Neo Yu Yao Terence A0164651E, Neo Jia Wen Rachel A0176763R GA:

Table of Contents

[Introduction and objectives 1](#_Toc529748750)

[Flowcharts describing the system design and processes 3](#_Toc529748751)

[Detailed implementation 6](#_Toc529748752)

[General Code Structure 8](#_Toc529748753)

[Enhancement 8](#_Toc529748754)

[7 Segment 8](#_Toc529748755)

[Music Player 8](#_Toc529748756)

[Motivation 8](#_Toc529748757)

[Frontend: Graphical User Interface Design 8](#_Toc529748758)

[Backend: Song Library Storage and Retrieval 9](#_Toc529748759)

[Backend: Processing 11](#_Toc529748760)

[UART interrupt 12](#_Toc529748761)

[Significant problems encountered and solutions proposed 12](#_Toc529748762)

[Reading of Temperature Sensor causes system lag 12](#_Toc529748763)

[Green RGB conflicts with OLED 13](#_Toc529748764)

[Default Jumper settings prevents affects SW4 functionality 13](#_Toc529748765)

[Blue RGB conflicts with Speaker 13](#_Toc529748766)

[Reset to Initialization Mode for Debugging 13](#_Toc529748767)

[Issues or suggestions 13](#_Toc529748768)

[Conclusion 13](#_Toc529748769)

**Page allocation (Total 10 pages, requirement around 8 pages) Total 60 marks**

* 1 page: content table, intro and objectives
* 3 pages: Flowcharts (10 marks)
* 2-1.5 pages: Detailed implementation
* 2-2.5 pages: Enhancement
* 2 pages: Significant problems, Suggestions, Conclusion

**Grading Criteria**

* Report (10 marks)
* Ability to use device interrupts and their understanding
* Extent of UART implementation, such as whether wireless UART has been implemented
* Responsiveness, performance and robustness of the system, good design with a full implementation
* Marks are awarded for reports that are more complete
* Extent of the application logic enhancements as described in section 1.4, and several other factors that demonstrate the ability to learn independently and program for computer interfaces (10 marks)

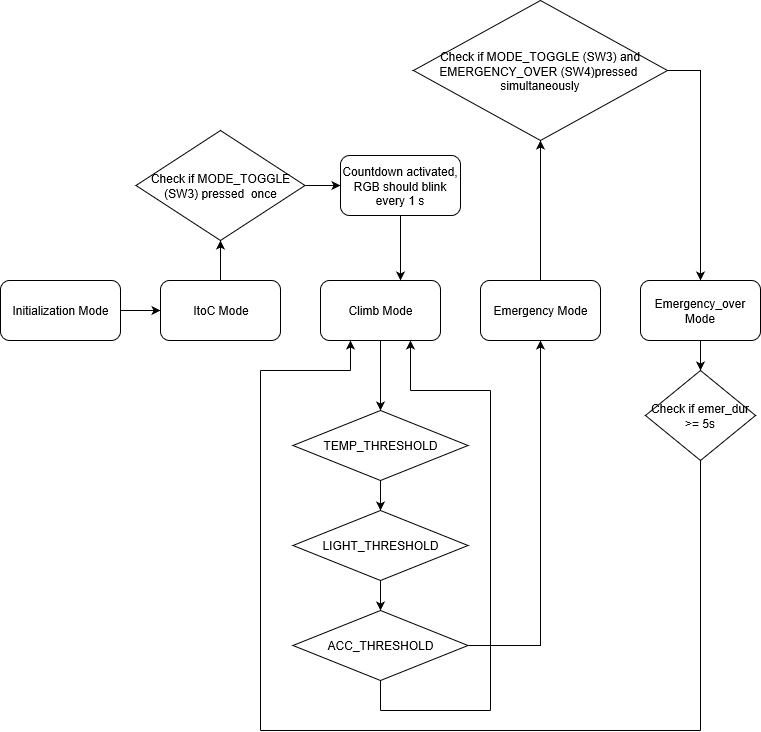
# Introduction and objectives

In this assignment, our group is tasked to implement a fitness tracking system, **FitNUS**. The main purpose of **FitNUS** is to boost daily workouts and make them easier to achieve. **FitNUS** detects acceleration, light and temperature changes. **FitNUS** sends data periodically to a server known as **FiTrackX**. The XBee RF module acts as a low powered wireless communication device that sends collected data to **FiTrackX**.

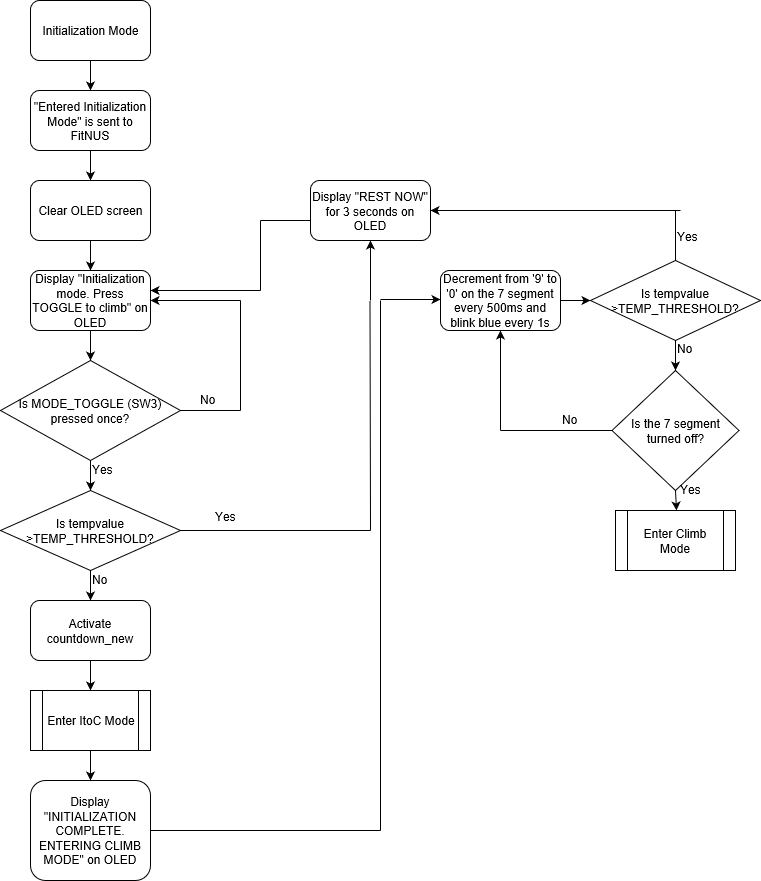
**FitNUS** has 3 modes of operation: Initialization, Climb and Emergency modes, and will transmit to **FiTrackX** is certain conditions are met. We also implemented ItoC and Emergency\_over modes which is later described in our report. Initialization mode would be active when the FitNUS system is first switched on. Climb mode would be active when MODE\_TOGGLE (SW3) is activated. Emergency mode would be active when the user decides to trigger fall detection by slightly shaking the board in Climb mode.

# Flowcharts describing the system design and processes

**int main**



**Initialization Mode**



|  |  |
| --- | --- |
| **Climb Mode** | **Emergency Mode** |

# Detailed implementation

|  |  |
| --- | --- |
| **int** **main** (**void**) {  init\_everything();  acc\_read(&x, &y, &z);  xoff = 0-x;  yoff = 0-y;  zoff = 64-z;  moveBar(1, dir);  oled\_clearScreen(*OLED\_COLOR\_BLACK*);  led7seg\_setChar(0xFF, *TRUE*);  **while** (1){  **if** (state == *Initialization*){  do\_Initialization();}  **if** (state == *ItoC*){  do\_toclimb();}  **if** (state == *Climb*){  do\_Climb();}  **if** (state == *Emergency*){  do\_Emergency();}  **if** (state == *Emergency\_over*){  do\_Emergency\_over(); }}} | When the system is first switched ON, all the peripherals will be initialized and the interrupts will be enabled. **FitNUS** will then enter Initialization Mode. The OLED should display “Initialization mode. Press TOGGLE to climb”. Sensors will not be reading any data and no UART transmission should be sent to **FitNUS**.  When SW3 is pressed, **FitNUS** will enter Climb Mode. The OLED should display “CLIMB”. The 7-segment will display the countdown, decrementing from ‘9’ to ‘0’. The sensors will obtain values and store them in variables to be utilised by other functions. The OLED should then display the values obtained.  When fall detection is triggered, **FitNUS** will enter Emergency Mode. The OLED should display “EMERGENCY!”.  In order to make our code less complex, we performed functional abstraction and segmented the codes for the operation modes into several functions outside of the main function and then integrated them back using the conditional while loop. |

|  |  |  |  |
| --- | --- | --- | --- |
| The function “init\_everything()” initializes all the peripherals required for **FitNUS** to work properly (e.g. i2c, GPIO, uart, OLED, etc). We integrated the segmented codes for the initialization of the peripherals back into the function. Additionally, when **FitNUS** is first switched ON, it would configure SysTick to generate an interrupt every 1ms. The SysTick handler updates msTicks every 1ms to give a real time reference to the system.   |  | | --- | | **void** **SysTick\_Handler**(**void**){  msTicks++;} |   We initialized the interrupts for EINT0 (SW3) and EINT3 (SW3, light sensor, temperature sensor and all functions of the joystick). The function will clear any pending interrupts first before clearing the interrupt flags, configuring them and then enabling the interrupt handler. The function will then enable the GPIO interrupt. For instance, to enable the GPIO interrupt for SW3, a ‘1’ would be shifted 4 bits into the register IO0IntEnF, for the GPIO interrupt P0.4 to be enabled, after which the EINT3 interrupt handler will be enabled. Furthermore, as higher pre-empt priority means lower priority, SysTick will come first, followed by EINT3, EINT0 then UART3. This is because SysTick is a clock that controls everything. If a tick is missed, timing is off, EINT3 is used to measure temperature, so it is the 2nd most important. If one interrupt timestep is missed, temperature goes slightly off. EINT0 is used for SW3. Between SW3 and UART, we chose SW3 to be more important so when SW3 is pressed, it is more responsive. | **static** **void** **init\_everything**(){  init\_i2c();  init\_ssp();  init\_GPIO();  init\_uart();  SysTick\_Config(SystemCoreClock/1000);  temp\_init(&Get\_Time);  pca9532\_init();  joystick\_init();  acc\_init();  oled\_init();  led7seg\_init();  speaker\_init();  rgb\_init();  lightSenIntInit();  LPC\_GPIOINT->IO2IntEnF |= 1<<10;  NVIC\_ClearPendingIRQ(*EINT0\_IRQn*);  NVIC\_EnableIRQ(*EINT0\_IRQn*);  LPC\_GPIOINT ->IO0IntEnF |= 1<<4;  LPC\_GPIOINT ->IO2IntEnF |= 1<<5;  LPC\_GPIOINT ->IO0IntEnR |= 1<<2;  LPC\_GPIOINT ->IO0IntEnF |= 1<<17;  LPC\_GPIOINT ->IO0IntEnF |= 1<<15;  LPC\_GPIOINT ->IO0IntEnF |= 1<<16;  LPC\_GPIOINT ->IO2IntEnF |= 1<<3;  LPC\_GPIOINT ->IO2IntEnF |= 1<<4;  NVIC\_ClearPendingIRQ(*EINT3\_IRQn*);  NVIC\_EnableIRQ(*EINT3\_IRQn*);  UART\_IntConfig(LPC\_UART3, *UART\_INTCFG\_RBR*, *ENABLE*);  NVIC\_ClearPendingIRQ(*UART3\_IRQn*);  NVIC\_EnableIRQ(*UART3\_IRQn*);  NVIC\_SetPriorityGrouping(5);  uint32\_t ans = NVIC\_EncodePriority(5, 0, 0);  NVIC\_SetPriority(*SysTick\_IRQn*,ans);  ans = NVIC\_EncodePriority(5, 1, 0);  NVIC\_SetPriority(*EINT3\_IRQn*,ans);  ans = NVIC\_EncodePriority(5, 2, 0);  NVIC\_SetPriority(*EINT0\_IRQn*,ans);  ans = NVIC\_EncodePriority(5, 3, 0);  NVIC\_SetPriority(*UART3\_IRQn*,ans);} | |
| **void** **EINT3\_IRQHandler**(**void**){  **if** ((LPC\_GPIOINT ->IO0IntStatR>>2) & 0x1){  LPC\_GPIOINT ->IO0IntClr = 1<<2;  temp\_periods++;  **if** (temp\_periods == 1) t1 = Get\_Time();  **else** **if** (temp\_periods == 11)  t2 = Get\_Time();  **else** **if** (temp\_periods == 20) temp\_periods = 0;} | | **Temperature sensor**  The EINT3 interrupt obtains the time taken for 11 rectangular wave periods. The temp\_periods value represents the number of times temperature interrupt has happened. This only resets when 20 rectangular wave periods have past. This is because computation time is required for the system to run smoothly. |
| int32\_t **fast\_temp\_read** (**void**){  int32\_t time\_diff = **abs**(t2-t1);  **return** (time\_diff\*1000 / (10\*TEMP\_SCALAR\_DIV10)) - 2731; //\*1000 to convert ms to microsecond} | | This code replaces the slow temp\_read() driver function. The time difference t2-t1 is later used to calculate the temperature, where 10T(C) = (period (us) / scalar\_div10) - 2731 K |
| **if**(temp\_on){  tempvalue = temp\_read();  **if** (tempvalue > TEMP\_THRESHOLD && temp\_flag == 0){  Saved\_State = Climb\_State;  Climb\_State = *Rest*;}  **if** (tempvalue <= TEMP\_THRESHOLD && temp\_flag == 1){  temp\_flag = 0;}} | | If the temperature exceeds TEMP\_THRESHOLD, the OLED screen should display “REST NOW” for 3 seconds before returning to CLIMB Mode. This should only be triggered once every time the temperature exceeds TEMP\_THRESHOLD unless the temperature goes below TEMP\_THRESHOLD and exceeds it once more. |

|  |  |
| --- | --- |
| **Light sensor**  We configure the pins for the light sensor to have a Funcnum of 0 and to be of P2.5. A ‘1’ has to be shifted by 5 bits for the interrupt P2.5 to be enabled. The function would first switch on as well as set the parameters for the light sensor. The interrupt status will be cleared and the light intensity values ranges from 0 Lux to 972 Lux, which is set by light\_setLoThreshold. | **void** **lightSenIntInit**(){  PINSEL\_CFG\_Type PinCfg;  PinCfg.Funcnum = 0;  PinCfg.OpenDrain = 0;  PinCfg.Pinmode = 0;  PinCfg.Portnum = 2;  PinCfg.Pinnum = 5;  PINSEL\_ConfigPin(&PinCfg);  GPIO\_SetDir(2, (1<<5), 0);  light\_clearIrqStatus();  light\_setLoThreshold(LIGHT\_THRESHOLD);} |
| The light sensor should continuously be read. If the light sensor reading falls below LIGHT\_THRESHOLD, the lights on LED\_ARRAY should light up proportionately to how low the ambient light is (i.e. the dimmer the ambient light, the greater the number of LEDs should be lit.) Otherwise, LED\_ARRAY should not be lit. pca9532\_setLeds(ledOn, 0xffff); turns on ledOn and turns off everything else. ledOn takes priority. | **if**(light\_on){  light\_enable();  luminI = light\_read();  shift = luminI / 18.75;  ledOn = (shift <= 16)?(1 << (16-shift)) - 1: 0x0; //max 1<<16 - 1 = 0xffff (16 1's), min 1<<0 - 1 = 0  // if (shift <= 16){ ledOn = (1 << (16-shift)) - 1;}  // else ledOn = 0x0;  pca9532\_setLeds(ledOn, 0xffff);} |

|  |  |
| --- | --- |
| **if**(acc\_on){  acc\_read(&x, &y, &z);  x = x+xoff;  y = y+yoff;  z = z+zoff;  net\_acc = (**sqrt**(x\*x + y\*y + z\*z))/ 64;  **if**(net\_acc > ACC\_THRESHOLD){  **printf**("State changed from Climb to Emergency\n");  state = *Emergency*;}} | **Accelerometer**  The net acceleration (to 1 d.p.) should be displayed on the OLED in the following format: “Acc: x.xx” where x.xx is the net acceleration accurate to 2 d.p., in ‘g’s (1g = 9.8m/s2). Emergency mode may be triggered through fall detection (shaking the board slightly), where net acceleration exceeds ACC\_THRESHOLD in Climb mode. No other modes should be able to trigger Emergency mode. |

|  |  |
| --- | --- |
| **UART** |  |

## General Code Structure

The general code structure that governs each state routine and their subroutines (if any) in our programme is as such:

1. Firstly, there is an if conditional where the current state of the programme is checked via polling. This conditional is the entry point at which the programme first enters each state, be it a main state or a sub-state. In the if conditional block, we execute instructions to initialise the state. For example, we cleared the OLED and 7-segments, and saved the accelerometer readings as we entered the Climb state.

**if**(state == *CurrentState*){

//Initialization of CurrentState

**while** (state == *CurrentState*){

//Remains in CurrentState

//Refreshes CurrentState values

//which may include changes to substates

}}

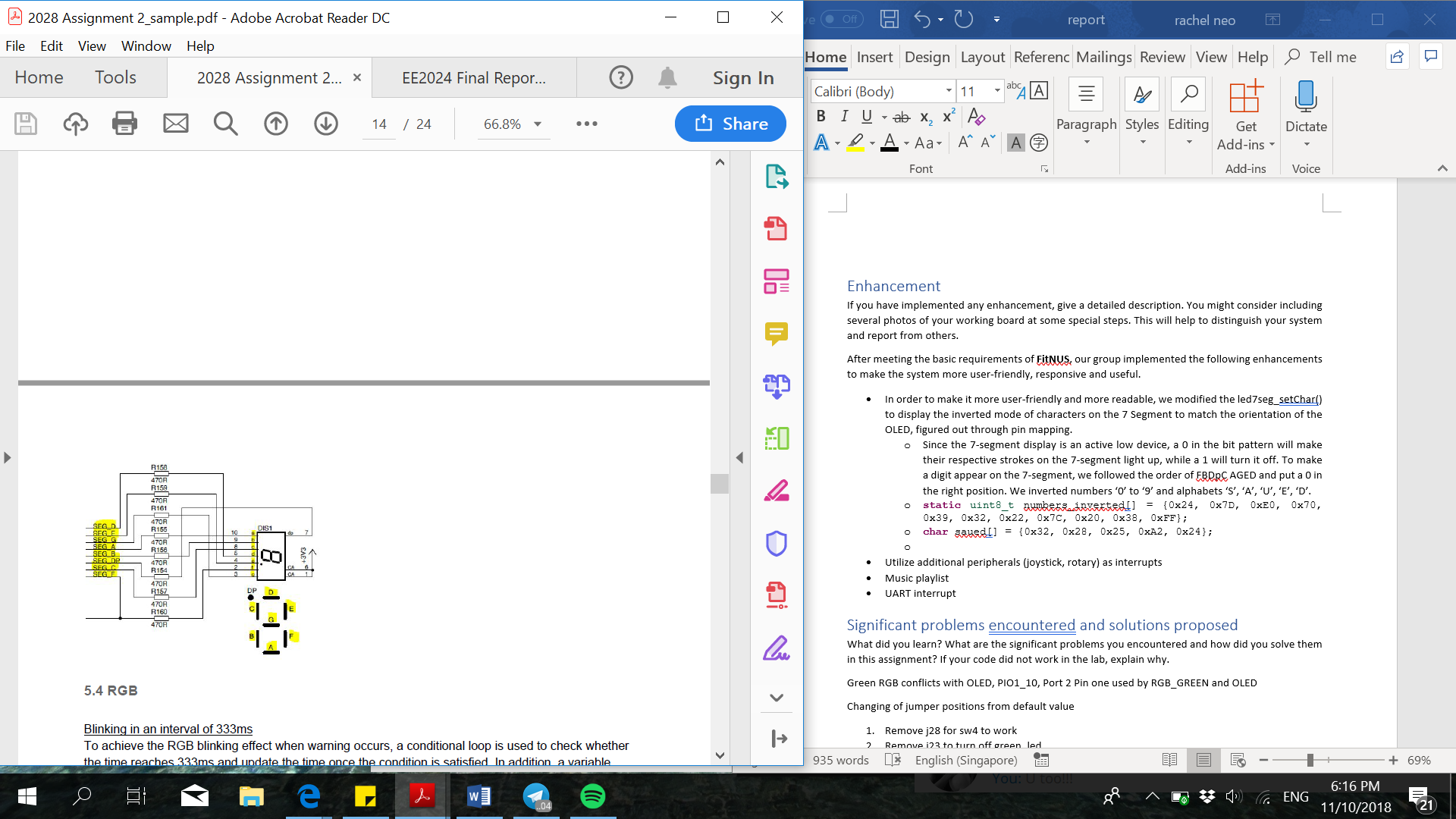
1. Secondly, after the initialization of the state is executed in the if block, there is a while conditional that cycles through instructions to update values and outputs as the programme remains in the state. For example, refreshing sensor readings and refreshing their values on the OLED.

# Enhancement

*If you have implemented any enhancement, give a detailed description. You might consider including several photos of your working board at some special steps. This will help to distinguish your system and report from others.*

After meeting the basic requirements of **FitNUS**, our group implemented the following enhancements to make the system more user-friendly, responsive and useful.

## 7 Segment

In order to make it more user-friendly and more readable, we modified the led7seg\_setChar() to display the inverted mode of characters on the 7 Segment to match the orientation of the OLED, figured out through pin mapping.

* Since the 7-segment display is an active low device, a 0 in the bit pattern will make their respective strokes on the 7-segment light up, while a 1 will turn it off. To make a digit appear on the 7-segment, we followed the order of FBDpC AGED and put a 0 in the right position. We inverted numbers ‘0’ to ‘9’ and alphabets ‘S’, ‘A’, ‘U’, ‘E’, ‘D’.
* **static** uint8\_t numbers\_inverted[] = {0x24, 0x7D, 0xE0, 0x70, 0x39, 0x32, 0x22, 0x7C, 0x20, 0x38, 0xFF};
* **char** saued[] = {0x32, 0x28, 0x25, 0xA2, 0x24};

## [Image result for ipod nano](https://www.google.com.sg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjEuveDvszeAhXMuY8KHcxwCZsQjRx6BAgBEAU&url=https://www.amazon.com/Apple-Graphite-Generation-Discontinued-Model/dp/B002L6HE9G&psig=AOvVaw1UF4kVDoqh-tkpb_VkBXEP&ust=1542030667570324)Music Player

### Motivation

Learning about interrupts that are able to pre-empt currently running processes, we wondered if we are able to design a programme in such a way to re-enter the thread mode, from the Interrupt Service Routine (ISR), at an instruction line different from where we left off. One such application of this would be to interrupt a playing song with the press of a button, pause the song and execute another function in thread mode with no intention of returning to play the remainder of the song. This can be done with hyper-threading which is unfortunately out of the scope of this project. Fortunately, this can also be done with logic enhancements to the code.

We shall hence attempt to implement this in the form of a Music Player, inspired by the iPod Nano.

### Frontend: Graphical User Interface Design

**Controls:** user input is done through the joystick using GPIO interrupts.

* **Up/ Down**: scroll up/down for song selection when no song is playing, next/ previous when a song is playing
* **Center**: play/ pause a song by selecting it
* **Left/ Right**: move to the menu screen on the left or right. For our case, as we only have two user selectable menu screens in Climb mode (the third begin Rest which can only be triggered from temperature), moving left or right from Music mode will result in the sensor reading screen and vice versa.

**Display:** Similar to how a handphone or an MP3 player displays songs, our GUI will take the form of the OLED, where song titles are displayed for the user to select from.

* As shown in the image, the currently selected song will be highlighted white
* **Scrolling**
  + One limitation we faced was that the OLED updates with a noticeable delay. Thus, it will not be viable to refresh the entire OLED each time there needs to be a change in some part of the screen. Our code will hence need to identify the parts of the screen to be updated each time the user scrolls to select a different song, and only refresh the identified pixels. This was done by setting flags and counters each time the up or down joystick buttons are pressed.

//JOYSTICK\_DOWN

**else** **if** ((LPC\_GPIOINT ->IO0IntStatF >> 15) & 0x1){

LPC\_GPIOINT ->IO0IntClr = 1<<15; //clear the interrupt

prev\_song\_index = song\_index;

song\_index = (song\_index < number\_of\_songs-1)? song\_index+1: 0;

scroll\_updated = 0;

song\_changed = 1;

}

//JOYSTICK\_UP

**else** **if** ((LPC\_GPIOINT ->IO2IntStatF >> 3) & 0x1){

LPC\_GPIOINT ->IO2IntClr = 1<<3; //clear the interrupt

prev\_song\_index = song\_index;

song\_index = (song\_index > 0)? song\_index-1: number\_of\_songs-1;

scroll\_updated = 0;

song\_changed = 1;

}

The flag, scroll\_updated, is set to 0 each time the button is pressed to indicate that the OLED is due for a refresh. It is checked via polling in the Music sub-routine.

song\_index and prev\_song\_index are counters that indiacate the pixels to be refreshed.

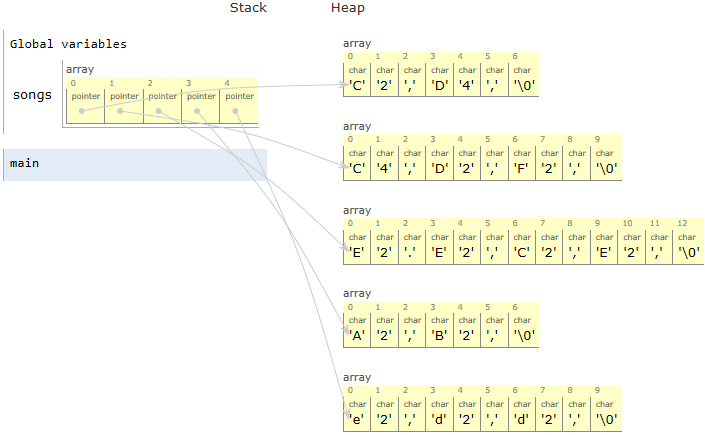
**if**(scroll\_updated == 0){

oled\_putString(0, prev\_song\_index\*10 + 10, (uint8\_t \*) song\_titles[prev\_song\_index],…

oled\_putString(0, song\_index\*10 + 10, (uint8\_t \*) song\_titles[song\_index],…

}

### Backend: Song Library Storage and Retrieval

Our library of songs is stored in a 2-dimensional array, songs, as illustrated in Figure 1. Each element in songs contains the pointer to the first note of each song which is stored in a heap. This way, when we want to access the second song in the array, we do not have to recurse through the first song to reach the starting address of the second song and can instead move to the next element in songs, the length of each song is hence also allowed to be arbitrary by this design.

To keep track of the progress as songs are played, we used 2 global variables:

1. song\_index: variable that tracks the Y-axis of the 2D array which is the starting address of the song currently selected relative to the starting address of the array.
2. song\_pointer\_count: variable that tracks the X-axis, the address of the last note that was played relative to the address of the first note in the current song.

Here, we note that every adjacent note is 3 intervals apart. Hence, the pointer will have to increase by 3 to point to the next note (line 25).

Figure 1: Song Library

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

**static** **void** **playSong**(uint8\_t \*song) {

……

**if**(song\_changed){

song\_pointer\_count = 0;

song\_changed = 0;}

**else**{

**while**(i<song\_pointer\_count){

\*song ++;

i++;}}

**if**(\*song != '\0' && play\_flag){

note = getNote(\*song++);

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;

**return**;}

dur = getDuration(\*song++);

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;

**return**;}

pause = getPause(\*song++);

playNote(note, dur);

Timer0\_Wait(pause);

song\_pointer\_count += 3;}

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;}}

**static** **void** **playSong**(uint8\_t \*song) {

……

**if**(song\_changed){

song\_pointer\_count = 0;

song\_changed = 0;

}

**else**{

**while**(i<song\_pointer\_count){

\*song ++;

i++;

}

}

**if**(\*song != '\0' && play\_flag) {

note = getNote(\*song++);

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;

**return**;

}

dur = getDuration(\*song++);

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;

**return**;

}

pause = getPause(\*song++);

playNote(note, dur);

//delay32Ms(0, pause);

Timer0\_Wait(pause);

song\_pointer\_count += 3;

}

**if** (\*song == '\0'){

song\_pointer\_count = 0;

play\_flag = 0;}}

### Backend: Processing

**if**(state == *Climb*){

**if**(Climb\_State == *Music*){

//JOYSTICK\_CENTER

**if** ((LPC\_GPIOINT ->IO0IntStatF >> 17) & 0x1){

LPC\_GPIOINT ->IO0IntClr = 1<<17; //clear the interrupt

play\_flag = (play\_flag)?0:1;

}

}

//JOYSTICK\_RIGHT

**if** ((LPC\_GPIOINT ->IO0IntStatF >> 16) & 0x1){

LPC\_GPIOINT ->IO0IntClr = 1<<16; //clear the interrupt

Climb\_State = (Climb\_State == *Music*)? *None*: *Music*;

}

//JOYSTICK\_LEFT

**else** **if** ((LPC\_GPIOINT ->IO2IntStatF >> 4) & 0x1){

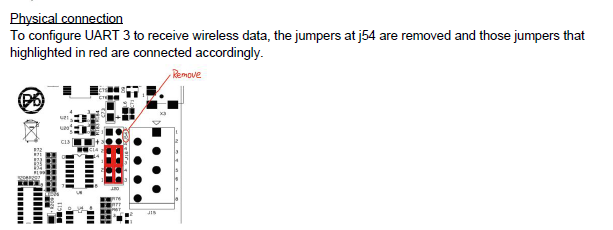
LPC\_GPIOINT ->IO2IntClr = 1<<4; //clear the interrupt

Climb\_State = (Climb\_State == *Music*)? *None*: *Music*;

}

}

## UART interrupt



# Significant problems encountered and solutions proposed

What did you learn? What are the significant problems you encountered and how did you solve them in this assignment? If your code did not work in the lab, explain why.

## Reading of Temperature Sensor causes system lag

The temp\_read() function provided in the temperature sensor library is a blocking function, containing lines such as shown below that waits for GET\_TEMP\_STATE to change before the function proceeds to the next instruction.

**while**(GET\_TEMP\_STATE == state);

Furthermore, there is a for loop that loops for up to 340 times when both pins U7-TSI0 and U7-TSI1 are set to 0. The purpose of this, we presume, is to do a smoothing on the temperature reading across the set time interval to minimise noise. As our programme is not reading the sensor in real time, but rather at a fixed time interval set by sensor\_refresh\_ticks, smoothing in sensor readings are not necessary for us. We will however, take the average temperature reading over 10 periods to get a more reliable reading. We have hence written our own temp read function using an interrupt.

**void** **EINT3\_IRQHandler**(**void**){

// Temperature sensor

**if** ((LPC\_GPIOINT ->IO0IntStatR>>2) & 0x1){

LPC\_GPIOINT ->IO0IntClr = 1<<2; //clear the interrupt

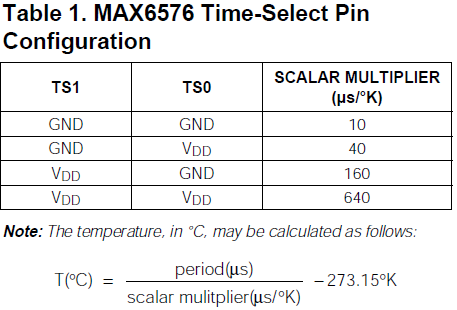
temp\_periods++;

**if** (temp\_periods == 1) t1 = Get\_Time();

**else** **if** (temp\_periods == 10) t2 = Get\_Time();

**else** **if** (temp\_periods == 20) temp\_periods = 0;

}

By this formula given in the datasheet, we can define our function as shown.

// Replacement for slow temp\_read() driver function

int32\_t **fast\_temp\_read** (**void**){

//10T(C) = (period (us) / scalar\_div10) - 2731 K

**return** **abs**(t2-t1)\*1000/(10\*TEMP\_SCALAR\_DIV10)-2731;

}

## Green RGB conflicts with OLED

**void** **rgb\_setLeds** (ledMask){

…

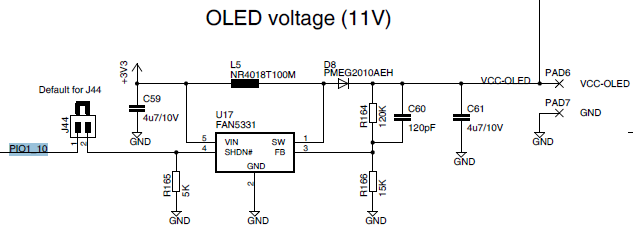
**if** ((ledMask & RGB\_GREEN) != 0)

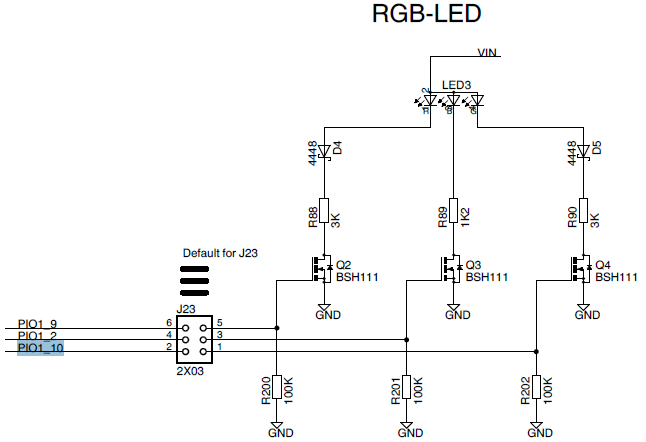
GPIO\_SetValue( 2, (1<<1) );

**else**

GPIO\_ClearValue( 2, (1<<1) );

PIO1\_10, which is connected to P2.1 is used by both RGB\_GREEN and OLED voltage. The default driver function **rgb\_setLeds** clears P2.1 each time the function is called and RGB\_GREEN is not turned on, affecting OLED functionality. For the blue and red LEDs to alternate every 500ms, the green LED should also be turned off throughout.

As RGB\_GREEN is not required for this project, we have written our own **setRGBLeds** function that does not clear P2.1 and removed the jumper J23 shown below to physically turn off RGB\_GREEN.



## Default Jumper settings prevents affects SW4 functionality

A jumper at J28 grounds PIO1\_4, incorrectly indicating active low SW4 as pressed. We remove jumper J28.

## Blue RGB conflicts with Speaker

Connecting Input of blue led to PWM output, PIO2\_6

## Reset to Initialization Mode for Debugging

# Issues or suggestions

These feedbacks, whether positive or negative, will not affect your marks in any way, but will make the report more complete.

As this is the first hardware programming project we did on LPC, there were many times when we got stuck, baffled by lines of codes that seems to work but did not. Fortunately, we were able to readily consult the various teachers, lab staff, and graduate assistances who are not only very knowledgeable, spotting our errors instantly, but also extremely patient when explaining the concepts to us. And we are very grateful for you all!

# Conclusion