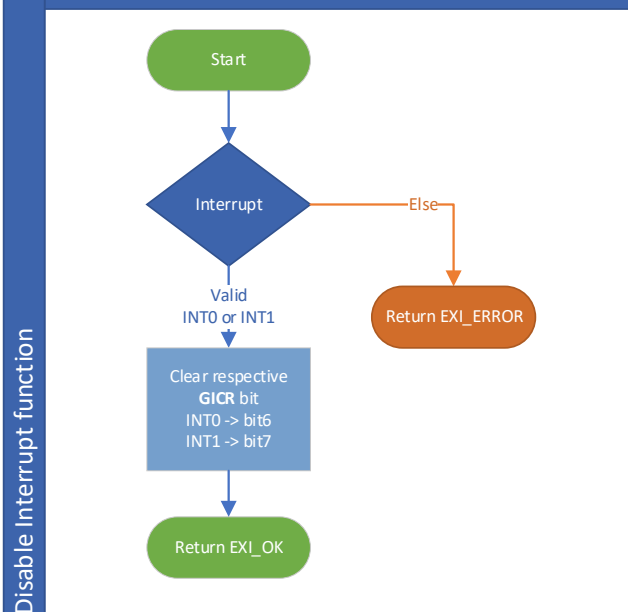
EXI Driver

`EXI_enableInterrupt(EN_EXI_INT_t interrupt, EN_EXI_SENSE_t interruptSenseMode);`



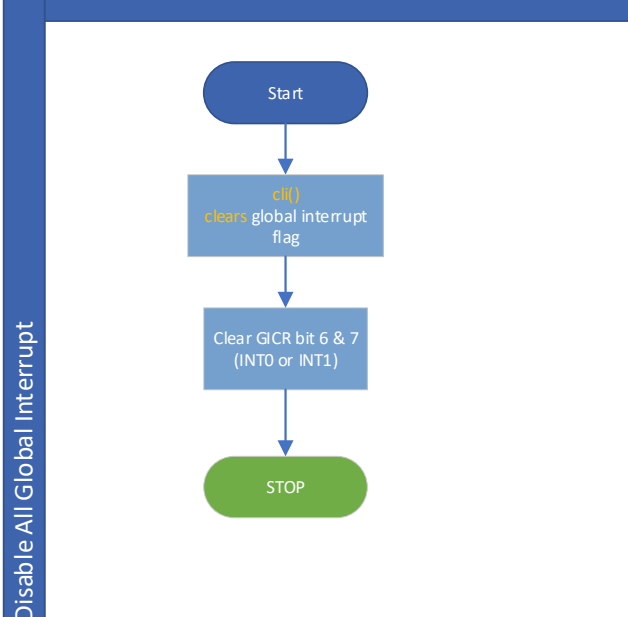
EXI Driver

`EXI_disableInterrupt(EN_EXI_INT_t interrupt)`



EXI Driver

`void EXI_disableAll(void)`

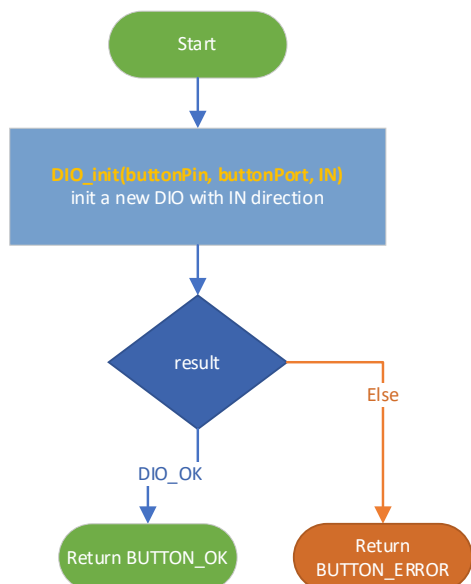


Button API Flowcharts

Button Driver

```
EN_ButtonError_t BUTTON_init(EN_DIO_PORT_T
buttonPort, uint8_t buttonPin);
```

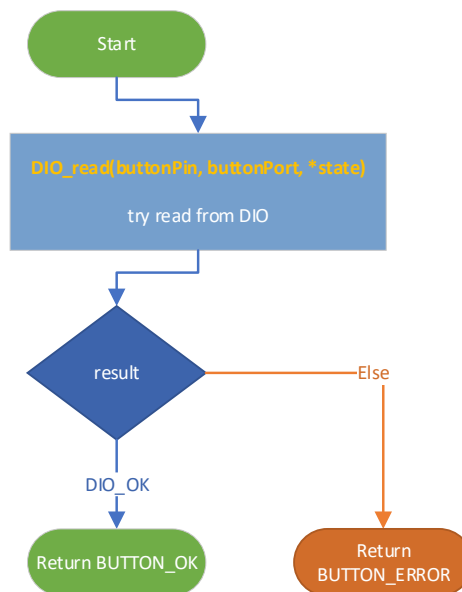
Button init function



Button Driver

```
BUTTON_read(EN_DIO_PORT_T buttonPort, uint8_t
buttonPin, uint8_t * buttonState);
```

Button read function

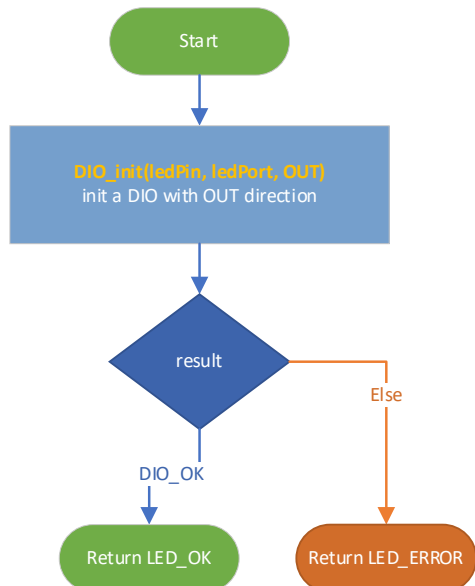


LED API Flowcharts

LED Driver

EN_LED_ERROR_t **LED_init**(EN_DIO_PORT_T ledPort, uint8_t ledPin);

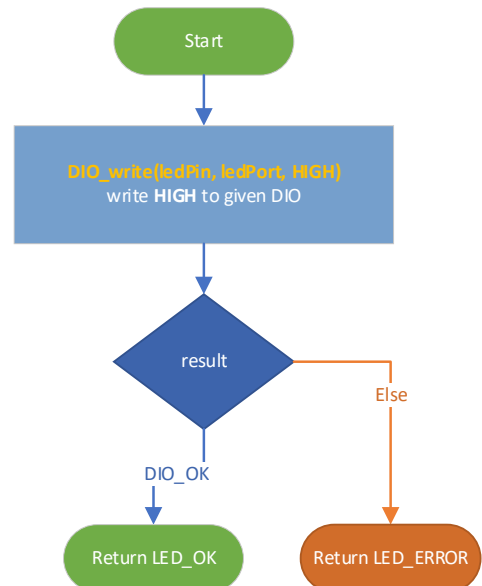
LED INIT FUNCTION



LED Driver

EN_LED_ERROR_t **LED_on**(EN_DIO_PORT_T ledPort, uint8_t ledPin);

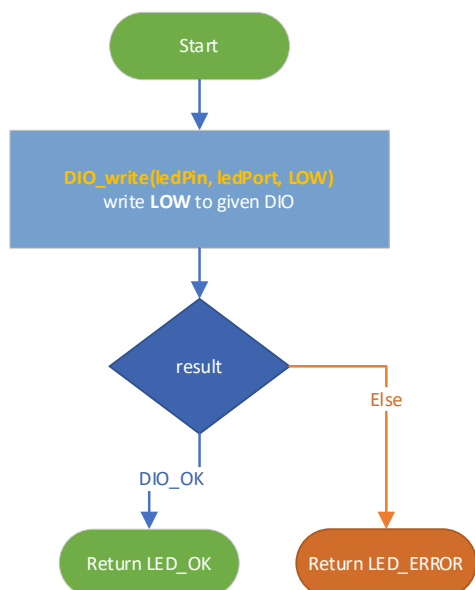
LED ON FUNCTION



LED Driver

EN_LED_ERROR_t **LED_off**(EN_DIO_PORT_T ledPort, uint8_t ledPin);

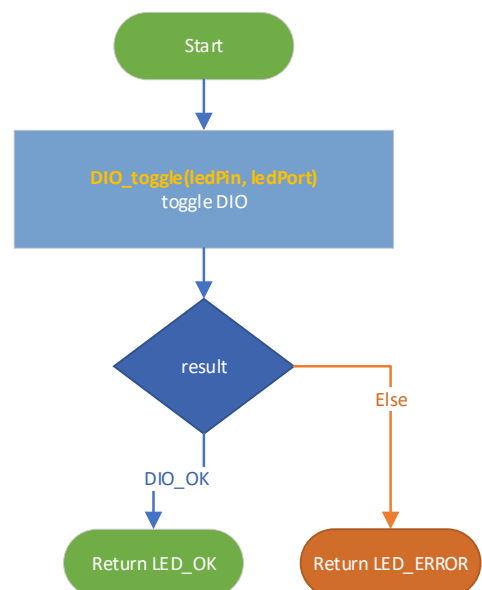
LED OFF FUNCTION



LED Driver

EN_LED_ERROR_t **LED_toggle**(EN_DIO_PORT_T ledPort, uint8_t ledPin);

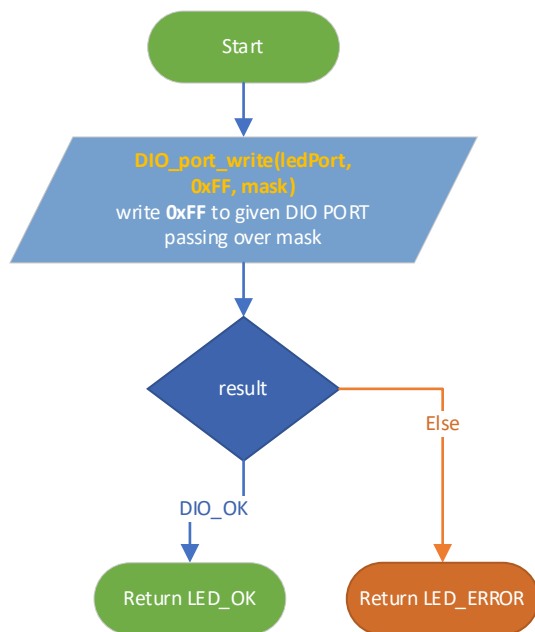
LED TOGGLE FUNCTION



LED Driver

EN_LED_ERROR_t LED_array_on(EN_DIO_PORT_T ledPort, uint8_t mask)

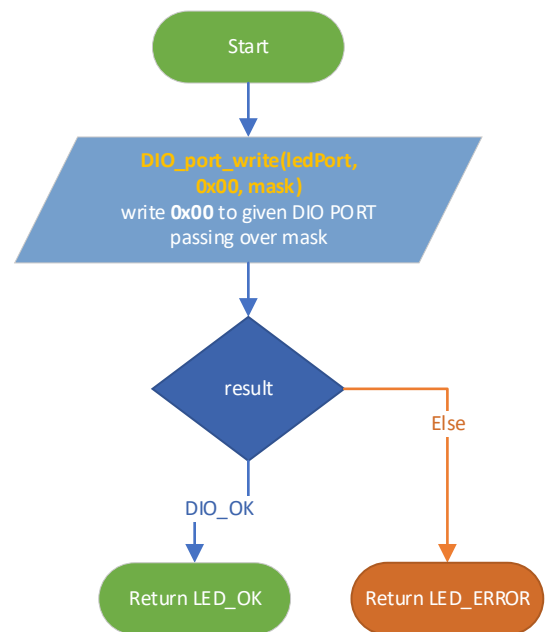
Led Array ON Function



LED Driver

EN_LED_ERROR_t LED_array_off(EN_DIO_PORT_T ledPort, uint8_t mask)

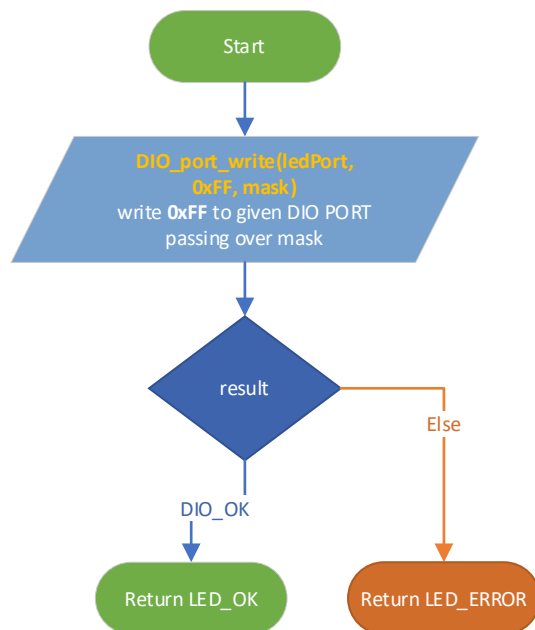
Led Array OFF Function



LED Driver

EN_LED_ERROR_t
LED_array_toggle(EN_DIO_PORT_T ledPort, uint8_t mask)

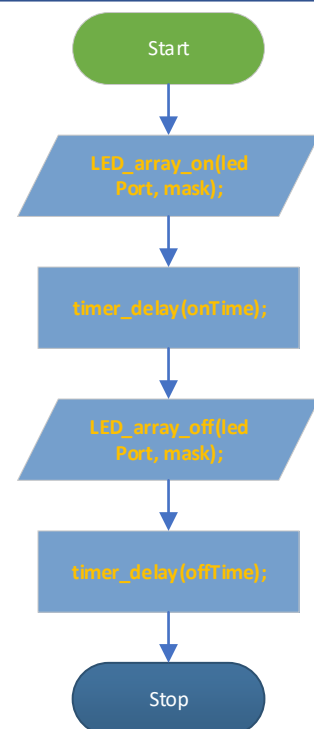
LED Array Toggle Function



LED Driver

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

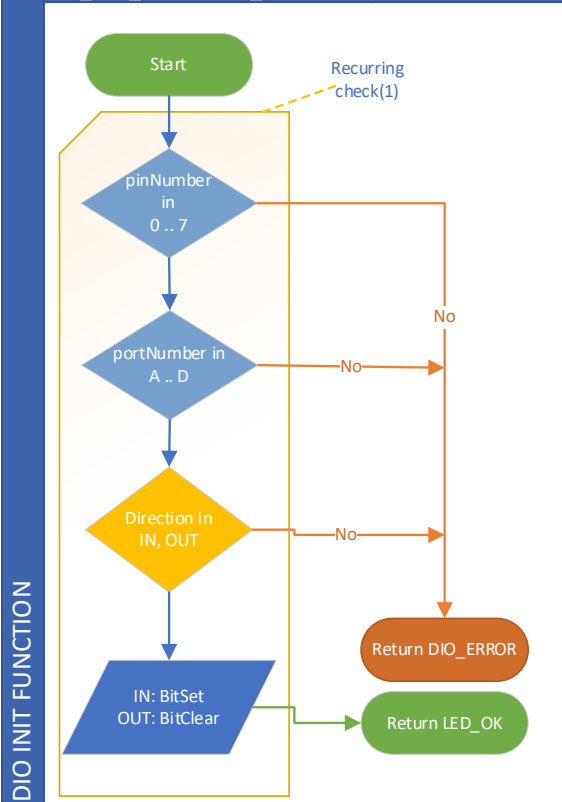
LED Array Toggle Function



DIO API Flowcharts

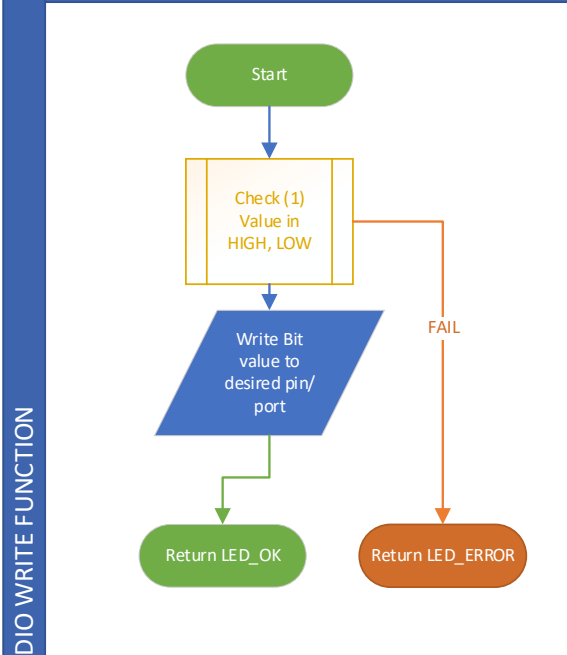
DIO Driver

```
EN_DIO_Error_T DIO_init(uint8_t pinNumber,  
EN_DIO_PORT_T portNumber,  
EN_DIO_DIRECTION_T direction);
```



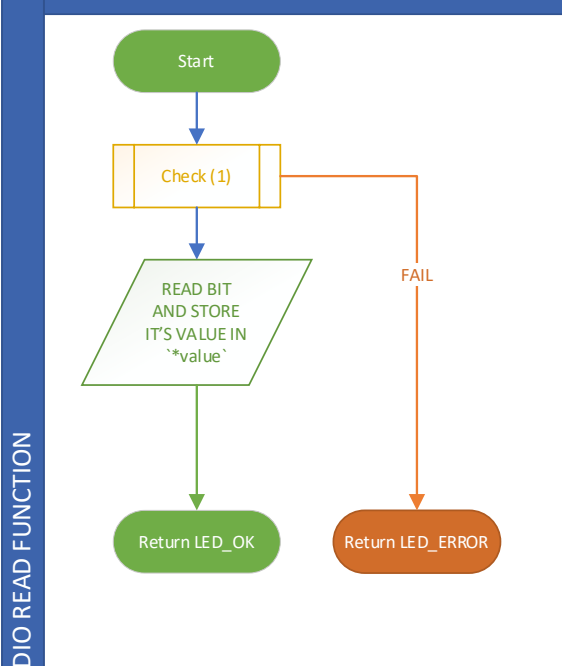
DIO Driver

```
EN_DIO_Error_T DIO_write(uint8_t pinNumber,  
EN_DIO_PORT_T portNumber, uint8_t value);
```



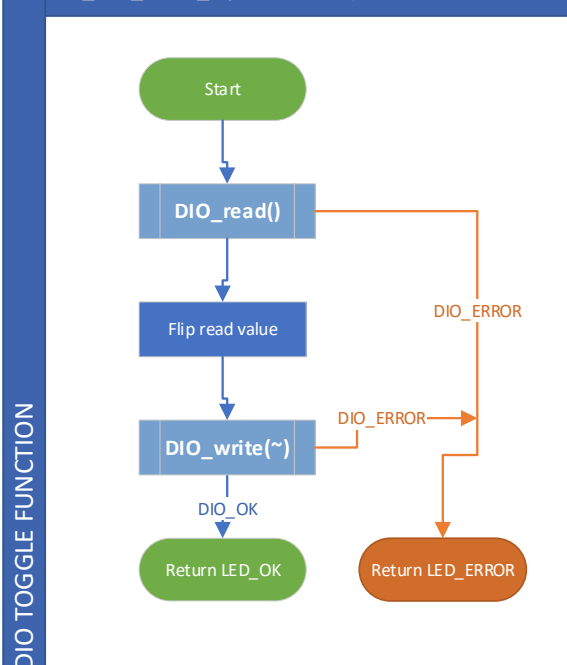
DIO Driver

```
EN_DIO_Error_T DIO_read(uint8_t pinNumber,  
EN_DIO_PORT_T portNumber, uint8_t *value);
```



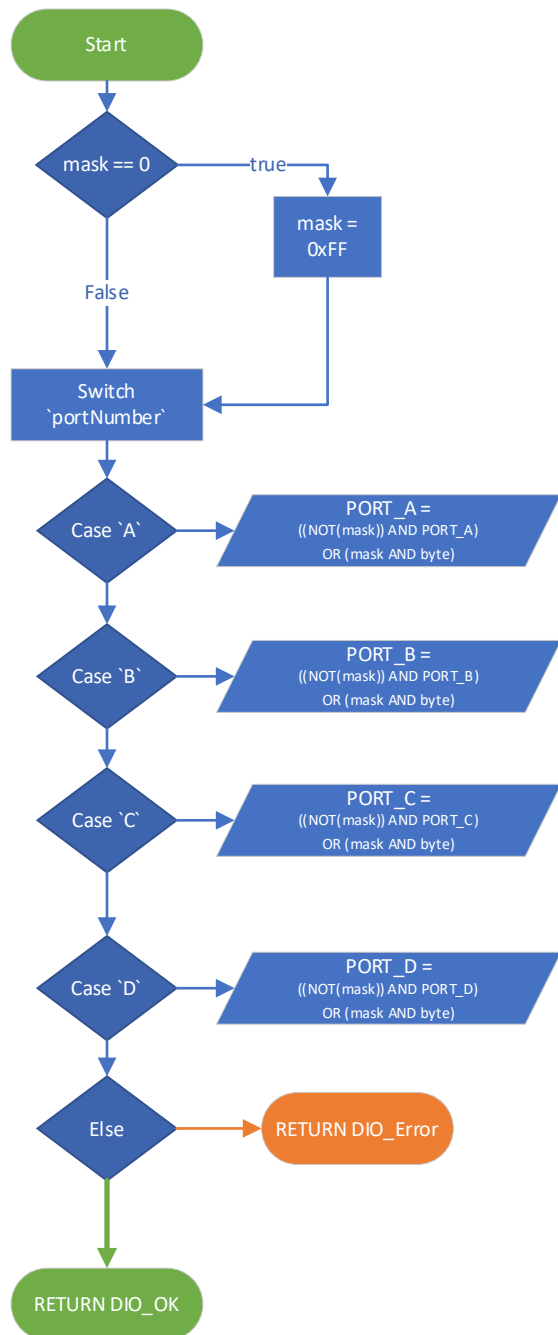
DIO Driver

```
EN_DIO_Error_T DIO_toggle(uint8_t pinNumber,  
EN_DIO_PORT_T portNumber);
```



DIO Driver

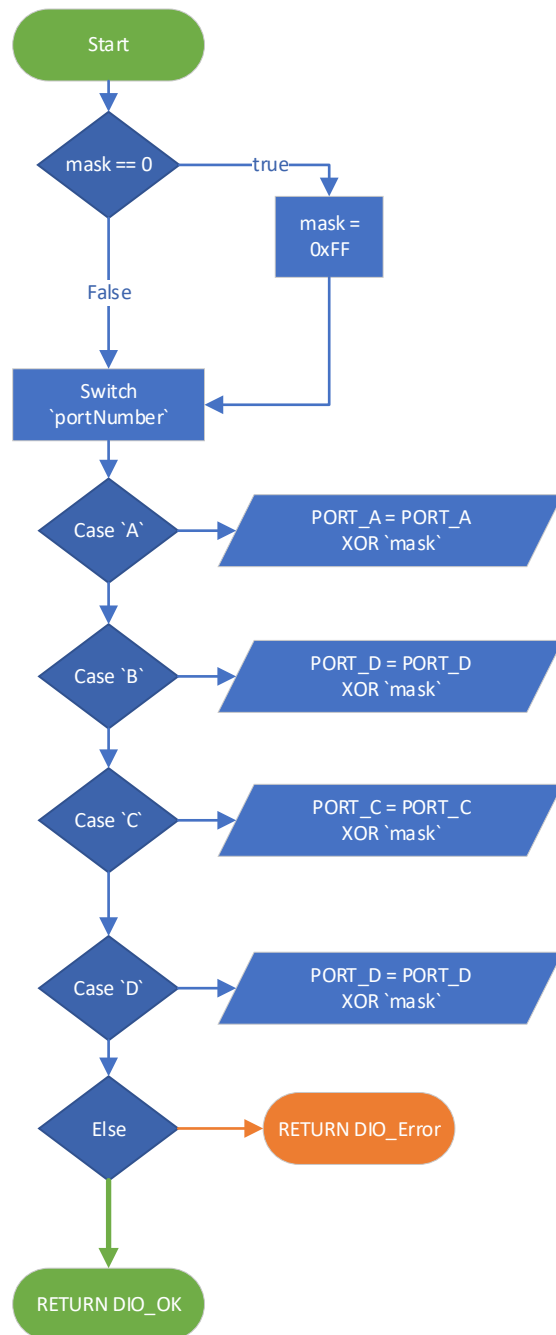
EN_DIO_Error_T **DIO_port_write**(EN_DIO_PORT_T portNumber, uint8_t byte, uint8_t mask)



DIO Port Write Function

DIO Driver

EN_DIO_Error_T
DIO_port_toggle(EN_DIO_PORT_T portNumber, uint8_t mask)

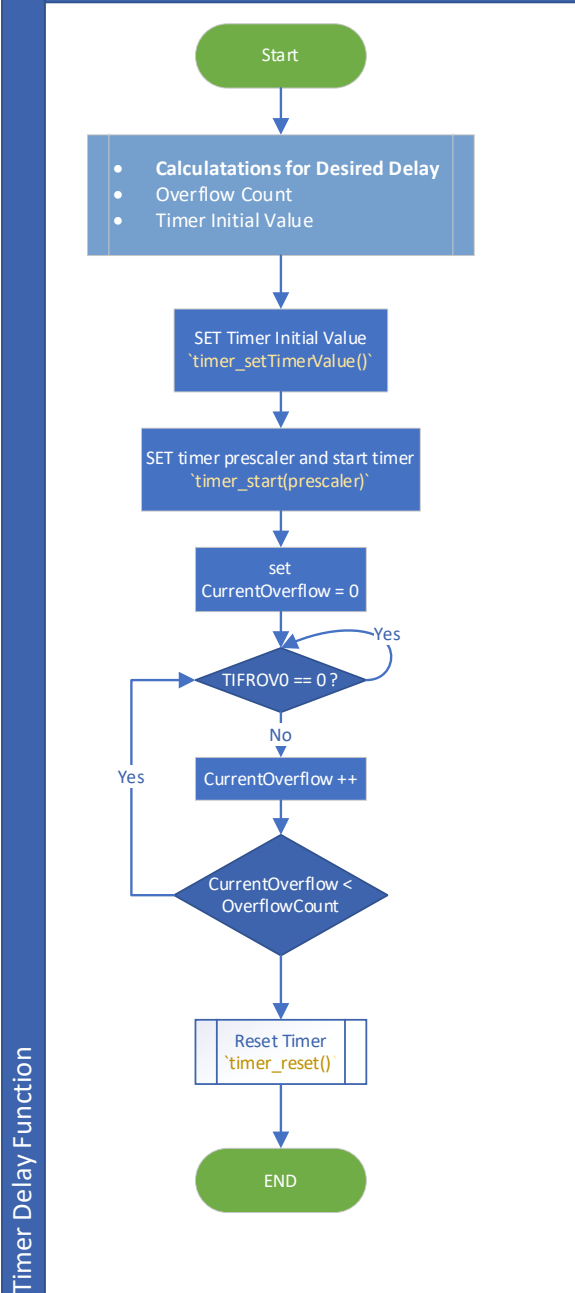


DIO Port Write Function

Timer API Flowcharts

Timer Driver

void timer_delay(uint16_t desiredDelay)



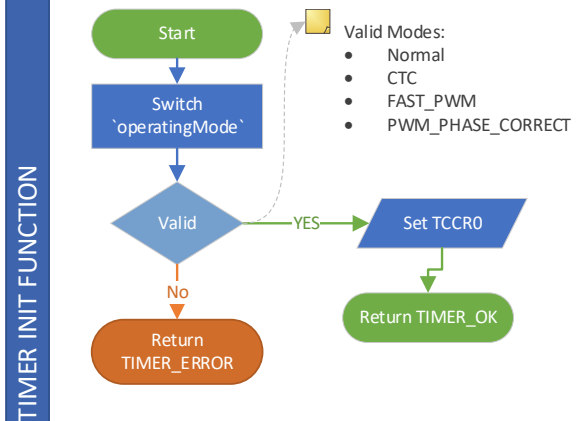
Timer Driver

void timer_reset()



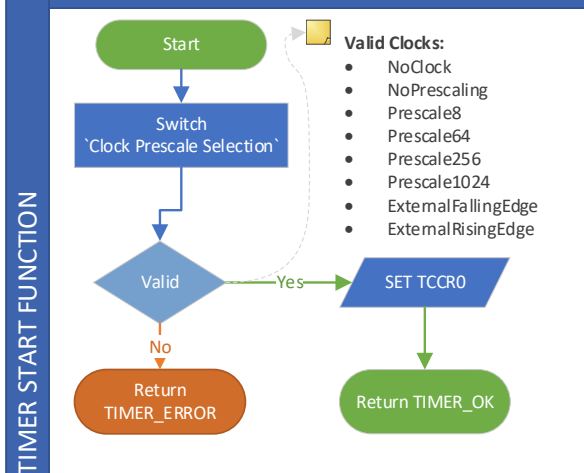
Timer Driver

**EN_DIO_Error_T DIO_init(uint8_t pinNumber,
EN_DIO_PORT_T portNumber,
EN_DIO_DIRECTION_T direction);**



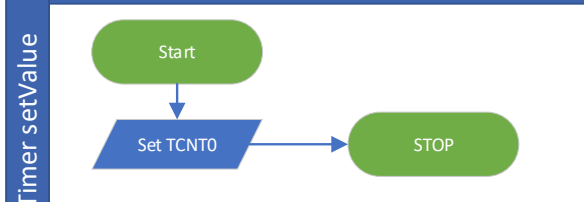
Timer Driver

**EN_timerError_t timer_start(EN_ClockSelection_t
enClockPrescaleSelection)**



Timer Driver

void timer_setTimerValue(uint8_t timerInitValue)



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

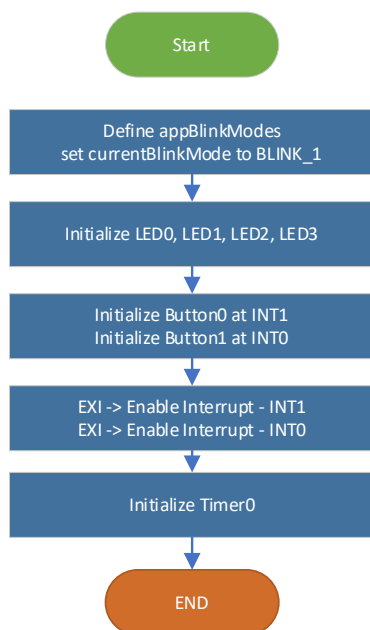
/* Global Variables */
uint8_t state_number = 0;
uint8_t current_blink_mode_index = 1;

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

Application

void App_init();

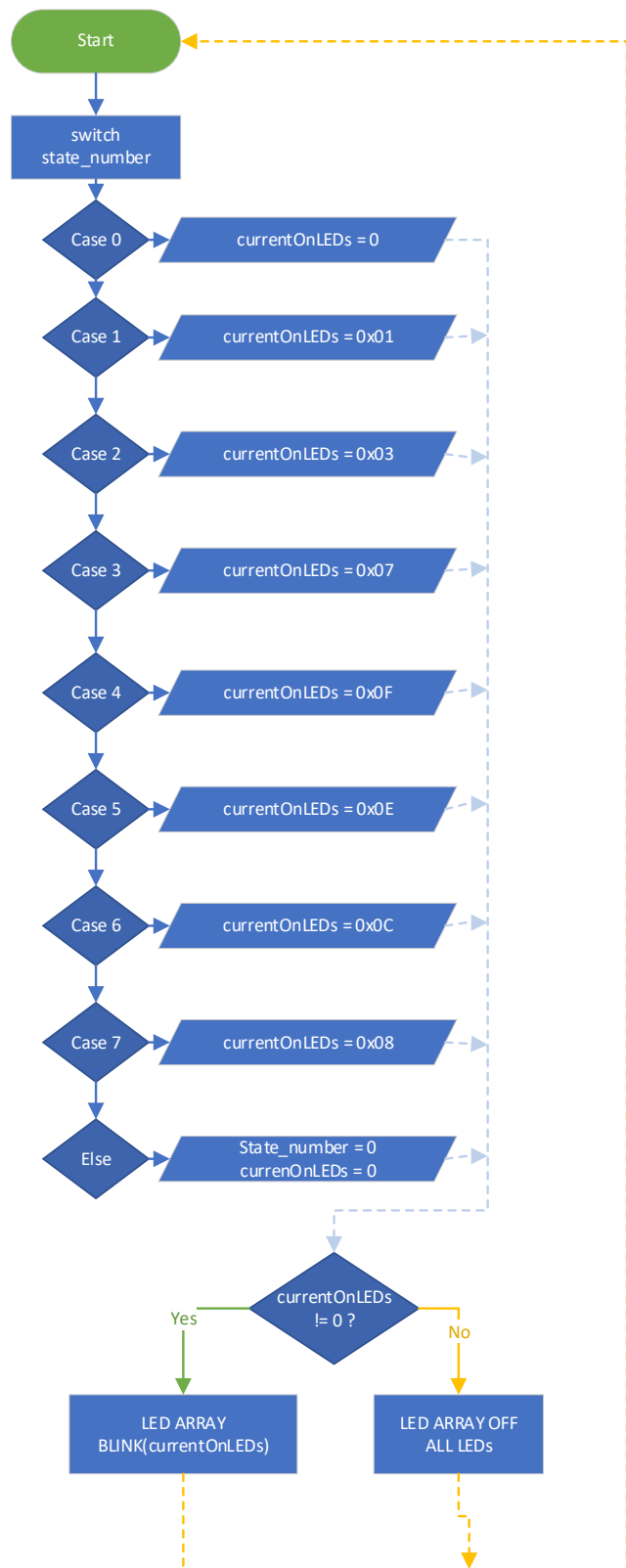
Application init function



Application

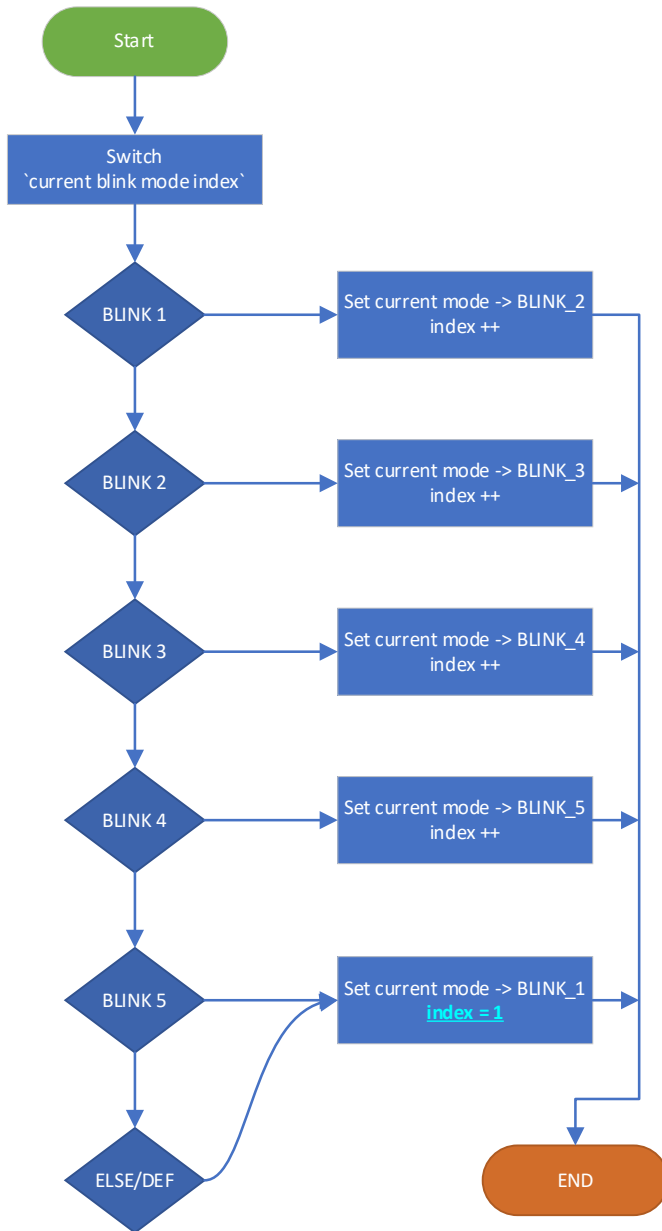
void App_Start();

Application Start Function



Application

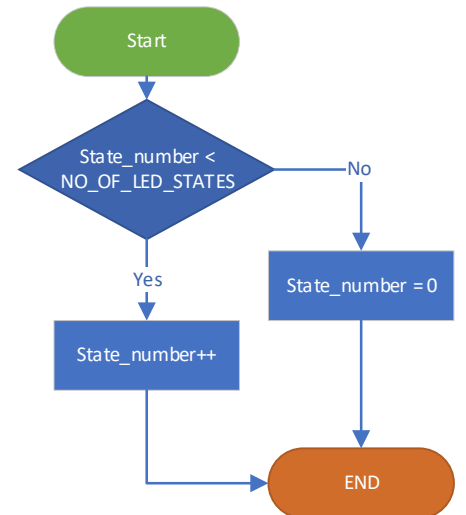
ISR(EXT_INT_0)



ISR function for INT0

Application

ISR(EXT_INT_1)



ISR function for INT1