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Course: ECC3303 Embedded System Design

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Project Report Group 12

AIoT – BASED SMART DIAPER

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1.0 Abstract

There are several common problems that usually happen during taking care of a baby, elders or even a patient regarding handling their diapering routine and their health. These problems could make the caretakers feel more stressful and tired of managing them as it continuously happens. In this project, we will discuss more on the problems that commonly occur during taking care of their cares and their solutions by using AIoT that we learned during the ECC3303 course. We will be exposed with a brand-new project, *Smart Diaper* which really benefits both the caretaker and the person in need themselves. This report will explain the problems, solutions, methodology, prototype and its results.

Keyword:
Smart Diaper; Diaper; Caretaker; AIoT; Embedded System.

2.0 Literature Review

2.1 Health Condition and Diaper Management Problems

Normal pH range of urine

The article discussed by Nall and medically reviewed by Amin in [2] has explained specifically on the normal pH range of urine and possible problems due to pH abnormalities. Urine is a liquid waste produces by body that comprises of water, salt, and waste products from the kidney. The average pH value of urine is at 6.0 but can vary from 4.5 to 8.0 as mentioned by American Association for Clinical Chemistry. High and low pH value of urine indicates changes in body and exposure to health problems. High alkalinity of urine pH alerts several medical conditions including kidney stones, urinary tract infection (UTI) and kidney-related disorders whereas the high acidity at low pH value open possibilities to diabetic ketoacidosis, diarrhea, and starvation. Urine pH is tested for it is feasible option to an early diagnose of infection.

Diaper Dermatitis in Infants

Pogacar et al. studied on the diagnosis and management of diaper dermatitis in infants and mentioned that diaper dermatitis is an inflammatory reaction of skin within the diaper area and includes buttocks, genitals, perianal area, inner thighs, and waistline [3]. Diaper dermatitis can cause a stress to both parents and infants even though it does not lead to severe medical condition. Various factors contribute to diaper dermatitis one which is a prolonged dampness and urine in the diaper, friction, and mechanical abrasion. The underlying causes to diaper dermatitis also include feces containing multiple irritants that disrupt the protective layer of skin, and the mixture of urine and feces resulting in skin exposure to bacterial colonization that increases pH level of skin which in turn leads to contraction of diaper dermatitis. Pogacor et al. also mentioned in [3] that infants are prone to skin inflammation and more vulnerable to pathogens and allergens. A correlation is made between diaper dermatitis and frequency of diaper change. Frequency of diaper dermatitis in infants is inversely correlated with the frequency of diaper change such that when the diaper is frequently changed, the infants are less vulnerable to microorganisms and less prone to contract diaper dermatitis. Pogacar et al. suggested in the study to practise hygienic cleansing routine, monitor the type of diaper used and increase the frequency of diaper change amongst other solutions to both prevent and treat diaper dermatitis. A fresh diaper should be used after each urination or defecation.

Urinary Incontinence in Elderly

According to [4], a common problem faced by the elderly population particularly who resides in nursing homes and have dementia is urinary incontinence (UI). Urinary incontinence is loss of bladder control or in other words, involuntary urination which is uncontrolled leakage of urine. Severe problem of urinary incontinence leads to urinary tract infections (UTI) which is often seen as a burden in healthcare. Urinary incontinence has caused distressing problems to both elderly and caregiver. The quality of life is compromised as elderly lose their self-esteem, pride, and dignity. The situation is detrimental for physical, social, and emotional state of elderly. The caregivers are put under pressure in such conditions to ensure an efficient continence management. Centers for Disease Control and Prevention recorded 45.4% of elderly in nursing homes with bladder and/or bowel control problems. 40.2% of them experiences difficulties to control bladder and 14.2% of them have problems with bowel control. The SenseLife Smart Diaper proposed in the study aims to aid the elderly with urinary incontinence problem and ease the life of caregiver, for it suggests an efficient continence management system. The diaper is equipped with wetness sensor with humidity sensor to determine the dampness of diaper, thermal detector for urine temperature and chemical analysis, and electrochemical biosensor to detect contraction of UTI. The drawbacks of the SenseLife Smart Diaper discussed in the study include the difficulty for the caregivers to familiarize with the system, and the implementation cost for the new technology is unascertained.

2.2 Smart Diaper Technology Implementation

RFID-Based Smart Diaper

Sidén et al. has conducted a research [5] to integrate a smart diaper with a moisture detection system that aims to modernize elderly’s lifestyle towards a more hygienic and improved healthcare environment, and efficient care management by the caregivers. The system implements an alarm system that will alert the caregiver to change the diapers when necessary.

In Sidén et al.'s research, RFID tag with integrated moisture sensor was incorporated on the diaper to test for its working and functionality. The moisture sensor is activated only when the diaper is wet, thus driven an adequate amount of energy to oscillator circuit for a radio signal transmission. The receiver is expected to produce an alarm when the transmitted RF signal is successfully detected on the end. In the research, the functionality of smart diaper was tested in a hospital ward setting with a wall-mounted docking station, handheld receiver unit and the diaper AAT sensors. Action Activated Tag (AAT) used in the system satisfied the ideal characteristic of a smart diaper with a relatively low cost, for the RFID tag chosen is inexpensive and disposable. The issue with EM radiation is eliminated, for the radiation is far too weak to expose the subjects and surroundings to danger.

In another study [6], Lazaro et al. has a unique approach on smart diaper implementation where the design proposed is a battery-less smart diaper that incorporates Near Field Communication (NFC) tag. Several works on smart diaper use Radio Frequency Identification (RFID), a passive wireless sensor due to the attractive properties and qualities including low production cost. RFID is a popular option to a widely endorsed and growing Internet of Things (IoT). NFC is a type of RFID commonly used in payment cards. Development of a low-cost low-range sensor is possible with NFC technology which is a practical choice for smart diaper. NFC eliminates the need for pairing and allows the smartphone to receive all information when the reader is placed near the tag. One downside of NFC is it can only read signal from a short range. The proposed technology for the diaper includes moisture sensor that is based on a capacitive sensor. According to Lazaro el al., the proposed NFC-based smart diaper is the pioneer to the technology without the need for tag insertion into the diaper and to the moisture detection system using capacitive sensor. The capacitive moisture detector is a connection of two electrodes to a microcontroller where the difference in capacitance between the electrodes are utilized to detect the presence of urine in the diaper. The I2C serial communication interface allows communication between microcontroller and NFC IC.

Chu in her article [7] mentioned that wearing a wet diaper can cause painful rash to babies. Researchers from Massachusetts Institute Technology (MIT) have proposed several design of smart diaper systems with embedded moisture sensor to notify the caregiver through smartphone when the diaper is wet. The super absorbent polymer has an RFID tag attached underneath that is triggered when the hydrogel is wet. RFID reader receives RF signal transmitted by the tag from up to a meter range. The proposed smart diaper appears handy particularly to nurses dealing with multiple babies and incontinence problems. The available moisture detection of diapers in the current market is in form of strips and stickers on the diaper that notices a colour change. The plan for further development of smart diaper includes reusable, wireless, Bluetooth-enabled sensors to be attached on the diaper. RFID tag is proposed by the researchers for its low-cost and disposable characteristics and can be printed out in rolls as stickers. The further development to improve RFID technology smart diaper shows that addition of a slight amount of copper to the sensor will enhance the sensor conductivity, therefore, allows signal to be read from a distance longer than one meter.

Bluetooh Low Energy (BLE) Technology

According to a study conducted by Arpitha et al. [8], rashes and dermatitis are often contracted by infants which put them in a detrimental condition, and all is due to wet diapers. The inconvenience from having to regularly monitor the diaper led Arpitha et al. in their study to design an IoT-based smart diaper to develop an intelligent healthcare system. Smartphone and Bluetooth low energy (BLE) transmitter detects the wetness of the diaper with flexible conductors placed into the area of highest urine absorption of the diaper. Implementation of a moisture detection system involves three sensors use in different layers of the diaper with the first is between waterproof and extra absorbent layer for an efficient fluid or moisture detection, and the remaining two sensors are between extra absorbent layer and wick away liner. The proposed diaper with moisture detection system aids in diaper removals, therefore, enhances productivity of parents, nurses, or caretaker, and prevents skin infection and inflammation in babies and urinary infection in elderly. The proposed system incorporates a wireless alert system via smartphone which starts ringing when received a signal from BLE transmitter which signal originates from the wet detection on the diaper. The modular design of the smart diaper allows notification management on the smartphone by parents or admin to be ON to receive notifications and to be OFF for otherwise.

According to a study by Wen [9], the proposed Goo9 system enable detection of wet diapers and reminder system through notification in Android or iOS smartphones. Implementation of Goo9 system include detection sensor module, data processing module, a cloud-based database, and a baby profile module. The wetness of the diaper is monitored by a temperature and humidity sensor under detection sensor. The technology applied in Goo9 is advanced and efficient where it consumes low power with Bluetooth 4.0 technology which ensure the infants' safety. The technology guarantees high precision on data collection with stable and precise temperature and humidity sensors from Sensirion. Data collection reveals information on the wetness level of the diapers. Parents or caretakes will be able to know the diaper condition whether it is dry, slightly wet, wet, or very wet using smartphone through notification system which the conditions are represented in four different emoticons: happy, mild, uncomfortable, and crying, respectively. Goo9 system also enable feedback by the users to provide a more precise deduction of the diaper condition in the future. Overall, Goo9 introduces the concept of "active reminding" which alerts the parents or caregivers right away and aims to replace the inefficient method of checking the diapers manually for every significant hour. The manual checking is impractical, wearying, and difficult for caregivers in day care, or hospitals.

In a study by Khan [10], a smart wearable gadget is proposed for diaper moisture detection and notification system. Smartphone will automatically receive a notification for every time the baby urinates from the signals transmitted by the gadget. The gadget is reusable, for it is a small, electronic device attached to the external side of diaper using hook-and-loop fasteners and can be worn to any type of disposable diapers. The gadget greatly improves the diaper change efficiency while maintaining a low-cost and safety properties. The proposed wearable gadget detects urination events by sensing the temperature rise on the outer surface of diaper. A healthy baby has body temperature between 97 to 100.3 ℉ in a room temperature of 65 to 74 ℉. Urination event is detected when one side of the diaper has an increase in temperature. Bluetooth Low Energy (BLE) module is used in the system to allow communication with smart mobile devices to enable notification. Two temperature sensors are used in the system architecture to detect both ambient temperature and temperature on the diaper surface. The gadget is to be attached to a new diaper after every change, and “new diaper button” is pressed to indicate a new diaper is put on. 3 volts and 240 mAh coin cell battery supplies current to the gadget.

RF Transceivers and mobile GSM alarm system

Mohamed et al. proposed in [11] a smart diaper which calls for an automated alarm system as a preventive solution for skin rashes due to wet diapers. The wet detector system comprises of wet sensor, wet detector unit, RF transceiver, GSM alarm system and computer. The proposed diaper is an alternative to the existing effort such as Huggies TweetPee and Potty Patrol with advanced features and high technology implementation. When the diaper is wet, alarm system is triggered and the person in charge of the diapers will be alerted through mobile call, audio alarm or SMS. The proposed design has RF transceiver and mobile call GSM alarm system integrated on the diaper. Amplitude Shift Keying (ASK) is used in the radio frequency (RF) transmission. The input signal is transmitted via RF to the receiver. Mohamed et al. implemented a four-channel system via GSM door sensor to enable wireless communication from when the diaper is wet to the alert from GSM alarm system. Mobile Call GSM alarm system has been used in various application. The smart diaper applies the concept of GSM alarm system such that when the alarm is triggered, mobile network allows users to be immediately notified through voice call or SMS. Wet detector transmits signal through RF transmitter to RF receiver which relays the wireless signal to GSM door sensor and GSM next. The caregiver or person in charge will receive a call or SMS which indicates the diaper is wet. The alarm system is operated by mobile call GSM system and allows up to six mobile numbers to be addressed.

3.0 Proposed Methodology

3.1 System Features

The features implemented in the smart diaper system aims to help the caretaker to monitor the diaper of the babies or elderly. The system implementation applies Artificial Intelligence of Things (AIoT) concept where it is divided into two elements which is Artificial Intelligence (AI) and Internet of things (IoT). The Artificial Intelligence of Things involves combination of Artificial intelligence technologies with the Internet of things infrastructure to achieve more efficient IoT operations, improve human-machine interactions and enhance data management and analytics. The system promotes an efficient diaper change management.

Artificial Intelligence

The system feature includes an embedded moisture sensor that can alert a caregiver when a diaper is wet. When the sensor detects dampness in the diaper, it sends a signal to a nearby receiver, which in turn can send a notification to the devices. It is also embedded with a MPU6050 sensor which detects gyroscope and an accelerometer. The gyroscope is used to determine the orientation and the accelerometer provides information about the angular parameter such as the three-axis data. Caretaker will know the body position of the user and detect if the user fall.

Internet of Things (IoT)

The WIFI module is used to connect and send the notification to alert the caretaker. The information of the diaper will be updated by sending the notification to the caretaker through the application on the smartphone. With the IoT technology equipped in the system, it is easier for parents or caretakers to monitor the condition of the diaper.

System Features

The proposed smart diaper consists of three system implementation which are moisture detection, posture monitor and fall detection. Notification is sent to the smartphone when the diaper is wet, and a fall is detected. The posture monitor enables the parents or caretaker to monitor the position the baby is in and make changes when necessary to prevent discomfort to baby.

3.2 Block diagram of the system

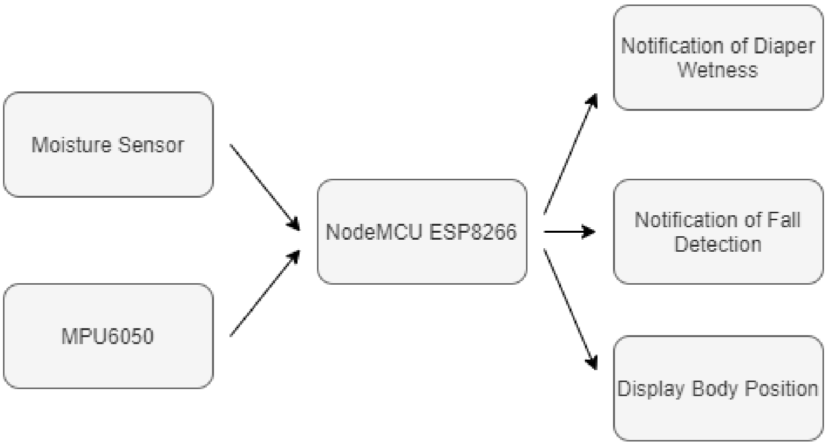


Figure 1: Block Diagram of AIoT Smart Diaper

In a smart diaper system as shown in the block diagram in Figure 1, there are two inputs and three outputs. The first input is the moisture sensor will read the updated sensor value to determine the wetness of the diaper. The next input is the pH sensor, it will read MPU6050 sensor which detects gyroscope and an accelerometer. It will detect the user's body position and fall detection. The microcontroller of the system is NodeMCU ESP8266 (WIFI module), it is used to connect with the application on the smartphone as it will transmit all the information that the sensor gained from the diaper. Meanwhile, the output of the system is the smartphone will receive three information in the notification which is the level of the diaper wetness, fall detection and the body position.

3.3 Flowchart

System Flowchart

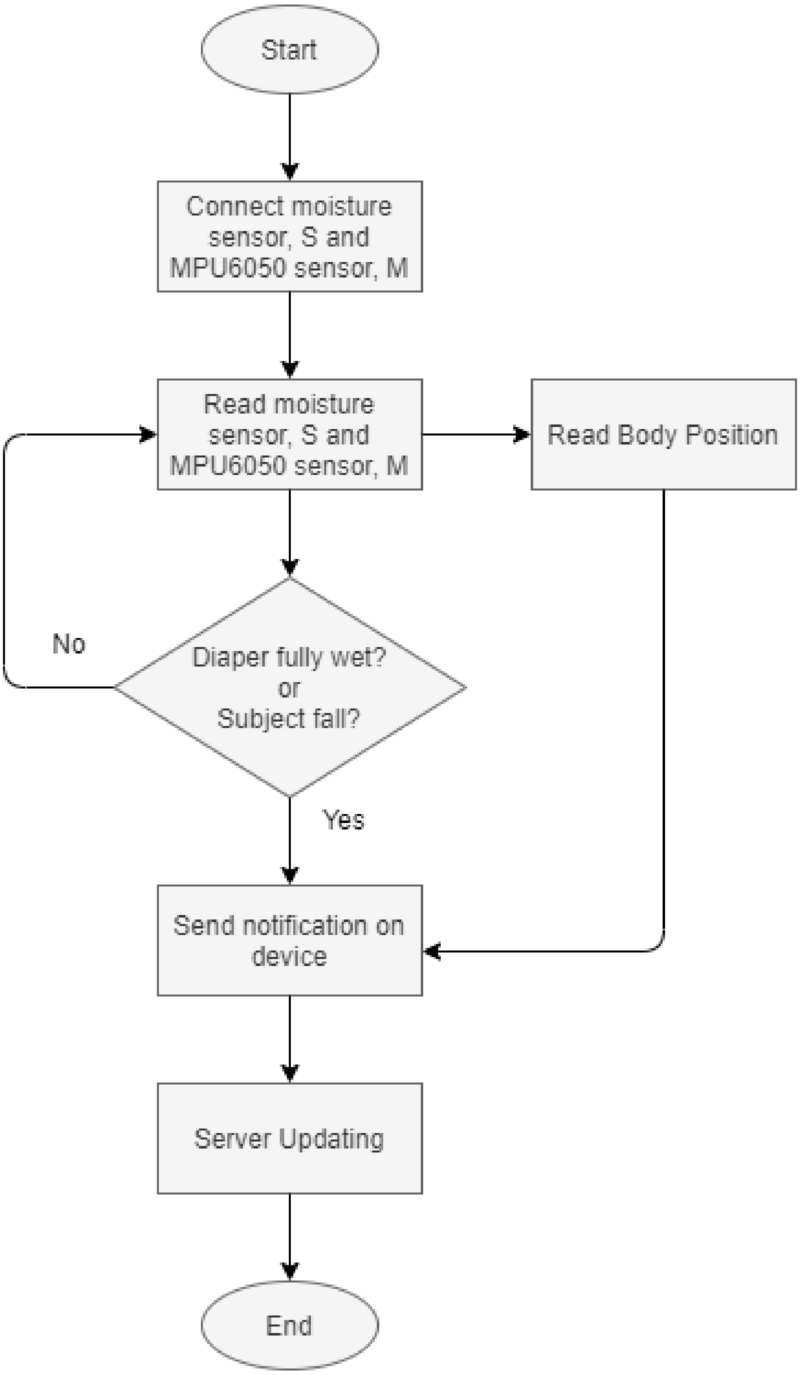


Figure 2 (a): System flowchart of AIoT Smart Diaper

Figure 2 (a) shows the flow chart of the smart diaper system. Firstly, the user needs to connect with our moisture detector sensor and MPU6050 sensor. After that Blynk application will always read the sensor data and determine either the diaper is dry, slightly wet, or too wet. When the diaper is wet by urine, sensor data fall than the threshold value. At this moment, the notification will be sent to the smartphone and upload a warning message to the server. The server sends messages to the entire user who wants to know the condition of the diaper. It also will send the notification if the user fall and display the user body position.

Programming Flowchart

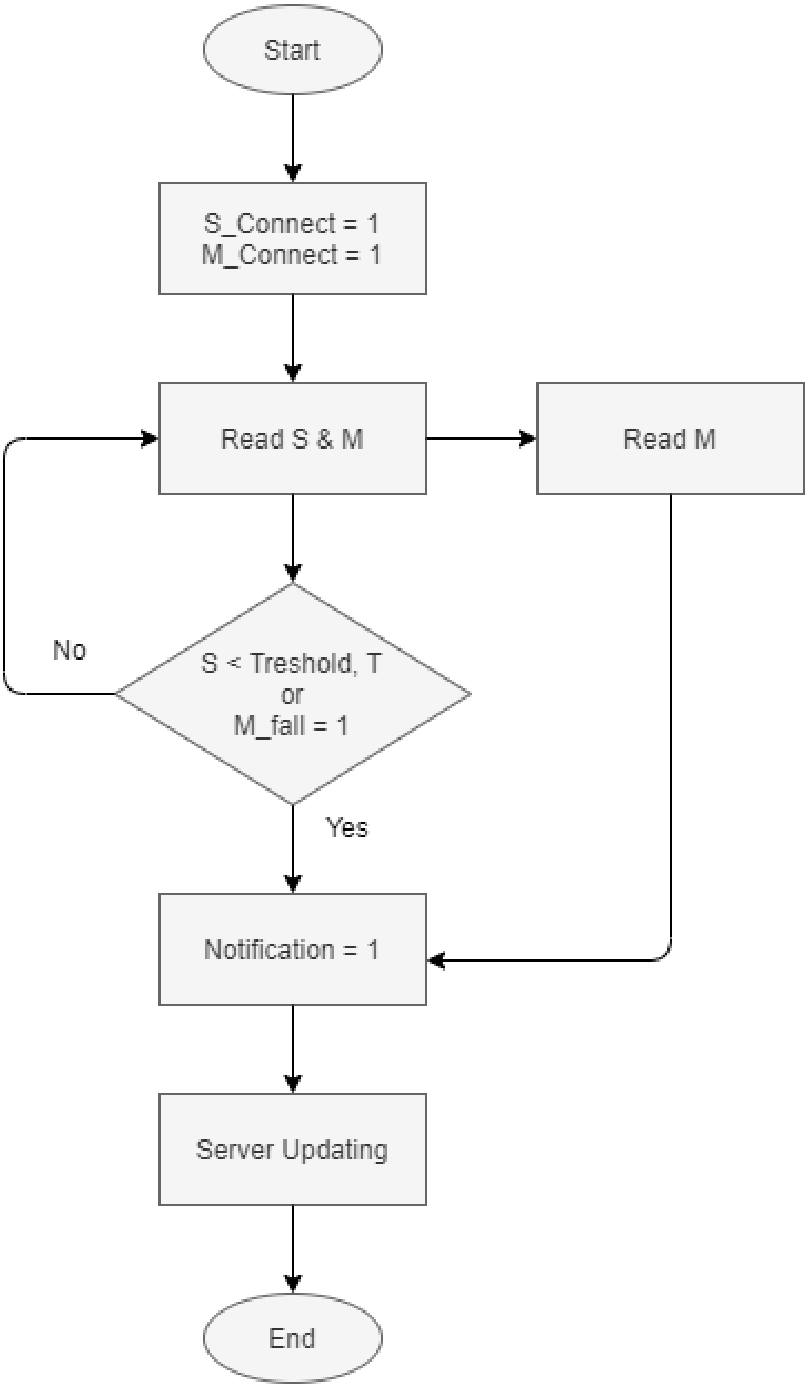


Figure 2 (b): Programming flowchart of AIoT Smart Diaper

Figure 2 (b) shows the programming flowchart of the smart diaper system. Firstly, the user needs to make sure that Sensor =1 is connected to the moisture detector sensor and MPU6050 sensor. After that, it will always read the sensor data, S, and compare with the threshold value, P. When the diaper is wet by urine, sensor data fall than the threshold value. This time, the Notification =

1 which sends a notification to the smartphone application and uploads a warning message to the server. The server sends messages to the entire user who wants to know the condition of the diaper. It also will send the notification if the user fall and display the user body position.

4.0 Results

The proposed smart diaper is equipped with three unique features which include moisture detection system, posture monitoring system, and fall detection system. The major components used in the implementation of smart-diaper are NodeMCU, MPU6050 and FC-28 moisture sensor.

- NodeMCU – low-cost open source IoT platform
- MPU6050 – sensor for motion processing device
- FC-28 – moisture sensor to detect wetness level.

Blynk application is used to develop the interface of the smart diaper system. Figure x below shows the interface the parents can monitor on smartphone.

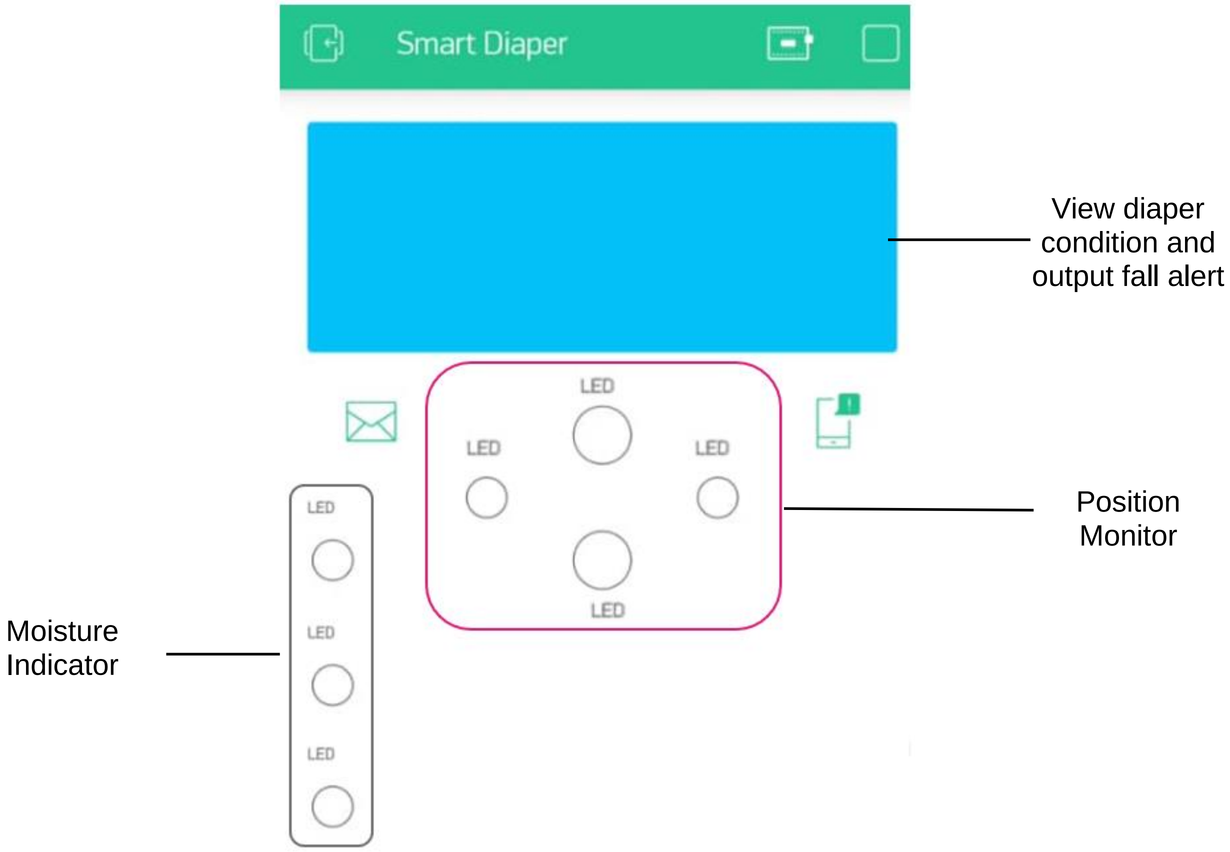


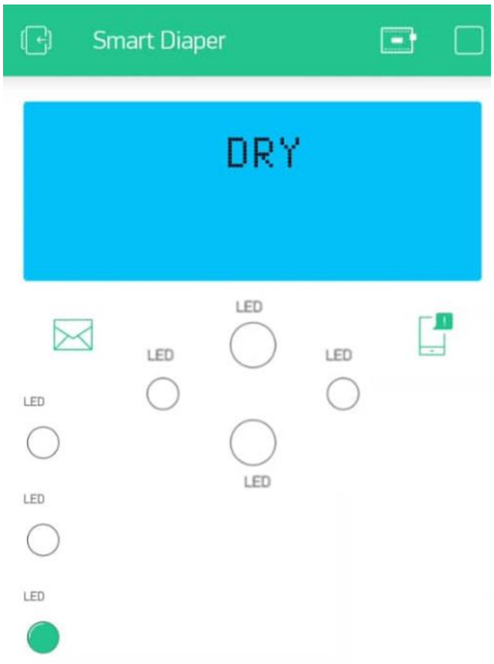
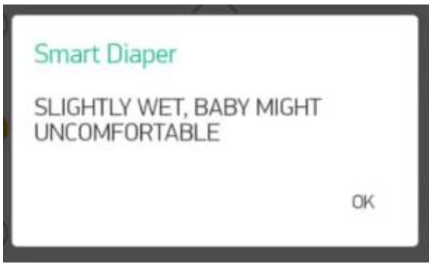
Figure 3: Interface of smart diaper system

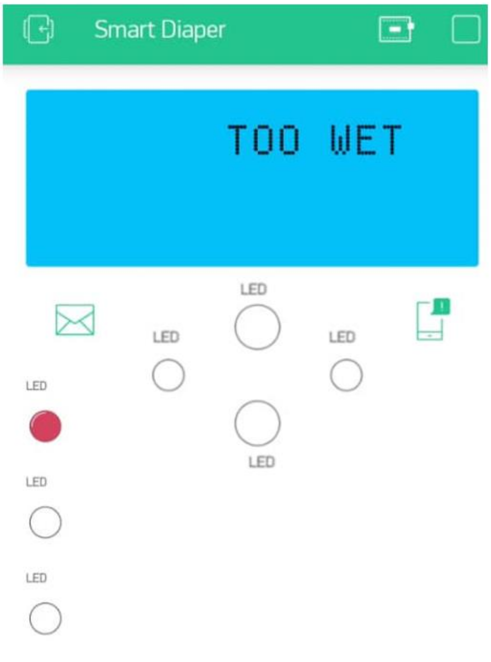
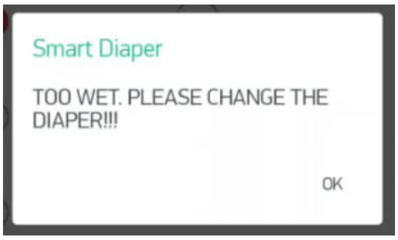
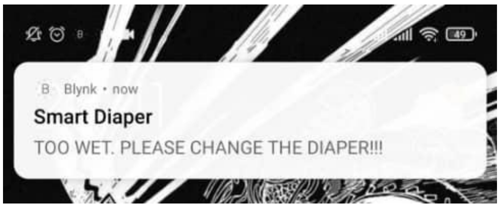
4.1 Moisture Detection System

Figure 4: Prototype testing for moisture detection

Moisture detection is implemented using FC-28 moisture sensor. The proposed smart diaper sends notification when the diaper is wet so that immediate action can be taken. The wetness level is classified into three which are dry, slightly wet, and extremely wet. Dry diaper will not send any notification or alert. The dry status of the diaper can be viewed in the Blynk application. When the diaper is slightly wet, a notification reads “slightly wet, baby might be uncomfortable” is sent to the smartphone. When the diaper is extremely wet, an output notification reads “too wet, please change the diaper!”. The wetness level is determined by adjusting the input value received by the sensor. Aside notification, the status of diaper can be viewed from the application. Three LEDs act as moisture indicator and different color of LED indicates the different status of diaper. LED is green, orange, and red when the diaper is dry, slightly wet, and extremely wet, respectively.

Table 1: Output of moisture detection system

Wetness Level	Output Interface	Notification
Dry		No notification
Slightly Wet		 Notification on Blynk  Notification on smartphone

Too Wet		 Notification on Blynk  Notification on smartphone

4.2 Posture Monitoring System

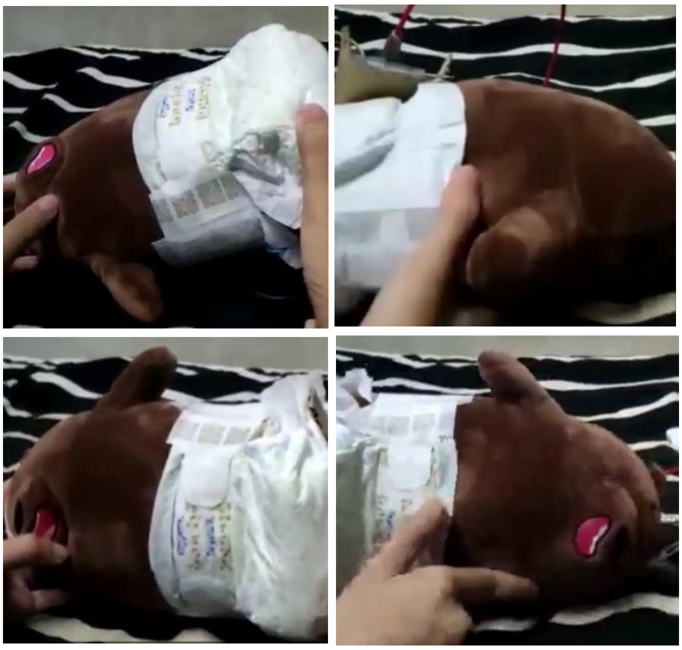


Figure 5: Prototype testing of posture monitoring system

MPU6050 consists of 3-axis accelerometer and 3-axis gyroscope that is suitable to determine the orientation of an object thus why it is used as the posture sensor. The serial monitor outputs a different x, y and z value for every posture. The posture sensor enables the parents or caretaker to monitor the posture of baby, so they can change the baby's position if the baby is in an uncomfortable position. The baby's posture is categorized into four possible postures with four

LEDs being used to determine the posture of the baby. When the baby is lying on his back and facing upwards, a blue LED will light up on screen. When the baby is lying flat on his tummy and facing downwards, green LED lights up. Red and green LED lights up next when the baby tosses and turns, and eventually faces the left and right sides, respectively.

The position of the baby is determined by manipulating the value of accelerometer at x and y-axis. Table 2 shows the threshold value for accelerometer at x and y axis whereas Figure 6 shows the output on serial monitor when the posture is varied.

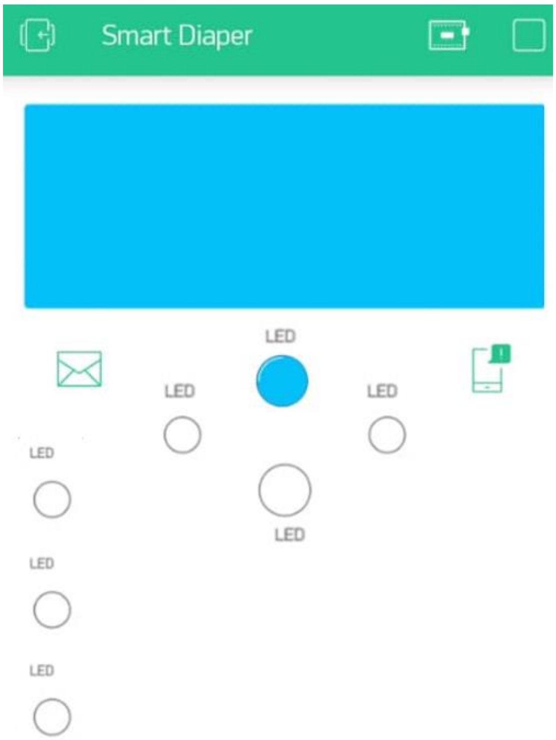
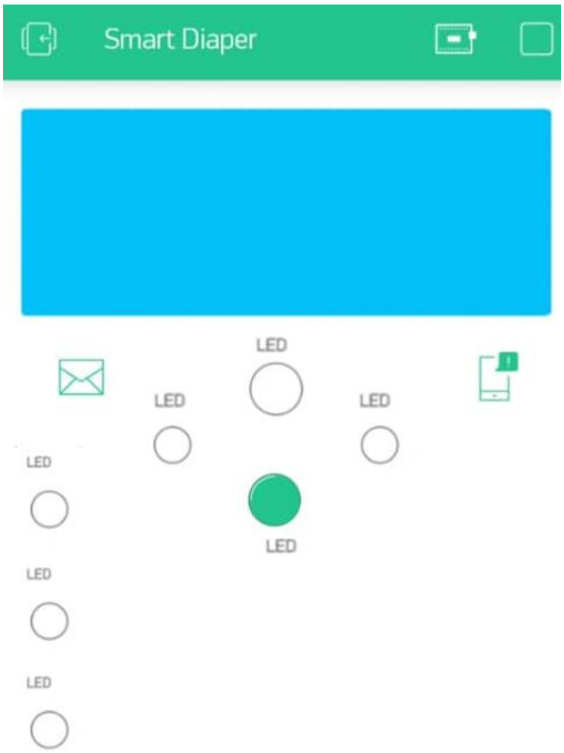
Table 2: Threshold value at x and y axis

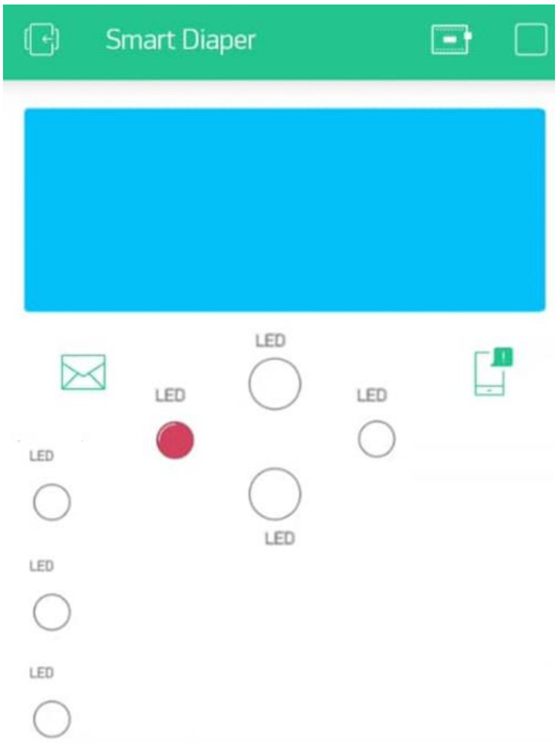
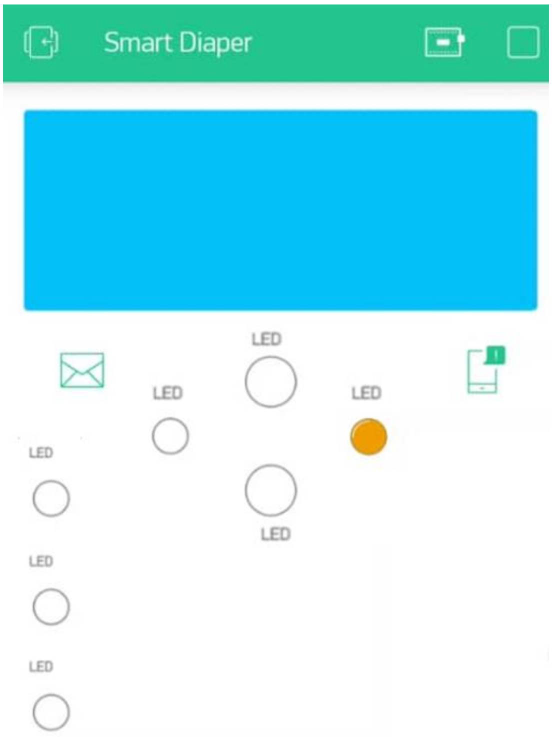
Posture	Accelerometer x	Accelerometer Y
Upwards	> 8000	< 1000
Downwards	> -8000	< 1000
Left	< 1000	< -8000
Right	< 1000	> 8000

```
aX =  -2956 | aY =   -756 | aZ =  16196 | tmp = 31.40 | gX =   -938 | gY =    -54 | gZ =  2631
aX =   9976 | aY =  -1404 | aZ =  12932 | tmp = 31.17 | gX =  -3792 | gY = -15059 | gZ =  -415
aX =   -596 | aY =    492 | aZ =  17032 | tmp = 30.93 | gX =   -479 | gY =   7178 | gZ =  1163
aX =   3164 | aY = -12648 | aZ =  10588 | tmp = 30.79 | gX =  -5358 | gY =  -8152 | gZ = -3161
aX =  12444 | aY =  -5420 | aZ =  10272 | tmp = 30.69 | gX =    350 | gY =  -4088 | gZ = -1461
aX =  16224 | aY =  -2800 | aZ =   4916 | tmp = 30.65 | gX =    910 | gY =  -2784 | gZ =  -693
aX =  13968 | aY =  -3528 | aZ =   8248 | tmp = 30.46 | gX =   2363 | gY =  14582 | gZ =  3272
aX =  -6260 | aY =  -1392 | aZ =  15124 | tmp = 30.41 | gX =    464 | gY =  10636 | gZ =  1093
aX = -14332 | aY =   -628 | aZ =   7792 | tmp = 30.41 | gX =   -188 | gY =   1615 | gZ =   137
aX =  -9348 | aY =  -1164 | aZ =  13604 | tmp = 30.41 | gX =   -308 | gY = -18053 | gZ = -2686
aX =   9720 | aY =  -2160 | aZ =  14300 | tmp = 30.41 | gX =  -1664 | gY =  -8199 | gZ = -1030
aX =  16044 | aY =  -1544 | aZ =   4116 | tmp = 30.27 | gX =   -333 | gY =  -2881 | gZ =  -305
aX =  11096 | aY =   -864 | aZ =  12816 | tmp = 30.18 | gX =   1608 | gY =  12140 | gZ =   -17
```

Figure 6: Serial monitor output

Table 3: Output of position monitoring system

Posture	Output Interface
Upwards	
Downwards	

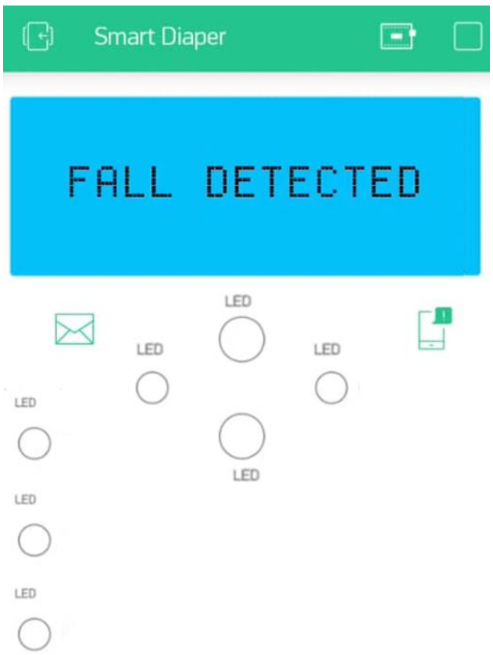
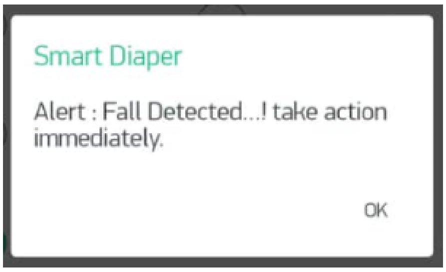
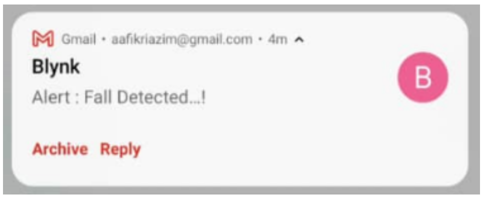
Left	Smart Diaper LED LED LED LED LED LED LED
Right	Smart Diaper LED LED LED LED LED LED LED

4.3 Fall Detection System

Figure 7: Prototype testing of fall detection system

MPU6050 is also used to implement a fall detection system. The value of accelerometer and gyroscope are calibrated in the program code. The sensor works such that there will be triggers to determine the baby does indeed fall by measuring and comparing the baby's activity. If the accelerometer exceeds the threshold value and the gyroscope shows a change in orientation, fall detection alert is activated. Fall detection system will notify the parents or caretaker when a fall is detected. Notification is sent to the smartphone, and through email so the parents can record the number of times the baby falls. Aside notification, the screen on application outputs "Fall Detected" so the parents are aware of the fall.

Table 4: Output of fall detection system

Motion	Output Interface	Notification
Fall		 Notification on Blynk  Notification on smartphone via email

5.0 Project Management

5.1 Project Personnel

AHMAD AZIM FIKRI

PROJECT MANAGER

- Responsible for scheduling, overseeing, and will lead the project until completion.
- Design and ensure the project is executed or completed according to milestones and specifications.
- Responsible for anything regarding the project including acting as a leader project, decision-maker, guiding the project, and conducting the management of the operation.

HASANAH RIDZUAN

FINANCIAL MANAGER

- Manages the finances of the project.
- Ensures the viability and cost for the product.
- Develop strategic sales plans and long-term financial benefits of the project.
- Ensure the cost of hardware and software that will be used during the project is within expectation.
- Analyse market trends to search for any opportunities and increase the profits.

MUHAMMAD MUSZAFFAR

HARDWARE & SOFTWARE LEAD
INTEGRATION & PRODUCT LEAD

- Design and developing the hardware and software of the system design based on specification.
- Direct and coordinate the invention to produce an impactful and usable product for society.
- Integrate the hardware and software into a complete electronic system.
- Design, build and develop the model or package the electronic systems from a design into a real complete product as it will be able to be used in real life.
- Manage product integration and completion according to the schedule and specifications.

5.2 Project Scheduling

Gantt Chart

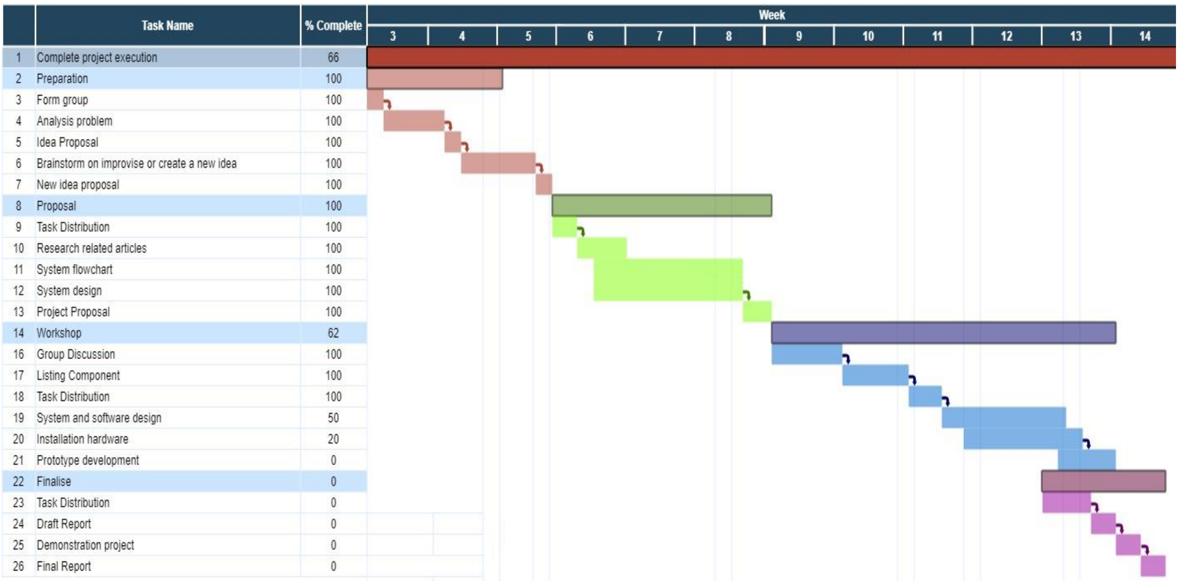


Figure 8: Planned Gantt Chart

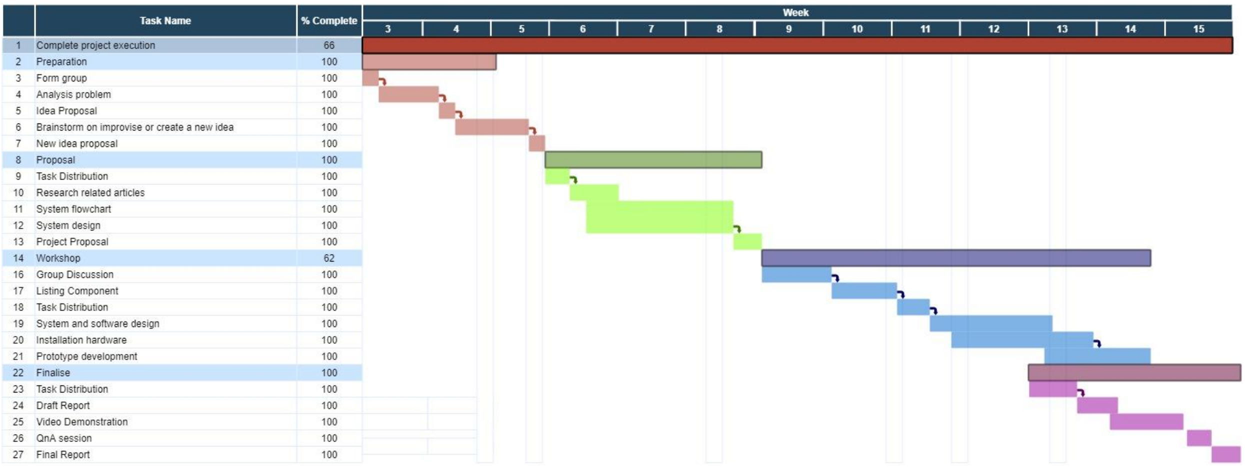


Figure 9: Real Execution Gantt Chart

Based on the diagram above, it shows two Gantt chart which are planned Gantt chart and real execution Gantt chart. As shown from the Gantt chart, the real execution Gantt chart have a slightly difference if compared to the planned one. It is because there are several errors and problems occur during the prototype development. During the recording session for task video demonstration, one of the components (MPU6050) broken which the students must buy a new one. It takes about 2 days for the item to safely arrived. Group 12 had to submit the video demonstration on 7th July 2021. The chart shows that it has an additional one week which make the total execution for the project become 13 weeks (Week 3 – Week 15). With that being said, the project was successfully done on week 15.

5.3 Project Costing

NRE Pricing			
1. MATERIAL			
Components		Quantity	Cost (RM)
Arduino UNO		1	25.90
WiFi Module ESP8266		1	19.50
Breadboard (large)		1	3.90
Jumper Wires Male to Male (20cm) set		40	3.70
Jumper Wires Male to Female (30cm) set		40	4.60
Moisture Sensor		1	3.90
MPU6050		1	11.00
Resistor (10kOhm) set		10	1.00
Resistor (1kOhm) set		10	1.00
Total Material			74.50
2. LABOUR			
	Labour Time (min)	Cost/Hour (RM)	Cost (RM)
Hardware	180	50.00	150.00
Software	300	70.00	350.00
Total Labour			500.00
3. OVERHEAD (MATERIAL & LABOUR COST)		20%	114.90
TOTAL			**689.40**

Table 5: Project Cost

6.0 Conclusion

Overall, the proposed system integrates both Artificial Intelligent and Internet of Things (IoT) primarily to deliver an efficient diaper change management system. The incorporation of the system using Arduino UNO, moisture sensor or humidity sensor, pH sensor along with a WiFi module to enable notification alert in smartphone offers a feasible solution to a passive alert from manual diaper check at every certain hour. The system provides an active reminder that signals for time to change the diaper which will protect the infants and elderly from skin rashes or bacterial infection. The proposed smart diaper can alert the parents when the diaper is wet, and a fall is detected. The proposed smart diaper allows monitoring of the posture, so any discomfort can be prevented. The system will greatly improve the quality of life of the subjects be it elderly or infants and boost productivity of parents, caregivers, nurses, or any person in charge.

7.0 Reference

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8.0 Appendix

Prototype

Figure 10 until Figure 13 shows the prototype of Smart Diaper from the front, back, right and left side. It is a diaper that was embedded with MPU6050, Moisture Sensor and ESP8266. The prototype used a real diaper, the components that were listed before and a teddy bear that acted as a user. The ESP8266 is a microcontroller that will handle the whole Smart Diaper's system and it itself has a Wi-Fi module so the connection to the application will become easier. It is connected to a USB to receive energy from the power supply. Moisture detector probe was attached inside the diaper so it can detect the urine (in this demonstration, mineral water was used). Several boxes were used as a cover that will hold and stick the component onto the diaper.

Figure 10: Front side for prototype

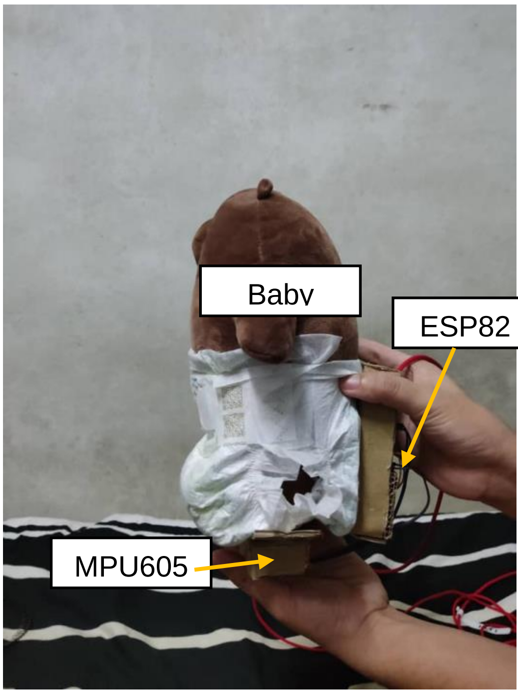

Figure 11: Right side for prototype

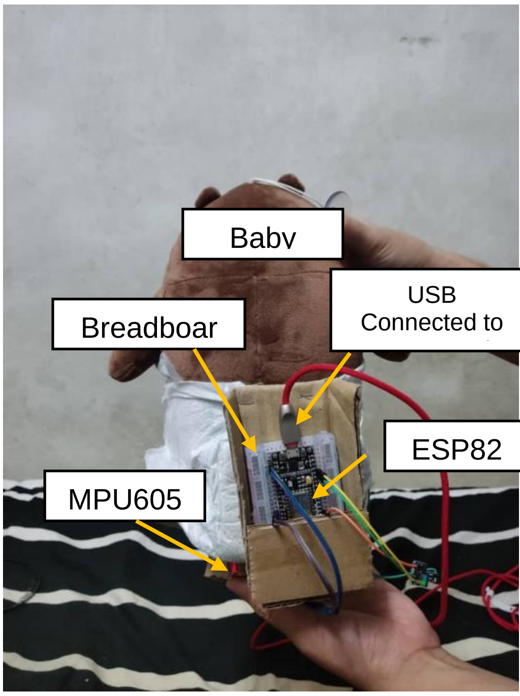

Figure 12: Back side for prototype

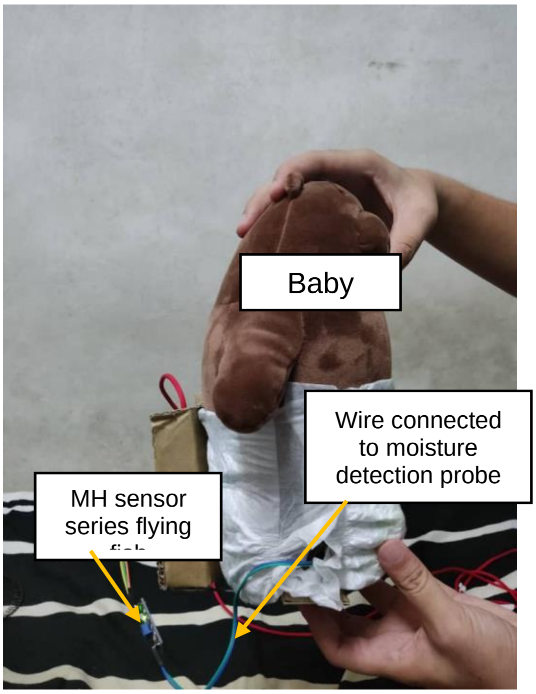

Figure 13: Left side for prototype

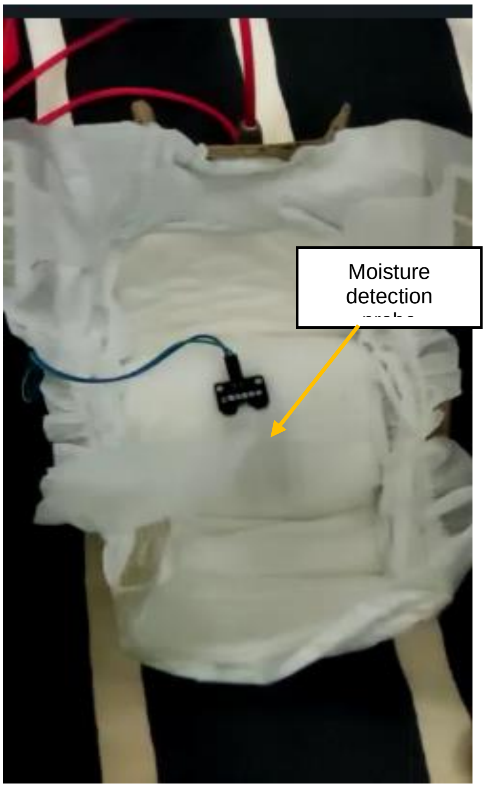

Figure 14: Inside the prototype

Circuit schematics

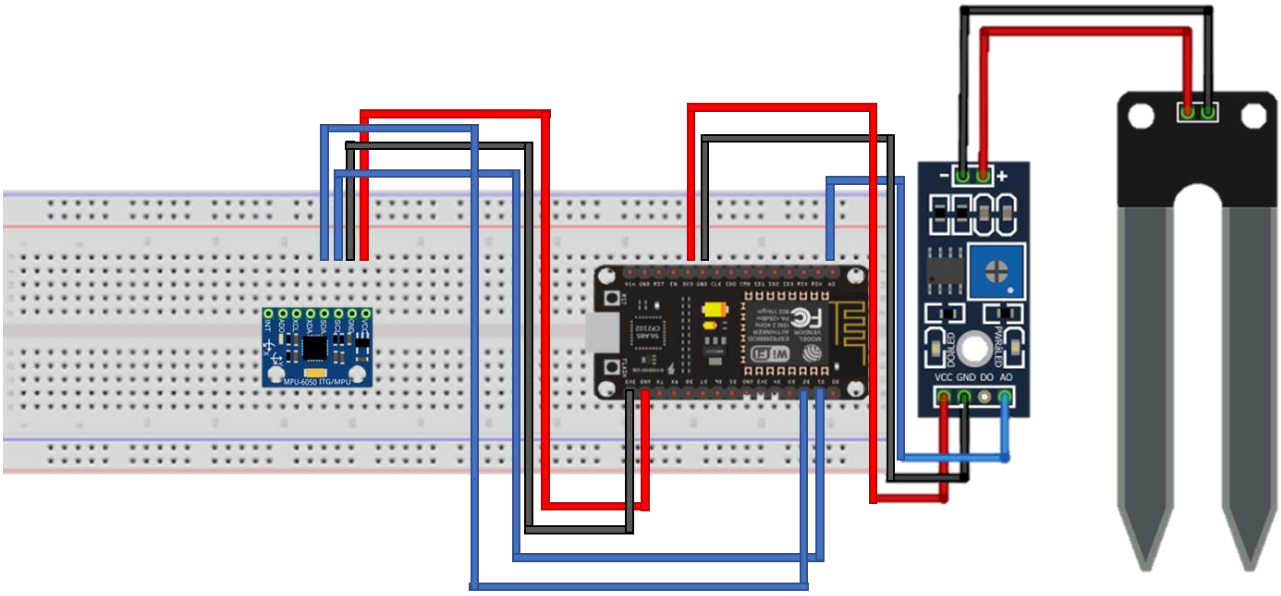

Figure 15: Circuit design for the Smart Diaper

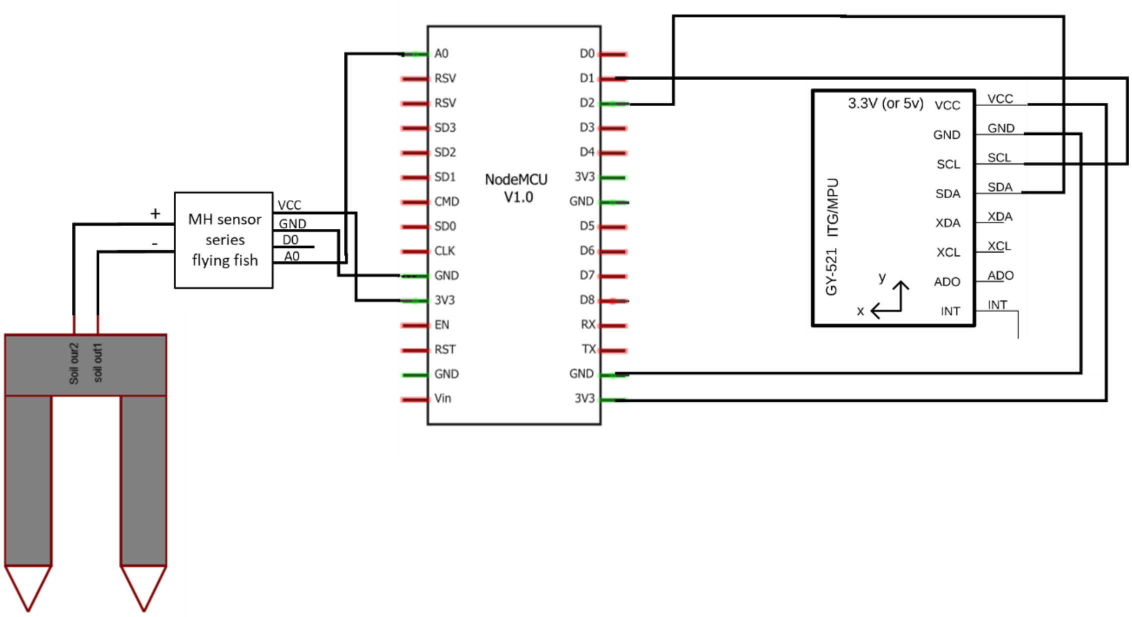

Figure 16: Circuit schematic for the Smart Diaper

Figure above shows the circuit design for Smart Diaper. It shows that ESP8266 will act as the microcontroller as the Arduino IDE will not be used in this project. The moisture sensor has 3 pins connected to ESP8266 which are a VCC pin connected with a 3V3 pin, GND with GND pin, and A0 with A0 pin. For MPU6050, the connection with ESP8266 is VCC with 3V3 pin, GND with GND pin, SCL with D1 pin, and SDA with D2 pin.

Source code

```
#include "Wire.h" // This library allows you to communicate with I2C devices.

#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

// activate LCD and LED on Blynk

WidgetLCD lcd(V1);

WidgetLED led1(V3);

WidgetLED led2(V2);

WidgetLED led3(V4);

WidgetLED led4(V5);

WidgetLED led5(V6);

WidgetLED led6(V7);

WidgetLED led7(V8);


const int MPU_ADDR = 0x68; // I2C address of the MPU-6050. If AD0 pin is set to HIGH, the I2C address will be 0x69.


int16_t accelerometer_x, accelerometer_y, accelerometer_z; // variables for accelerometer raw data

int16_t gyro_x, gyro_y, gyro_z; // variables for gyro raw data

int16_t temperature; // variables for temperature data

char tmp_str[7]; // temporary variable used in convert function


char* convert_int16_to_str(int16_t i) { // converts int16 to string. Moreover, resulting strings will have the same length in the debug monitor.

  sprintf(tmp_str, "%6d", i);

  return tmp_str;

}


 //const int MPU_addr = 0x68; // I2C address of the MPU-6050
```

```
int16_t AcX, AcY, AcZ, Tmp, GyX, GyY, GyZ;
float ax = 0, ay = 0, az = 0, gx = 0, gy = 0, gz = 0;
boolean fall = false; //stores if a fall has occurred
boolean trigger1 = false; //stores if first trigger (lower threshold) has occurred
boolean trigger2 = false; //stores if second trigger (upper threshold) has occurred
boolean trigger3 = false; //stores if third trigger (orientation change) has occurred
byte trigger1count = 0; //stores the counts past since trigger 1 was set true
byte trigger2count = 0; //stores the counts past since trigger 2 was set true
byte trigger3count = 0; //stores the counts past since trigger 3 was set true
int angleChange = 0;

int sensorPin = A0;
int sensorValue;
int limit = 900;
int limit1 = 700;

// WiFi network info.
char auth[] = "JXK04vVhY83nAhMbQVwQxP62_vtnN4E7"; //Auth code sent via Email
const char *ssid = "4G-UFI-B22F"; // Enter your Wi-Fi Name
const char *pass = "12345678"; // Enter your Wi-Fi Password

void setup() {
 Serial.begin(115200);
 Serial.begin(9600);
 Blynk.begin(auth, ssid, pass);
 Wire.begin();
 Wire.beginTransmission(MPU_ADDR); // Begins a transmission to the I2C slave (GY-521 board)
 Wire.write(0x6B); // PWR_MGMT_1 register
 Wire.write(0); // set to zero (wakes up the MPU-6050)
 Wire.endTransmission(true);
 Serial.println("Wrote to IMU");
 Serial.println("Connecting to ");
```

```
  Serial.println(ssid);
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED)
   {
     delay(500);
     Serial.print(".");            // print ... till not connected
   }
   Serial.println("");
   Serial.println("WiFi connected");

    pinMode(13, OUTPUT);
     lcd.clear();
}

void loop() {
  Blynk.run();
  //posture sensor
  Wire.beginTransmission(MPU_ADDR);
  Wire.write(0x3B); // starting with register 0x3B (ACCEL_XOUT_H) [MPU-6000 and MPU-6050 Register Map and Descriptions Revision 4.2, p.40]
  Wire.endTransmission(false); // the parameter indicates that the Arduino will send a restart. As a result, the connection is kept active.
  Wire.requestFrom(MPU_ADDR, 7*2, true); // request a total of 7*2=14 registers

  // "Wire.read()<<8 | Wire.read();" means two registers are read and stored in the same variable
  accelerometer_x = Wire.read()<<8 | Wire.read(); // reading registers: 0x3B (ACCEL_XOUT_H) and 0x3C (ACCEL_XOUT_L)
  accelerometer_y = Wire.read()<<8 | Wire.read(); // reading registers: 0x3D (ACCEL_YOUT_H) and 0x3E (ACCEL_YOUT_L)
  accelerometer_z = Wire.read()<<8 | Wire.read(); // reading registers: 0x3F (ACCEL_ZOUT_H) and 0x40 (ACCEL_ZOUT_L)
  temperature = Wire.read()<<8 | Wire.read(); // reading registers: 0x41 (TEMP_OUT_H) and 0x42 (TEMP_OUT_L)
```

```
 gyro_x = Wire.read()<<8 | Wire.read(); // reading registers: 0x43 (GYRO_XOUT_H) and 0x44 (GYRO_XOUT_L)

 gyro_y = Wire.read()<<8 | Wire.read(); // reading registers: 0x45 (GYRO_YOUT_H) and 0x46 (GYRO_YOUT_L)

 gyro_z = Wire.read()<<8 | Wire.read(); // reading registers: 0x47 (GYRO_ZOUT_H) and 0x48 (GYRO_ZOUT_L)


 // print out data

 Serial.print("aX = "); Serial.print(convert_int16_to_str(accelerometer_x));

 Serial.print(" | aY = "); Serial.print(convert_int16_to_str(accelerometer_y));

 Serial.print(" | aZ = "); Serial.print(convert_int16_to_str(accelerometer_z));

 // the following equation was taken from the documentation [MPU-6000/MPU-6050 Register Map and Description, p.30]

 Serial.print(" | tmp = "); Serial.print(temperature/340.00+36.53);

 Serial.print(" | gX = "); Serial.print(convert_int16_to_str(gyro_x));

 Serial.print(" | gY = "); Serial.print(convert_int16_to_str(gyro_y));

 Serial.print(" | gZ = "); Serial.print(convert_int16_to_str(gyro_z));

 Serial.println();


 //light LED on Blynk

 if (accelerometer_x < 1000 && accelerometer_y < -8000)

 led1.on();

 else if (accelerometer_x < 1000 && accelerometer_y > 8000)

 led2.on();

 else if (accelerometer_x > 8000 && accelerometer_y < 1000)

 led3.on();

 else if (accelerometer_x < -8000 && accelerometer_y < 1000)

 led4.on();

 else {

  led1.off();

  led2.off();

  led3.off();

  led4.off();
```

```
 }
 //fall detection
  mpu_read();
  ax = (AcX - 2050) / 16384.00;
  ay = (AcY - 77) / 16384.00;
  az = (AcZ - 1947) / 16384.00;
  gx = (GyX + 270) / 131.07;
  gy = (GyY - 351) / 131.07;
  gz = (GyZ + 136) / 131.07;
  // calculating Amplitute vactor for 3 axis
  float Raw_Amp = pow(pow(ax, 2) + pow(ay, 2) + pow(az, 2), 0.5);
  int Amp = Raw_Amp * 10;  // Mulitiplied by 10 bcz values are between 0 to 1
  Serial.println(Amp);
if (Amp <= 1 && trigger2 == false) { //if AM breaks lower threshold (0.4g)
trigger1 = true;
Serial.println("TRIGGER 1 ACTIVATED");
}
if (trigger1 == true) {
trigger1count++;
if (Amp >= 1) { //if AM breaks upper threshold (3g)
     trigger2 = true;

     Serial.println("TRIGGER 2 ACTIVATED");
     trigger1 = false; trigger1count = 0;
   }
  }
  if (trigger2 == true) {

    trigger2count++;
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5); Serial.println(angleChange);
    if (angleChange >= 30 && angleChange <= 400) { //if orientation changes by between 80-100 degrees
```

```
trigger3 = true; trigger2 = false; trigger2count = 0;
Serial.println(angleChange);
Serial.println("TRIGGER 3 ACTIVATED");
}
}
if (trigger3 == true) {
trigger3count++;
if (trigger3count >= 10) {
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
    //delay(10);
    Serial.println(angleChange);
    if ((angleChange >= 0) && (angleChange <= 10)) { //if orientation changes remains between 0-10 degrees
fall = true; trigger3 = false; trigger3count = 0;
Serial.println(angleChange);    }
else { //user regained normal orientation
trigger3 = false; trigger3count = 0;
Serial.println("TRIGGER 3 DEACTIVATED");
}
}
}
if (fall == true) { //in event of a fall detection
Serial.println("FALL DETECTED");
lcd.print(3, 1, "FALL DETECTED");
Blynk.notify("Alert : Fall Detected…! take action immediately.");
Blynk.email("aafikriazim@gmail.com", "Alert : Fall Detected…!", "Alert : Fall Detected…! take action immediately.");
fall = false;
}
if (trigger2count >= 6) { //allow 0.5s for orientation change
   trigger2 = false; trigger2count = 0;
   Serial.println("TRIGGER 2 DECACTIVATED");
```

```
 }
 if (trigger1count >= 6) { //allow 0.5s for AM to break upper threshold
   trigger1 = false; trigger1count = 0;
   Serial.println("TRIGGER 1 DECACTIVATED");
 }
 //moisture sensors
lcd.clear();
sensorValue = analogRead(sensorPin);
Serial.println("Analog Value : ");
Serial.println(sensorValue);

if (sensorValue<limit && sensorValue>limit1) {
led6.on();
led5.off();
led7.off();
led4.off();
lcd.print(5, 0, "SLIGHTLY");
lcd.print(7, 1, "WET");
 Blynk.notify("SLIGHTLY WET, BABY MIGHT UNCOMFORTABLE ");
}
else if(sensorValue>limit){
led7.on();
led5.off();
led6.off();
led4.off();
lcd.print(7, 0, "DRY");
}
else if(sensorValue<limit1){
led7.off();
led5.on();
led6.off();
led4.off();
```

```
lcd.print(7, 0, "TOO WET");
Blynk.notify("TOO WET. PLEASE CHANGE THE DIAPER!!!");
}
 // delay
 //delay(100);
}
void mpu_read() {
  Wire.beginTransmission(MPU_ADDR);
  Wire.write(0x3B);  // starting with register 0x3B (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_ADDR, 14, true); // request a total of 14 registers
  AcX = Wire.read() << 8 | Wire.read(); // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
  AcY = Wire.read() << 8 | Wire.read(); // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
  AcZ = Wire.read() << 8 | Wire.read(); // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
  Tmp = Wire.read() << 8 | Wire.read(); // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
  GyX = Wire.read() << 8 | Wire.read(); // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
  GyY = Wire.read() << 8 | Wire.read(); // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
  GyZ = Wire.read() << 8 | Wire.read(); // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
}
```

Picture of all group member with prototype


HASANAH BINTI RIDZ...
Muhammad Muszaffar
AHMAD AZIM FIKRI BI...