

Pressure Controller Project

Mastering Embedded System Online Diploma

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First Term (Final Project 1)

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Design sequence:

1. Case study:

A pressure controller that keep track of the pressure in the cabin and if it exceeds 20 bar it informs the crew using an alarm for 60 seconds

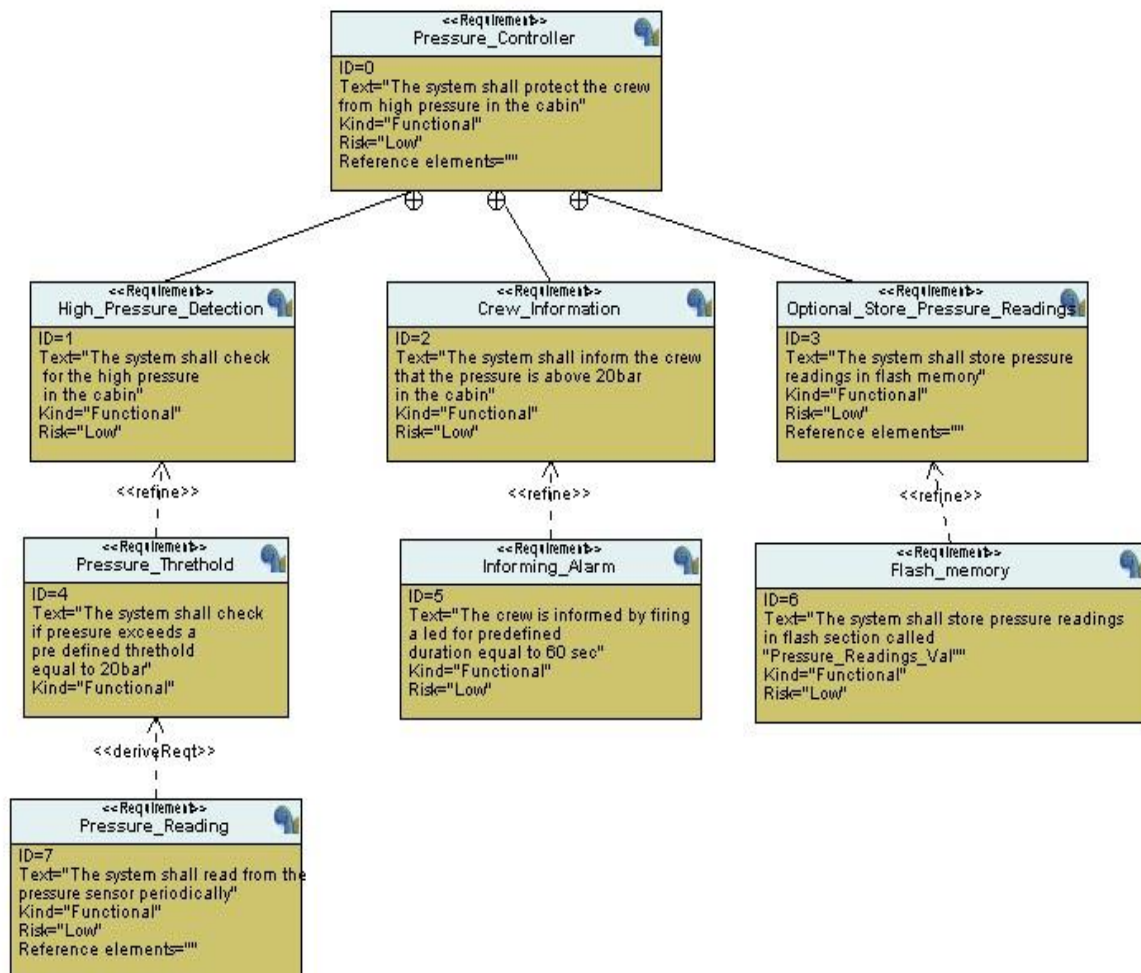
Keep track of the pressure readings

- Assumptions:
 - The system maintenance is not supported.
 - The pressure sensor never fails.
 - The alarm never fails.
 - The controller never faces a power cut-off.
 - The system setup and shutdown procedures are not modeled.
 - The power supply of the system is not modeled.

2. Method:

V-model method is used in this project.

3. Requirement:

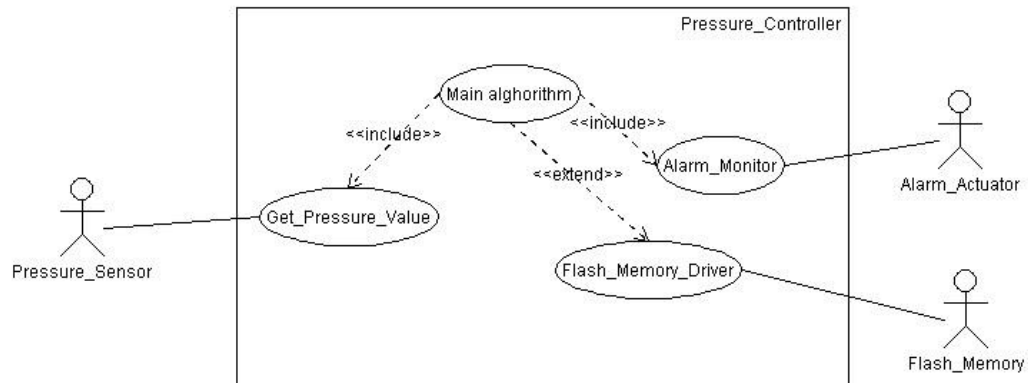


4. Space exploration

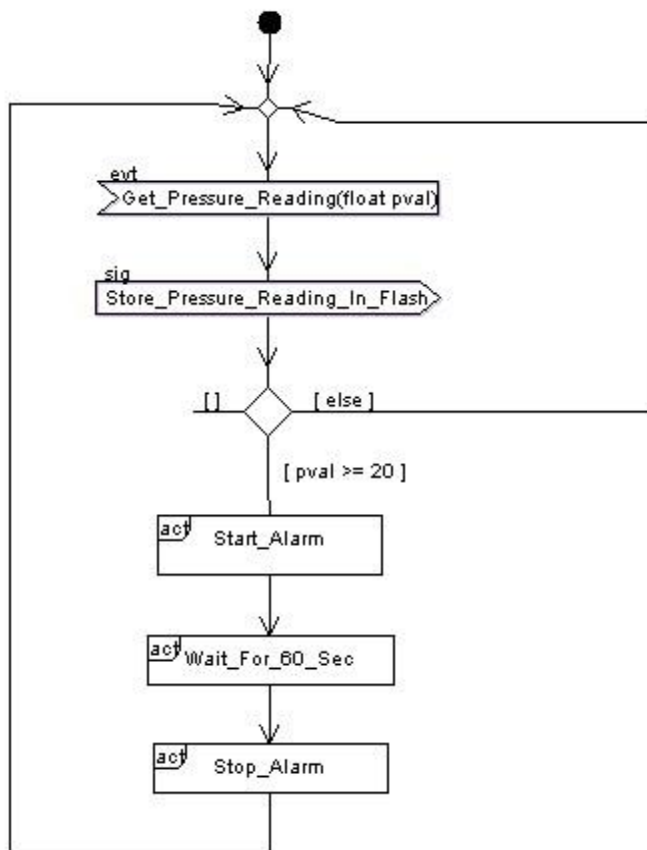
It was found that using STM32 microcontroller with cortex-M3 processor will suit the requirements of the system the best

5. System analysis:

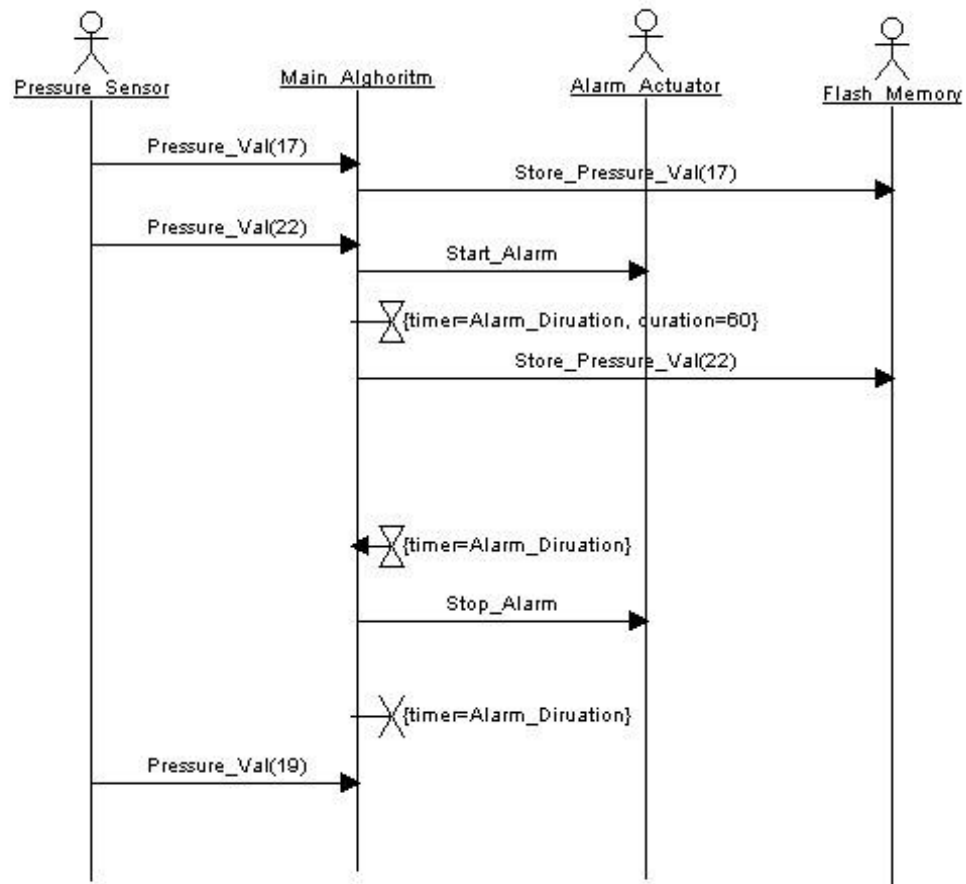
a. Use-Case diagram:



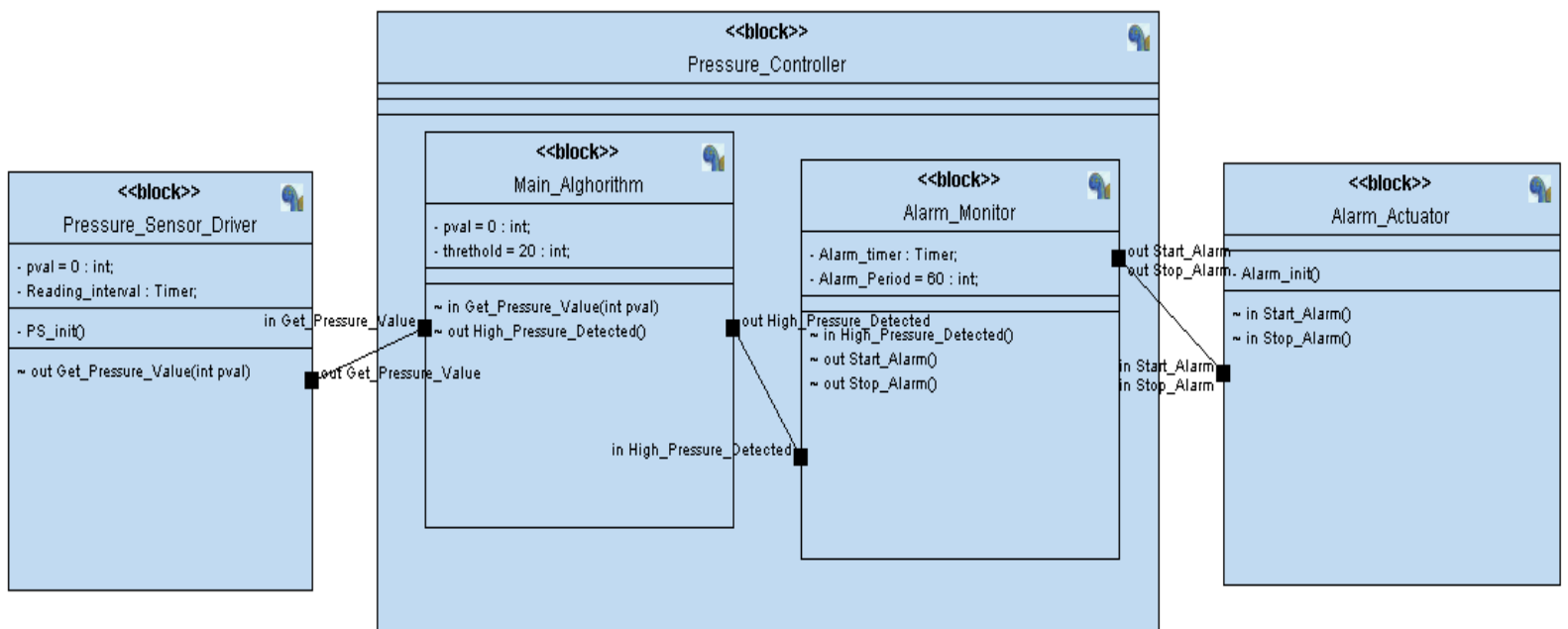
b. Activity diagram:



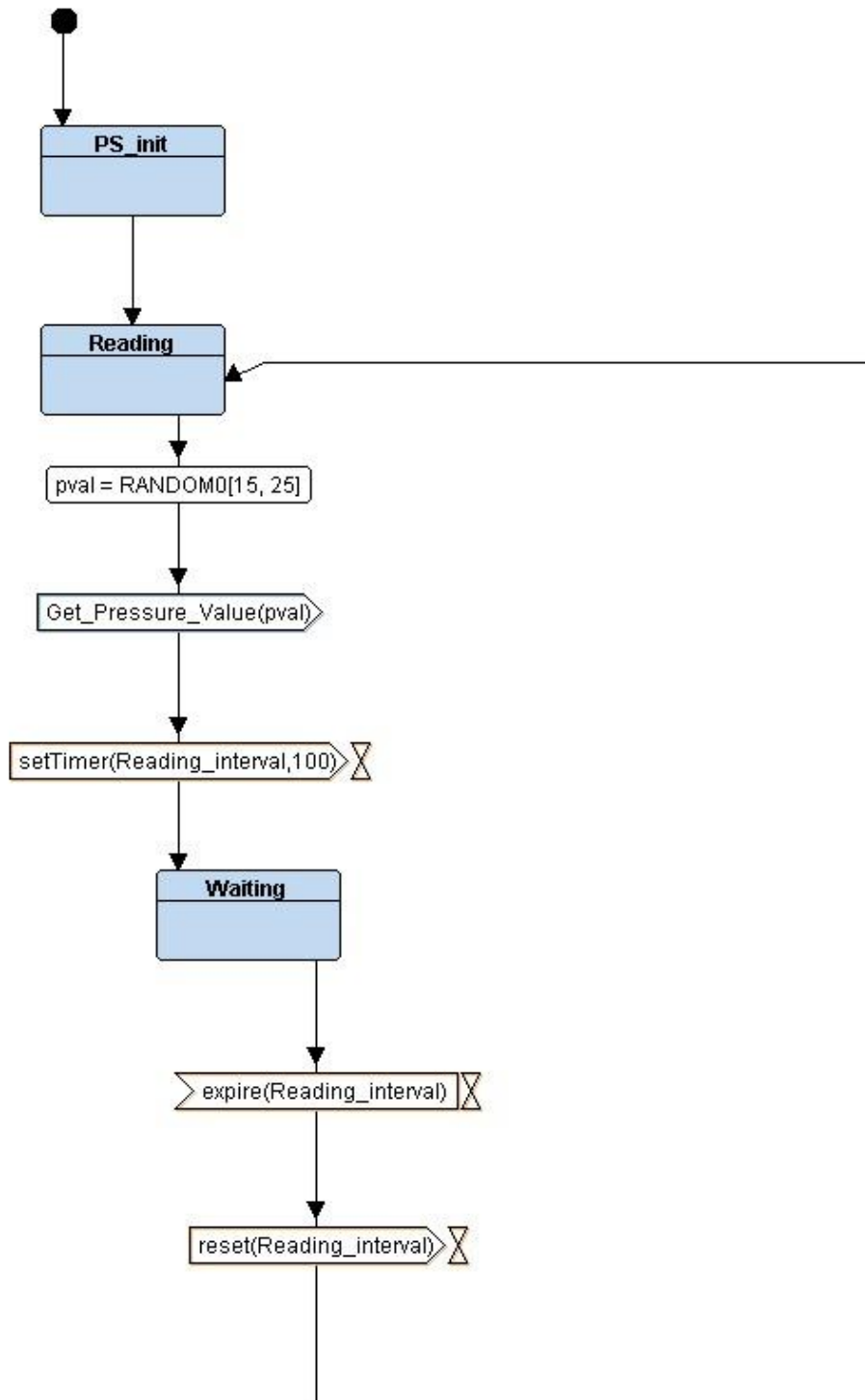
c. Sequence diagram:



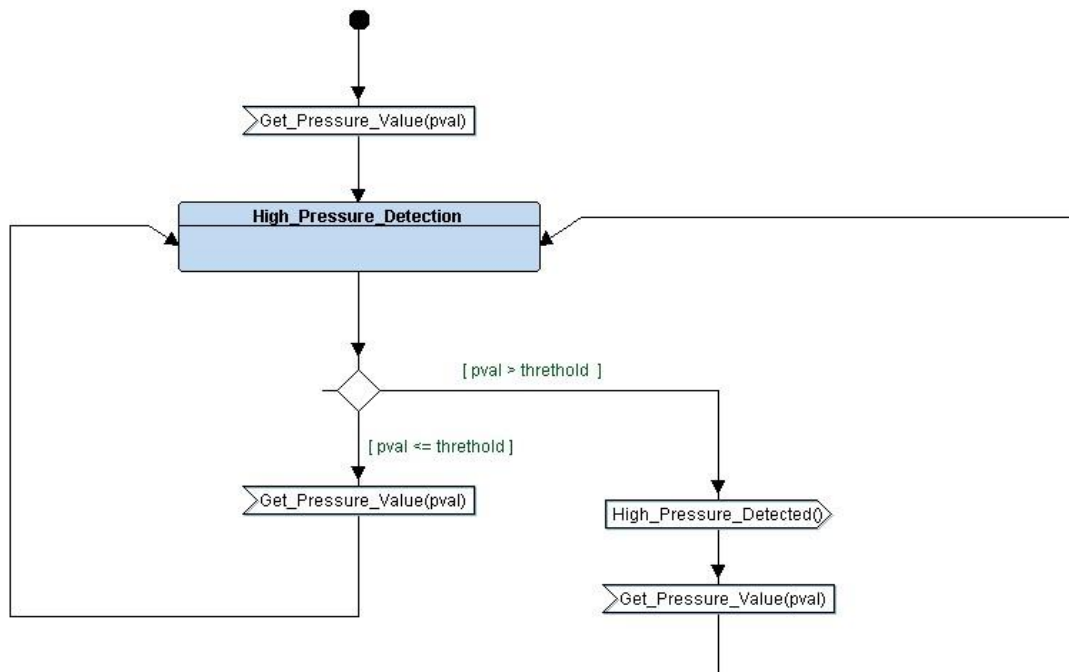
6. System Design



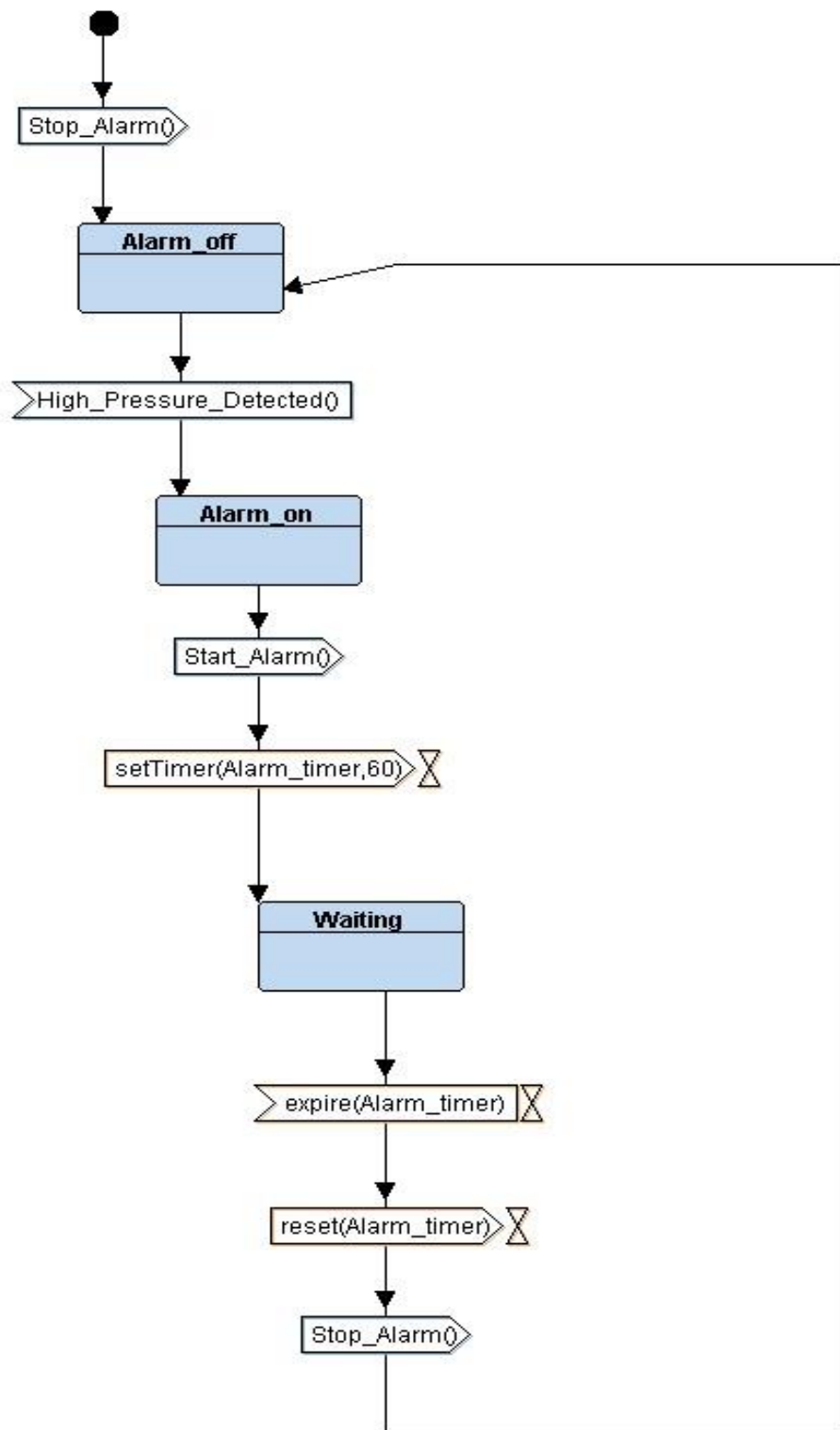
○ Pressure sensor state diagram:



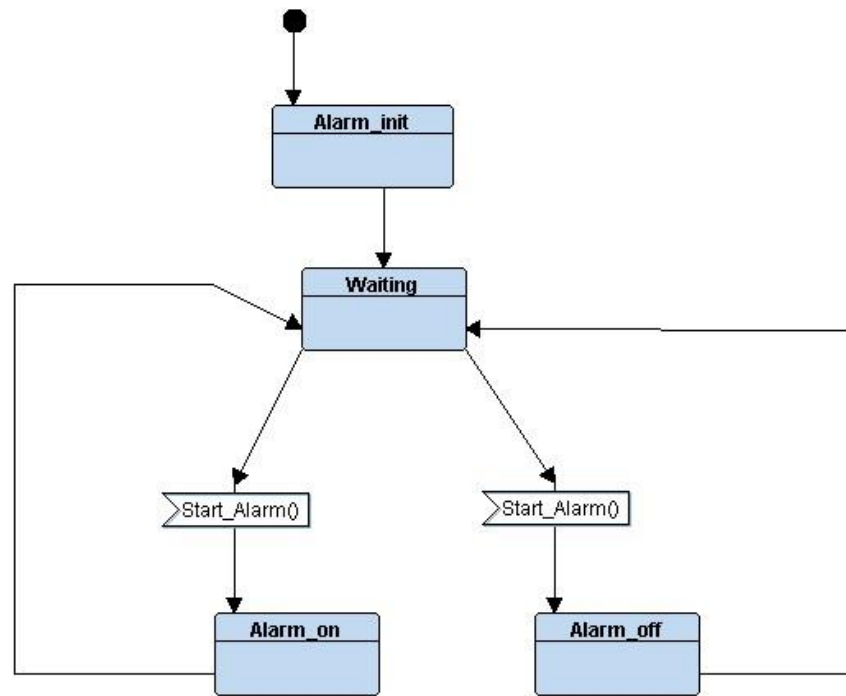
○ Main algorithm state diagram:



○ Alarm monitor state diagram:

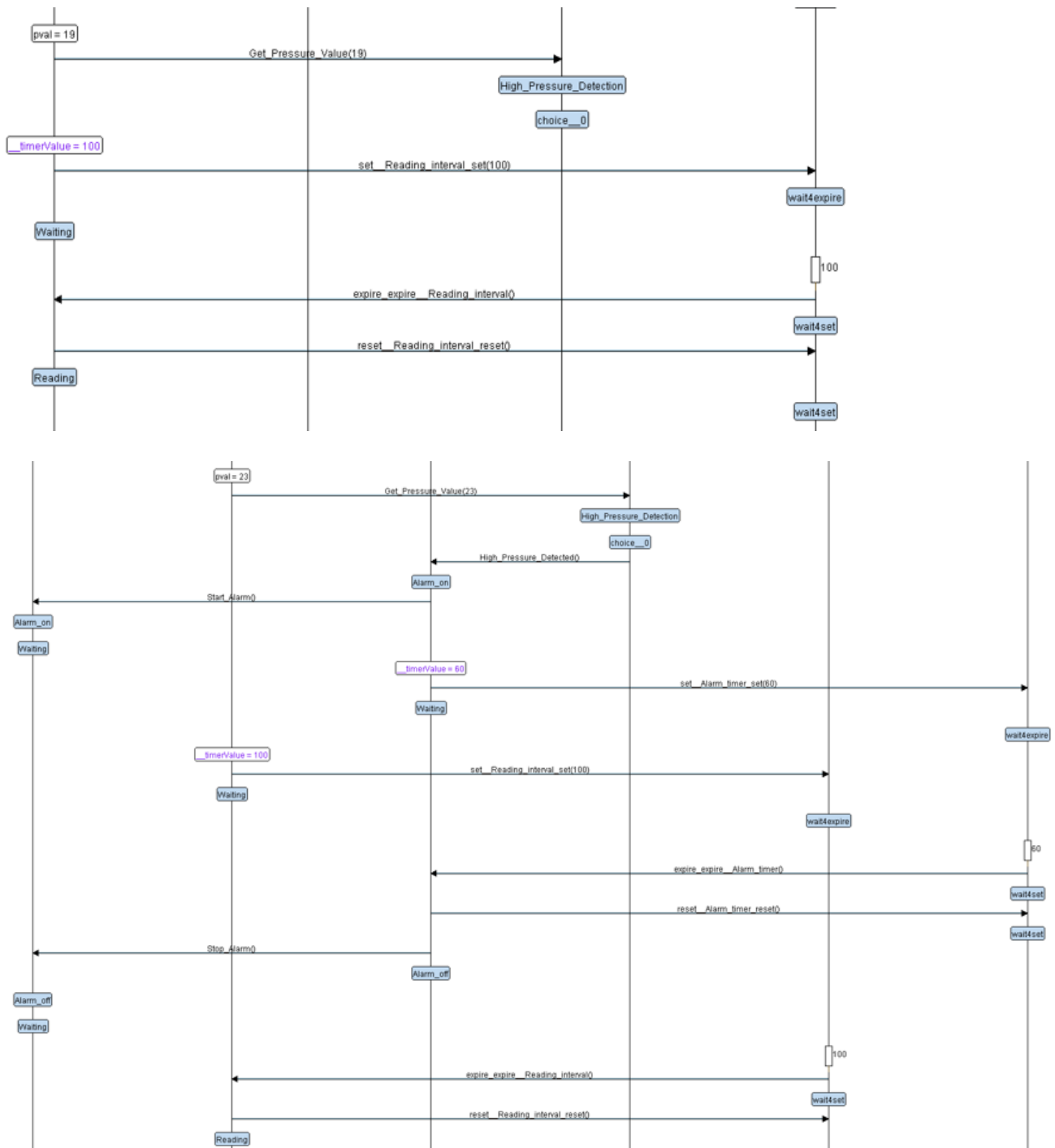


○ Alarm actuator state diagram:



○

Whole trace:



Code screenshots:

○ Pressure sensor driver:

```
1  /*
2   * PS_Driver.c
3   *
4   * Created on: Feb 14, 2024
5   * Author: user
6   */
7
8  #include "PS_Driver.h"
9
10 //pointer to current state
11
12 static uint32_t pval;
13
14 enum {
15     PS_INIT,
16     PS_READING,
17     PS_WAITING
18 }PS_State_ID;
19
20
21 ST_Define(PS_INIT){
22     PS_State_ID = PS_INIT;
23
24     PS_current_state = STATE(PS_READING);
25
26 }
27
28 ST_Define(PS_READING){
29     PS_State_ID = PS_READING;
30     pval = getPressureVal();
31     PS_current_state = STATE(PS_WAITING);
32 }
33
34
35 ST_Define(PS_WAITING){
36     PS_State_ID = PS_WAITING;
37     Delay(1000);
38     PS_current_state = STATE(PS_READING);
39 }
40
41
42 uint32_t Get_Pressure_Value(){
43     return pval;
44 }
```

```
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 * PS_Driver.h
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 * Created on: Feb 14, 2024
 * Author: user
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```

○ Main Algorithm:

```
/*
 * Main_Algo.c
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#include "Main_Algo.h"

enum {
    HIGH_PRESSURE_DETECTION
}MAIN_ALGO_State_ID;

static uint32_t Pval;
static uint32_t threshold = 20;

ST_Define(HIGH_PRESSURE_DETECTION) {
    MAIN_ALGO_State_ID = HIGH_PRESSURE_DETECTION;
    Pval = Get_Pressure_Value();
    MAIN_ALGO_current_state = STATE(HIGH_PRESSURE_DETECTION);
}

uint32_t High_Pressure_Detected() {
    return (Pval > threshold);
}
```

```
/*
 * Main_Algo.h
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#ifndef MAIN_ALGO_H_
#define MAIN_ALGO_H_

#include "state.h"

ST_Define(HIGH_PRESSURE_DETECTION);

extern void (*MAIN_ALGO_current_state) ();

#endif /* MAIN_ALGO_H_ */
```

○ Alarm actuator:

```
/*
 * Alarm_Actuator.c
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#include "Alarm_Actuator.h"

enum {
    ALARM_INIT,
    ALARM_WAITING,
    ALARM_ON,
    ALARM_OFF,
}ALARM_ACTUATOR_State_ID;

ST_Define(ALARM_INIT){
    ALARM_ACTUATOR_State_ID = ALARM_INIT;
    ALARM_ACTUATOR_current_state = STATE(ALARM_WAITING);
}

ST_Define(ALARM_WAITING){
    ALARM_ACTUATOR_State_ID = ALARM_WAITING;
}

ST_Define(ALARM_ON){
    ALARM_ACTUATOR_State_ID = ALARM_ON;
    Set_Alarm_actuator(1);
    ALARM_ACTUATOR_current_state = STATE(ALARM_WAITING);
}

ST_Define(ALARM_OFF){
    ALARM_ACTUATOR_State_ID = ALARM_OFF;
    Set_Alarm_actuator(0);
    ALARM_ACTUATOR_current_state = STATE(ALARM_WAITING);
}

void Start_Alarm(){
    ALARM_ACTUATOR_current_state = STATE(ALARM_ON);
}

void Stop_Alarm(){
    ALARM_ACTUATOR_current_state = STATE(ALARM_OFF);
}
```

```
/*
 * Alarm_Actuator.h
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#ifndef ALARM_ACTUATOR_H_
#define ALARM_ACTUATOR_H_

#include "state.h"

ST_Define(ALARM_INIT);
ST_Define(ALARM_WAITING);
ST_Define(ALARM_ON);
ST_Define(ALARM_OFF);

extern void (*ALARM_ACTUATOR_current_state) ();

#endif /* ALARM_ACTUATOR_H_ */
```

○ Alarm monitor:

```
/*
 * Alarm_Monitor.c
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#include "Alarm_Monitor.h"

enum {
    ALARM_MOINTOR_OFF,
    ALARM_MOINTOR_ON,
    ALARM_MOINTOR_WAITING
}ALARM_MOINTOR_State_ID;

ST_Define(ALARM_MOINTOR_OFF){
    ALARM_MOINTOR_State_ID = ALARM_MOINTOR_OFF;
    Stop_Alarm();
    if(High_Pressure_Detected()){
        ALARM_MOINTOR_current_state = STATE(ALARM_MOINTOR_ON);
    }
}

ST_Define(ALARM_MOINTOR_ON){
    ALARM_MOINTOR_State_ID = ALARM_MOINTOR_ON;
    Start_Alarm();
    ALARM_MOINTOR_current_state = STATE(ALARM_MOINTOR_WAITING);
}

ST_Define(ALARM_MOINTOR_WAITING){
    ALARM_MOINTOR_State_ID = ALARM_MOINTOR_WAITING;
    Delay(500);
    ALARM_MOINTOR_current_state = STATE(ALARM_MOINTOR_OFF);
}
```

```
/*
 * Alarm_Monitor.h
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#ifndef ALARM_MONITOR_H_
#define ALARM_MONITOR_H_

#include "state.h"

ST_Define(ALARM_MOINTOR_OFF);

ST_Define(ALARM_MOINTOR_ON);

ST_Define(ALARM_MOINTOR_WAITING);

extern void (*ALARM_MOINTOR_current_state) ();

#endif /* ALARM_MONITOR_H_ */
```


○ State.h

```
1  /*
2  * state.h
3  *
4  * Created on: Feb 14, 2024
5  * Author: user
6  */
7
8  #ifndef STATE_H_
9  #define STATE_H_
10
11  #include "Platform_Types.h"
12  #include "DRIVER.h"
13
14
15  #define ST_Define(_state_)      void ST_##_state_()
16  #define STATE(_state_)         ST_##_state_
17
18  //signal from PS driver to main algorithm
19  uint32_t Get_Pressure_Value();
20  //signal from main algorithm to alarm monitor
21  uint32_t High_Pressure_Detected();
22  //signals from alarm monitor to alarm actuator
23  void Stop_Alarm();
24  void Start_Alarm();
25
26
27
28  #endif /* STATE_H_ */
29
```

○ Driver:

```
/*
 * DRIVER.c
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#include "DRIVER.h"

void Delay(int nCount)
{
    for(; nCount != 0; nCount--);
}

int getPressureVal(){
    return (GPIOA_IDR & 0xFF);
}

void Set_Alarm_actuator(int i){
    if (i == 1){
        RESET_BIT(GPIOA_ODR,13);
    }
    else if (i == 0){
        SET_BIT(GPIOA_ODR,13);
    }
}

void GPIO_INITIALIZATION (){
    SET_BIT(APB2ENR, 2);
    GPIOA_CRL &= 0xFF0FFFFFFF;
    GPIOA_CRL |= 0x00000000;
    GPIOA_CRH &= 0xFF0FFFFFFF;
    GPIOA_CRH |= 0x22222222;
    RESET_BIT(GPIOA_ODR,13);
}
```

```
/*
 * DRIVER.h
 *
 * Created on: Feb 14, 2024
 * Author: user
 */

#ifndef DRIVER_H_
#define DRIVER_H_

#include "Platform_Types.h"

#define SET_BIT(ADDRESS,BIT)  ADDRESS |= (1<<BIT)
#define RESET_BIT(ADDRESS,BIT) ADDRESS &= ~(1<<BIT)
#define TOGGLE_BIT(ADDRESS,BIT) ADDRESS ^= (1<<BIT)
#define READ_BIT(ADDRESS,BIT) ((ADDRESS) & (1<<(BIT)))

#define GPIO_PORTA 0x40010800
#define BASE_RCC 0x40021000

#define APB2ENR *(volatile uint32_t *) (BASE_RCC + 0x18)

#define GPIOA_CRL *(volatile uint32_t *) (GPIO_PORTA + 0x00)
#define GPIOA_CRH *(volatile uint32_t *) (GPIO_PORTA + 0x04)
#define GPIOA_IDR *(volatile uint32_t *) (GPIO_PORTA + 0x08)
#define GPIOA_ODR *(volatile uint32_t *) (GPIO_PORTA + 0x0C)

void Delay(int nCount);
int getPressureVal();
void Set_Alarm_actuator(int i);
void GPIO_INITIALIZATION ();

#endif /* DRIVER_H_ */
```

○ Main:

```
1  /*
2  * main.c
3  *
4  * Created on: Feb 14, 2024
5  * Author: user
6  */
7
8  #include "Platform_Types.h"
9  #include "DRIVER.h"
10 #include "Alarm_Actuator.h"
11 #include "Alarm_Monitor.h"
12 #include "PS_Driver.h"
13 #include "Main_Algo.h"
14
15
16 void (*PS_current_state) () = STATE(PS_INIT);
17 void (*ALARM_ACTUATOR_current_state) () = STATE(ALARM_INIT);
18 void (*ALARM_MOINTOR_current_state) () = STATE(ALARM_MOINTOR_OFF);
19 void (*MAIN_ALGO_current_state) () = STATE(HIGH_PRESSURE_DETECTION);
20
21 int main() {
22     GPIO_INITIALIZATION();
23     while(1) {
24         PS_current_state();
25         ALARM_ACTUATOR_current_state();
26         ALARM_MOINTOR_current_state();
27         MAIN_ALGO_current_state();
28     }
29 }
30
```

○ Startup:

```
/*
 * startup.c
 *
 * Created on: Feb 14, 2024
 *     ENG.Kareem Khaled Abdelazim
 */

#include "Platform_Types.h"

extern uint32_t _STACK_TOP;
extern int main();
void Reset_Handler();

void Default_Handler(){
    Reset_Handler();
}

void NMI_Handler () __attribute__((weak, alias("Default_Handler")));
void H_Fault_Handler () __attribute__((weak, alias("Default_Handler")));
void MM_Fault_Handler () __attribute__((weak, alias("Default_Handler")));
void Bus_Fault () __attribute__((weak, alias("Default_Handler")));
void Usage_Fault_Handler () __attribute__((weak, alias("Default_Handler")));

uint32_t vectors[] __attribute__((section(".vectors"))) = {
    (uint32_t) & _STACK_TOP,
    (uint32_t) & Reset_Handler,
    (uint32_t) & NMI_Handler,
    (uint32_t) & H_Fault_Handler,
    (uint32_t) & MM_Fault_Handler,
    (uint32_t) & Bus_Fault,
    (uint32_t) & Usage_Fault_Handler
};

extern uint32_t _E_TEXT ;
extern uint32_t _S_DATA ;
extern uint32_t _E_DATA ;
extern uint32_t _S_BSS ;
extern uint32_t _E_BSS ;

void Reset_Handler(){
    uint32_t Data_Size = (uint8_t*)&_E_DATA - (uint8_t*)&_S_DATA ;
    uint8_t* P_SRC = (uint8_t*)&_E_TEXT ;
    uint8_t* P_DST = (uint8_t*)&_S_DATA ;

    for (int i = 0 ; i < Data_Size ; i++){
        *((uint8_t*)P_DST++) = *((uint8_t*)P_SRC++);
    }

    uint32_t BSS_Size = (uint8_t*)&_E_BSS - (uint8_t*)&_S_BSS ;
    uint8_t* P_BSS = (uint8_t*)&_S_BSS ;

    for (int i = 0 ; i < BSS_Size ; i++){
        *((uint8_t*)P_BSS++) = (uint8_t)0;
    }

    main();
}
```

○ LinkerScript:

```
/*
 * STM32 linkerScript
 *
 * Created on: Feb 14, 2024
 *      ENG.Kareem Khaled Abdelazim
 */

MEMORY
{
    flash(RX) : ORIGIN = 0x08000000 , LENGTH = 128K
    sram(RWX)  : ORIGIN = 0x20000000 , LENGTH = 20K
}

SECTIONS
{
    .text :
    {
        *(.vectors*)
        *(.text*)
        *(.rodata*)
        _E_TEXT = . ;
    }>flash

    .data :
    {
        _S_DATA = . ;
        *(.data*)
        . = ALIGN(4);
        _E_DATA = . ;
    }>sram AT> flash

    .bss :
    {
        _S_BSS = . ;
        *(.bss*)
        _E_BSS = . ;
        . = ALIGN(4);
        . = . + 0x1000;
        _STACK_TOP = . ;
    }>sram
}
```

○ MakeFile:

```
##@copyright : kareem

CC=arm-none-eabi-
CFLAGS= -mcpu=cortex-m3 -gdwarf-2 -g
INCS=-I .
LIBS=
SRC= $(wildcard *.c)
OBJ=$(SRC:.c=.o)
As=$(wildcard *.s)
AsOBJ=$(As:.s=.o)
Project_name=Pressure_Controller

all: $(Project_name).bin
    @echo "Build is done"

%.o: %.c
    $(CC)gcc.exe -c $(CFLAGS) $(INCS) $< -o $@

#startup.o: startup.s
#    $(CC)as.exe $(CFLAGS) $< -o $@

$(Project_name).elf: $(OBJ) $(AsOBJ)
    $(CC)ld.exe -T linker_script.ld $(LIBS) $(OBJ) $(AsOBJ) -o $@ -Map=map_file.map
    cp $(Project_name).elf $(Project_name).axf

$(Project_name).bin: $(Project_name).elf
    $(CC)objcopy.exe -O binary $< $@

$(Project_name).hex: $(Project_name).elf
    $(CC)objcopy.exe -O ihex $< $@

clean_all:
    rm *.o *.elf *.bin *.map *.axf *.hex

clean:
    rm *.elf *.bin

header:
    $(CC)objdump.exe -h $(Project_name).elf
```

○ Map file:

Allocating common symbols		
Common symbol	size	file
MAIN_ALGO_State_ID	0x1	Main_Algo.o
ALARM_MOINTOR_State_ID	0x1	Alarm_Monitor.o
ALARM_ACTUATOR_State_ID	0x1	Alarm_Actuator.o
PS_State_ID	0x1	PS_Driver.o

Memory Configuration			
Name	Origin	Length	Attributes
flash	0x08000000	0x00020000	xr
sram	0x20000000	0x00005000	xrw
default	0x00000000	0xffffffff	

Linker script and memory map

.text	0x08000000	0x3dc
(.vectors)		
.vectors	0x08000000	0x1c startup.o
	0x08000000	vectors
(.text)		
.text	0x0800001c	0xc4 Alarm_Actuator.o
	0x0800001c	ST_ALARM_INIT
	0x08000040	ST_ALARM_WAITING
	0x08000058	ST_ALARM_ON
	0x08000080	ST_ALARM_OFF
	0x080000a8	Start_Alarm
	0x080000c4	Stop_Alarm
.text	0x080000e0	0x7c Alarm_Monitor.o
	0x080000e0	ST_ALARM_MOINTOR_OFF
	0x08000110	ST_ALARM_MOINTOR_ON
	0x08000134	ST_ALARM_MOINTOR_WAITING
.text	0x0800015c	0xd4 DRIVER.o
	0x0800015c	Delay
	0x0800017c	getPressureVal
	0x08000194	Set_Alarm_actuator
	0x080001d0	GPIO_INITIALIZATION
.text	0x08000230	0x34 main.o
	0x08000230	main
.text	0x08000264	0x58 Main_Algo.o
	0x08000264	ST_HIGH_PRESSURE_DETECTION
	0x08000294	High_Pressure_Detected
.text	0x080002bc	0x90 PS_Driver.o
	0x080002bc	ST_PS_INIT
	0x080002e0	ST_PS_READING
	0x08000310	ST_PS_WAITING
	0x08000338	Get_Pressure_Value
.text	0x0800034c	0x90 startup.o
	0x0800034c	H_Fault_Handler
	0x0800034c	MM_Fault_Handler
	0x0800034c	Usage_Fault_Handler
	0x0800034c	Bus_Fault
	0x0800034c	Default_Handler
	0x0800034c	NMI_Handler

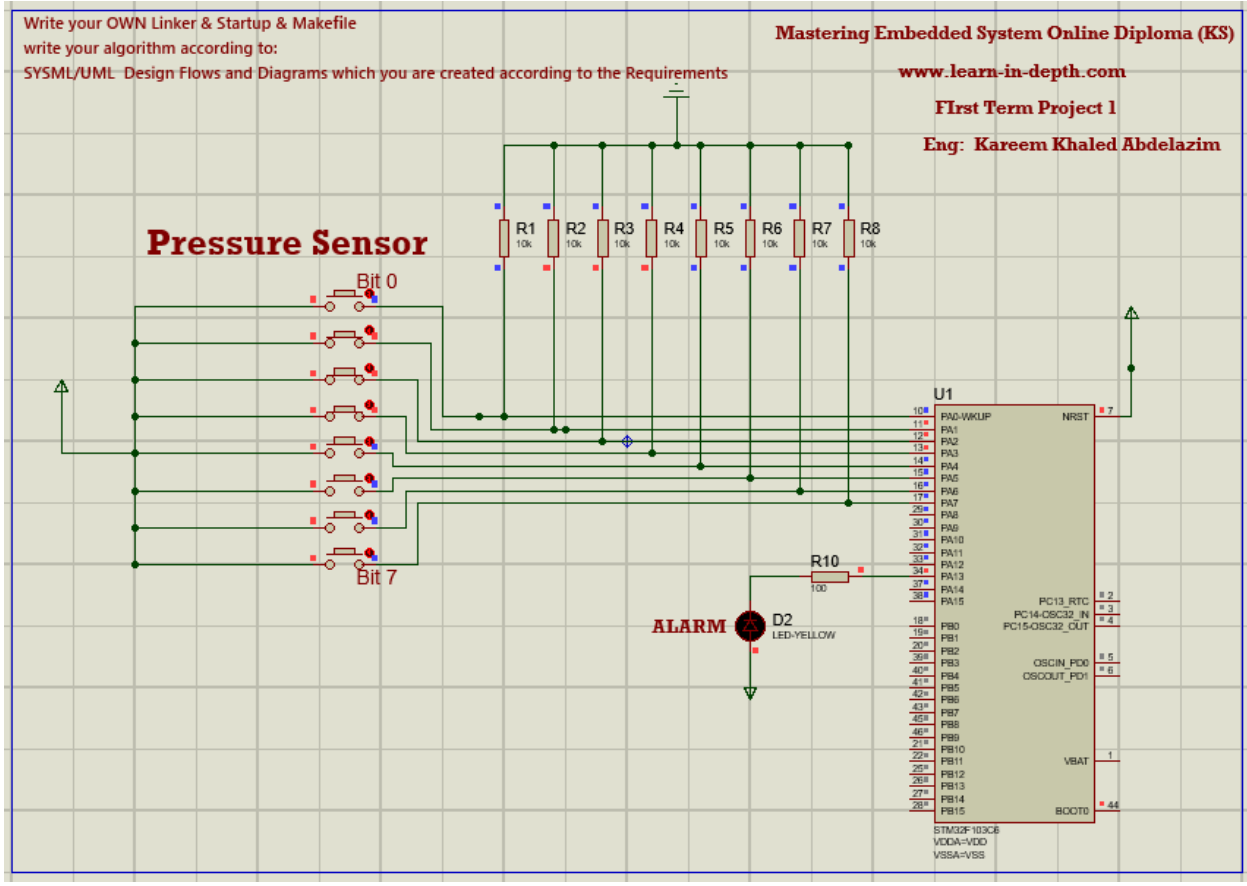
○ Headers and sections:

```
$ make header
arm-none-eabi-objdump.exe -h Pressure_Controller.elf

Pressure_Controller.elf:      file format elf32-littlearm

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 .text          000003dc  08000000  08000000  00010000  2**2
    CONTENTS, ALLOC, LOAD, READONLY, CODE
  1 .data          00000014  20000000  080003dc  00020000  2**2
    CONTENTS, ALLOC, LOAD, DATA
  2 .bss           0000100c  20000014  080003f0  00020014  2**2
    ALLOC
  3 .debug_info     00000850  00000000  00000000  00020014  2**0
    CONTENTS, READONLY, DEBUGGING
  4 .debug_abbrev   000004d6  00000000  00000000  00020864  2**0
    CONTENTS, READONLY, DEBUGGING
  5 .debug_loc      00000524  00000000  00000000  00020d3a  2**0
    CONTENTS, READONLY, DEBUGGING
  6 .debug_aranges  000000e0  00000000  00000000  0002125e  2**0
    CONTENTS, READONLY, DEBUGGING
  7 .debug_line     0000031c  00000000  00000000  0002133e  2**0
    CONTENTS, READONLY, DEBUGGING
  8 .debug_str      000003fb  00000000  00000000  0002165a  2**0
    CONTENTS, READONLY, DEBUGGING
  9 .comment        0000007e  00000000  00000000  00021a55  2**0
    CONTENTS, READONLY
10 .ARM.attributes 00000033  00000000  00000000  00021ad3  2**0
    CONTENTS, READONLY
11 .debug_frame     0000031c  00000000  00000000  00021b08  2**2
    CONTENTS, READONLY, DEBUGGING
```


- *Simulation results:*



The sensor reading in this case is 14 bar which is under the threshold determined by the user so no alarm is produced.

SYSML/UML Design Flows and Diagrams which you are created according to the Requirements

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