Design, Construction and Test Individual Report

The Department of Electronic Engineering

19/4/2020

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1 – Abstract

This report details the design, construction and testing of a fully functional digital multimeter using the STM32F4 Discovery Board and its accompanying analogue to digital converter. The final product is required to be capable of taking readings of DC voltage, DC current and resistance with the readings being displayed to the user via an LCD screen mounted on the board. On completion of the initial product, the remaining time should have been used to add extended features such as the ability to take AC measurements. However, due to the coronavirus pandemic, the task was not completed. However, an in-depth analysis of future tasks has been included.

This report will also provide an analysis of the product's environmental impact and how it could potentially be marketed. An in-depth review of the group's performance will also be completed.

2 – Product Concept

There are several marketing opportunities available for this type of product. Firstly, the product could be marketed as an educational package. A pre-programmed discovery board would be provided as part of a kit, along with some tried and tested circuit diagrams. Older students could then build and test the circuits, giving them an insight into the inner workings of a multimeter. An option would be for the circuits to be inaccurate forcing the student to work out how to increase the accuracy. This product would be suitable for marketing to schools and would include comprehensive documentation for the teacher and questions for the students to answer, as well as a help guide for the construction of different circuits.

A second option would be the creation of a 'right to repair' multimeter. There is a growing demand for manufacturers to design products that are more serviceable and although the number of people currently requesting this is small, they are the people who could be very interested in such a product. Our product would be supplied with a removable cover, giving the user access to the internal workings, which would be designed with reparability in mind. For instance, the LCD screen could be held in place with a retaining clip and a removable connector rather than the most common method, with glue and solder.

The third proposition is that of a 'rugged multimeter. This would be a mass-produced unit manufactured using toughened materials. The casing would need to be waterproof and contain a gel layer between the components and the casing, absorbing damage thus making this product ideal for builders and tradesmen. An LCD screen with a variable backlight and a rechargeable battery pack would make the device stand out from its competition.

The idea of a 'rugged multimeter would be more about the development of the casing than the development of the meter. In addition, to appeal to tradesmen it would have to function safely whilst measuring very high voltages. Currently, high voltages cannot be safely tested in the laboratory and so this idea was abandoned. The 'right to repair' movement is still in its infancy and thus the decision was taken not to pursue this option now. However, some of the ideology behind this idea could be applied to the educational kit.

In an educational setting, such as a class of 30 students in an electronics class, handing out a selection of specific, tiny components to each pupil would be a challenge. A simpler alternative is to provide each pupil with a single device that has every component attached to it but not connected. Pupils can then make the connections between the components using generic cables, which would be supplied. In addition, if a cable is missing, it would be simpler to replace than a unique component. This is where the 'right to repair' ideology comes into play. The proposed product is an educational kit, consisting of all the necessary components to make the multimeter. However, they will be fitted into a 'right to repair' style product, but without the wiring. The student will construct the multimeter using the components provided. The end product will be in the form of a stackable slab which will simplify storage.

The product could be advertised on electronic suppliers' websites, such as rapid electronics, who have a section dedicated to education. A different approach would be to contact schools and exam boards to determine if this product would fit into the school curriculum. Pricing would be focused around selling a service rather than a product, with an institution purchasing a fixed number of the products. The purchase would include an information pack, containing circuit diagrams, methods, theory and challenges for the pupils to work on.

From this discussion, it has been ascertained that the main aim of this process is to develop a digital multimeter, which can measure DC voltage, current and resistance. The process should be meticulously documented so it can be duplicated for use as an educational tool. Time permitting, other features could be developed to increase the complexity of the product.

3- Initial steps

In the first group meeting, the work breakdown and a clear design specification were outlined.

Initial Approach

At the first group meeting it was decided to divide the work into small tasks, which could be assigned to individuals. The initial research showed that the following would need to be developed:

- Three individual circuits capable of obtaining a DC voltage, current or a resistance value and then converting it into a 0 to 3.3 volt range for analysis by the discovery board.
- An analogue to digital converter that can digitalise the value provided by the circuit.
- A conversion factor for each circuit, which takes the digitalised value from the analogue to digital converter and stores it in its true form.
- A display driver, which displays the required value on the LCD.
- A main program that allows the user to select the desired type of measurement. It will also need to incorporate the other group members code, effectively tying the program together.
- A control bus situated between the measurement circuit and the discovery board, which tells the measurement circuitry which type of measurement the user is requesting.

Following the initial discussion, two groups were formed, with two clear specifications to meet. The first group was responsible for the creation of the circuitry required to measure the values and the second group was responsible for the programming of the discovery board. Group members were free to choose which group to join based on their skill set. Tianyi, Peter and Harry chose the programming aspect of the project while William and Yewen chose the electronic side of the project. An initial design specification was then drawn up, so that the product could be tested against a set of clear specifications, before proceeding to develop any extended features.

Initial Design Specification

In order to progress to the development of extended features, the product must:

- Be able to measure DC voltage, current and resistance within +/- 0.5 of the respective unit.
- Allow the user to choose between the measurement of voltage, current and resistance.
- Display the measurement on the LCD.

Work Breakdown

The group was now in the position for individual tasks to be assigned. The measurements circuit team, consisting of William and Yewen opted to carry out the task jointly. Between them they had to:

> "Construct circuitry capable of measuring voltage, current and resistance in a DC circuit, which takes a 3-bit control input and uses it to select which item to measure. The circuit

needs to be able to output its findings between 0 and 3.3 volts and come with an accompanying equation which will convert this value into its original value."

The programming group opted for a slightly different approach. Three individual tasks were created which, when combined would achieve the common goal.

- Peter took control of designing the LCD. He would have to design and program the screens that would display a measured voltage, current and resistance as well as setting up the drivers for the LCD.
- Tianyi opted to manage the analogue to digital converter. He would have to learn how to take an analogue input into the discovery board and to convert this input into its true value for display on the LCD.
- The author (Harry) chose to manage the bulk of the program and had to create a main function that booted the discovery board, controlled the user inputs and, when it was complete, add Peter's and Tianyi's work to the main program.

It was agreed that the aim would be to read a voltage first, adding other functionalities afterwards. This is an iterative approach. We created steps, with specifications to meet before we could proceed.

To convey this process effectively, a flowchart was produced showing the steps each group member would follow:

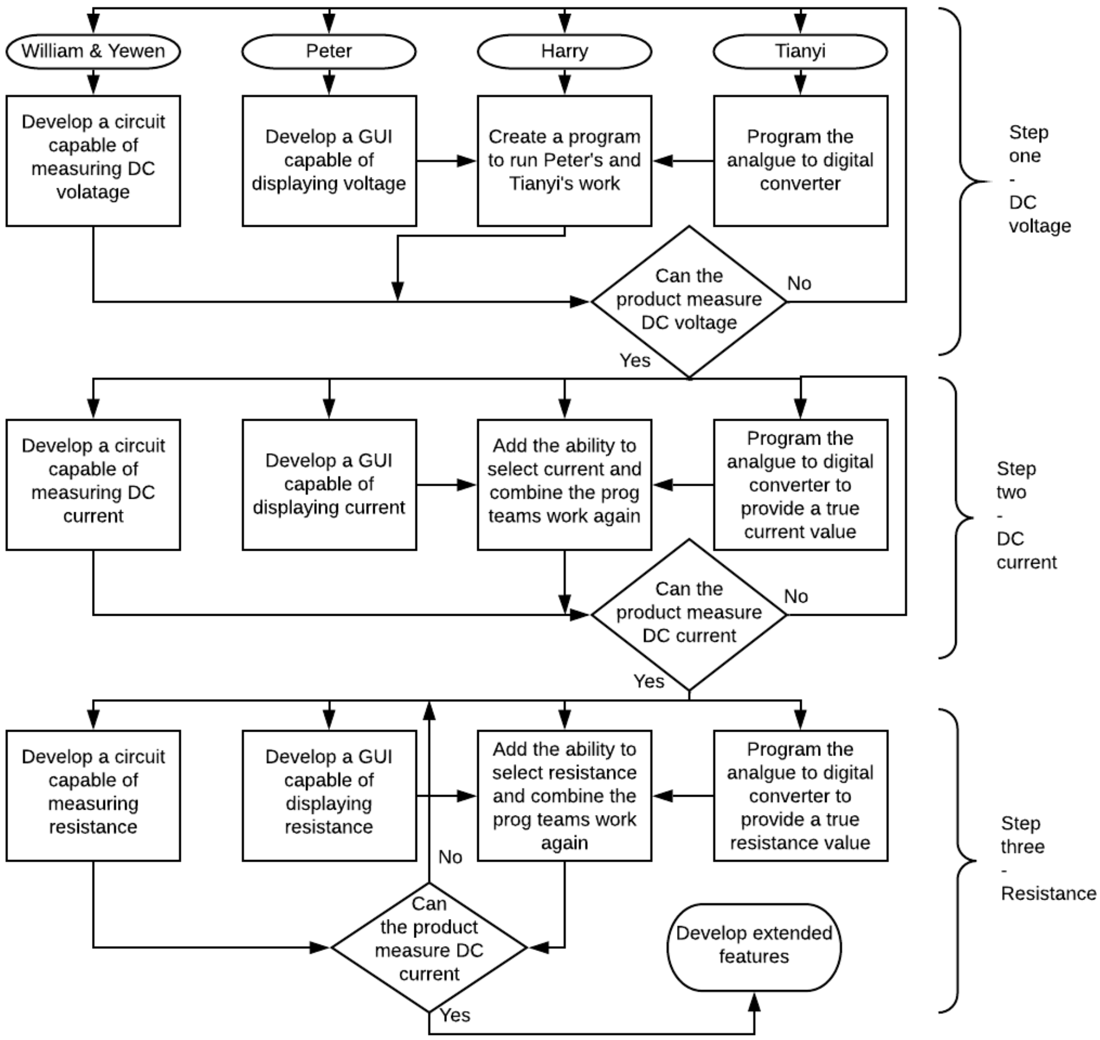

Figure 1 – A flowchart showing each individuals task and the common goals in order to produce the first prototype.

Each step should produce a functional prototype that can then be tested and compared to the specifications in figure one. As stated previously, measurements should be accurate to +/- 0.5 of the relevant unit.

The time management of the project was split into 3 phases:

- By the Easter holidays, a functional DC voltage prototype should be developed. This was to allow everyone in the group to understand the theory, software and discovery board itself.
- During the Easter holiday, the theory and programming required for DC current and resistance should be completed.
- Following the Easter holiday, the DC current and resistance should be tested, with the remaining few weeks being used to develop any extended features.

4- Development of the first prototype

However, due to the ongoing Covid-19 pandemic, construction of the first prototype was not completed and the measurement group were unable to complete their first circuit. In spite of this, good progress was made and will be detailed in this section. The programming group's work was very nearly complete, with a functional UI and main program, but no analogue to digital converter.

The User Interface (UI)

Peter was responsible for the development of the UI. In order to make the code simple enough to add into the main program he created a set of functions that would take the current measured value from a global variable and display it.

```
// Clear LCD display
void dispClear(void){
    PB_LCD_GoToXY(0,0);
    PB_LCD_WriteString("                ",16);
    PB_LCD_GoToXY(0,1);
    PB_LCD_WriteString("                ",16);
}

// Display voltage on LCD
void dispVotlage(double voltage){
    PB_LCD_GoToXY(0,0);
    PB_LCD_WriteString("Voltage", 7);
    PB_LCD_GoToXY(0,1);
    PB_LCD_WriteString(voltage, 5);
    PB_LCD_GoToXY(5,1);
    PB_LCD_WriteString("V", 1);
}
// Display current on LCD
void dispCurrent(double current){
    PB_LCD_GoToXY(0,0);
    PB_LCD_WriteString("Current", 7);
    PB_LCD_GoToXY(0,1);
    PB_LCD_WriteString(current, 5);
    PB_LCD_GoToXY(5,1);
    PB_LCD_WriteString("A", 1);
}
// Display resistance on LCD
void dispResistance(double resistance){
    PB_LCD_GoToXY(0,0);
    PB_LCD_WriteString("Resistance", 10);
    PB_LCD_GoToXY(0,1);
    PB_LCD_WriteString(resistance, 5);
```

```
    PB_LCD_GoToXY(5,1);
    PB_LCD_WriteString("Ohms", 4);
}
```

Figure 2 – The UI code of the first prototype

Peter also setup of the drivers for the LCD screens. He found that running "PB_LCD_Init();" would enable the LCD screen, provided PB_LCD_Drivers.c & .h had been included in the program.

The Analogue to Digital Converter (ADC)

Tianyi struggled with the development of the ADC. When Peter and I became aware of the situation, assistance was offered. Peter developed the required functions for converting the ADC's value to its true value while I managed the development of the ADC. We then provided Tianyi with the formula for converting between the ADC and true values for DC voltage and requested that he convert them into C code to add to Peter's functions. These functions remain unfinished, as this mathematical code was never provided.

```
double scaleUpVoltage (oldV){
    // Perform Calculation
    return newV;
}
double scaleUpCurrent (oldI){
    // Perform Calculation
    return newI;
}
double scaleUpResistance (oldR){
    // Perform Calculation
    return newR;
}
```

Figure 3 – The unfinished ADC to true conversion functions.

The programming of the ADC was now the responsibility of the author of this paper. It will be detailed in the "description of individual contribution" section, along with details of the main program.

The Measurement Circuits

The measurements team provided two equations for the programming team. Given more time, these would have been incorporated into the ADC to true conversion functions is figure 3.

$$V_{True} = \frac{V_{ADC} - 1.5}{0.15} \;\&\; I_{True} = \frac{I_{ADC} - 0.15}{0.15} \div 100$$

As the measurements team had no working circuit diagram one cannot be included in this report. The lack of data shared between the measurements team and the programming team will be mentioned in the evaluation. However, a block diagram of their progress so far can be compiled.

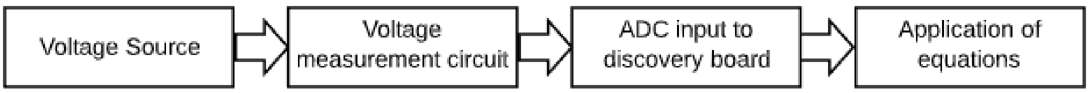

Figure 4 – A summary of the measurement team's intended system

5- Description of Individual Contribution

This section will detail the author's contribution to the work completed as a group, before the closure of the University laboratories. A detailed proposition of the work that the author would carry out to complete the project will be documented in the "Description of future individual contributions section."

Harry Thomas's Individual Role and Contribution to the Project

I undertook the role of programmer; to program the analogue to digital converter pin, to develop the buttons on the discovery board and to create the main program, capable of utilizing the rest of the functions to run the multimeter.

The Main Program and the Analogue to Digital Converter (ADC)

Initially, I was working through the laboratory scripts supplied by Dave Pearce to gain a deeper understanding of the discovery board and associated systems. However, during this process I became responsible for the development of the ADC too. This combined with a leave of absence, which will be mentioned in my evaluation, meant that I needed to take a more direct approach in order to produce a functioning program in keeping with the deadline set for voltage testing.

This was achieved using an application called STM32CubeMx. Details on how to use this software were found in chapter 12 of Dave Pearce's "How To" guide. When CubeMx is first started and the user has selected their board, they are presented with a screen on which the various GPIO pins can be assigned roles. The discovery board required the following inputs and outputs:

Inputs	Outputs
An analogue to digital converter to allow the measurements to be taken.	8 LEDs, these will be used as indicator lights to let the user know which setting they have selected.
8 inputs for the 8 buttons mounted to the University of York motherboard. These will allow the user to press a button to select a measurement option.	A 3-bit bus for control of the measurement circuitry, allowing the measurement circuits system to select the correct measurement circuit.

Figure 5 – The input/output table for the ARM chip.

Extra buttons were added to allow for expansion of the program. When production is complete they can be simply removed if not required.

In order to relate the buttons, LEDs and the breadboard output on the motherboard to the pins on the actual chip, I consulted the datasheets provided on the internal web. They show that the buttons are connected to GPIO bus E, pins 8-15 and that the LEDs are connected to GPIO bus D, pins 8-15. As for the pinout of the breadboard connector on the motherboard, we find an ADC at GIPO C4 and 3 useable GIPOs for the 3-bit bus at GIPO bus B pins 4, 5 and 7. These details were inputted into the program setup screen on cubeMX.

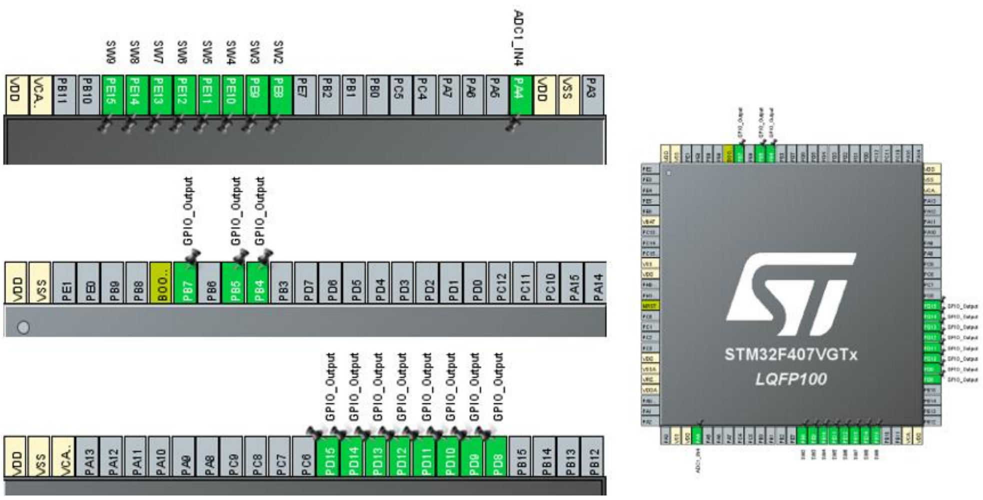

Figure 6 – The STM32CubeMX software showing how the inputs and outputs of the ARM chip were set up.

The buttons were configured as interrupts, meaning that the program would sit idling, until a button was pressed triggering the respective functions. The software was then used to generate a basic program, which would set all the registers as required. This provided a base program which could run the UI functions and the interrupts. To program the interrupts a flowchart was created.

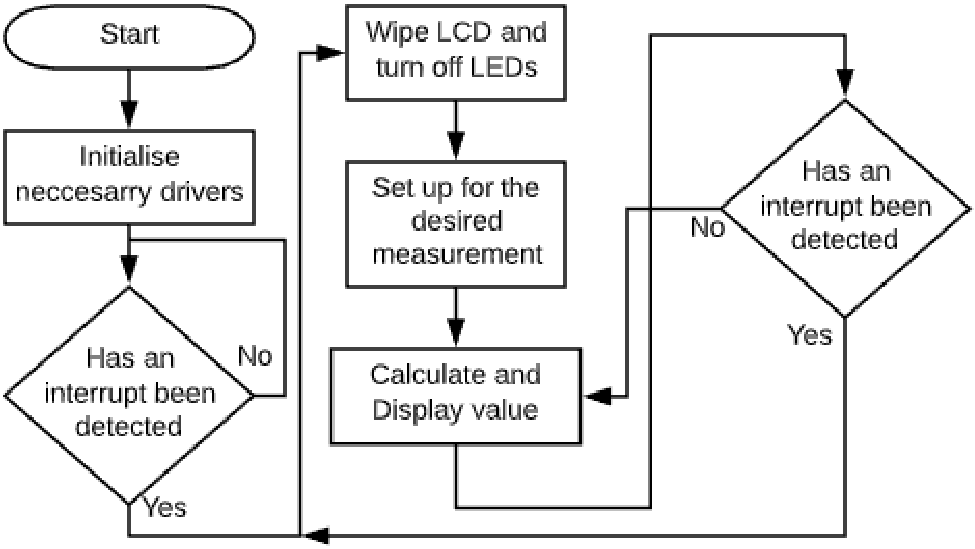

Figure 7 – A flowchart showing the intended function of the interrupt program.

From here, the first interrupt handler can be written. The functions that are called when an interrupt is pressed are found in "stm32f4xx_it.c." For basic functionality, the main function did not need modifying. The infinite while loop would leave the processor idling, waiting for an interrupt. The program is untested as the measurement circuit was not ready for testing. However, I strongly believe a wait function will be necessary, so that the LCD is not overwhelmed with too much data.

```
/**
 * This function will run if an interrupt is detected on GPIO Pins 8 or 9.
*/
void EXTI9_5_IRQHandler(void)
{

  //Turns off all the LEDs
  deactivateLEDs();

  HAL_GPIO_EXTI_IRQHandler(GPIO_PIN_8);
  HAL_GPIO_EXTI_IRQHandler(GPIO_PIN_9);

    /**
     * Checks of button two has been pressed, if it has the discovery board is
     * rigged for DC Voltage measurement
    */
    if (GPIOE -> IDR & GPIO_PIN_8) {

      //Turns on the LED above SW2 on the motherboard.
      GPIOD -> ODR |= GPIO_PIN_8;

      //Output a binary number 1 for the measurement circuitry.
      GPIOB -> ODR |= GPIO_PIN_7;//1
      GPIOB -> ODR &= ~GPIO_PIN_5;//0
      GPIOB -> ODR &= ~GPIO_PIN_4;//0

      while (1) {
```

```
        //Clears the previous value from the screen.
        dispClear();

        //Takes the input from the ADC and converts it ready for displaying on
        //the LCD.
        displayV = scaleUpVoltage(oldV);

        //Displays the voltage on the LCD
        dispVoltage(displayV);

    }

    //Checks if SW3 was pressed, if it was the respective LED is lit.
    if (GPIOE -> IDR & GPIO_PIN_9) {
      GPIOD -> ODR |= GPIO_PIN_9;
    }

void deactivateLEDs(void){
  //Just turns all leds off before new one is turned on by master function
  GPIOD -> ODR &= ~GPIO_PIN_8;
  GPIOD -> ODR &= ~GPIO_PIN_9;
  GPIOD -> ODR &= ~GPIO_PIN_10;
  GPIOD -> ODR &= ~GPIO_PIN_11;
  GPIOD -> ODR &= ~GPIO_PIN_12;
  GPIOD -> ODR &= ~GPIO_PIN_13;
  GPIOD -> ODR &= ~GPIO_PIN_14;
  GPIOD -> ODR &= ~GPIO_PIN_15;
}     }
```

Figure 8 – The interrupt program for DC voltage measurement.

6- Analysis of Effectiveness of Completed Tasks

When access to the laboratory was stopped, the only complete part of the project was the user interface. It was simplistic, but effective with the measurement type and value displayed. A welcome screen would improve the current implementation, but it would only be an aesthetic improvement and would not add any additional functionality to the system. Unfortunately, at this stage, no points on the main design specification had been met.

7- Future Development

Because of the reasons outlined in the “analysis of effectiveness,” it has become evident that a restructuring of the group was required. I propose a restructuring of the original group as in the flowchart in figure 9. The flowchart also outlines the work required to complete the project, should the project be continued by another group. The tasks will need reassigning to suit each individuals’ abilities.

William and Tianyi are now in one group. William proved to be very good at explaining things to Yewen and so hopefully, he would be able to assist Tianyi in the same way. Yewen developed the circuitry for the first prototype and I developed the code, so we should continue working as before. Peter would then be left to program the final two interrupt functions, using the first as an example. I would more than likely finish before the rest of the group as I have a smaller task and so I would move to develop the first extended feature, a hold function.

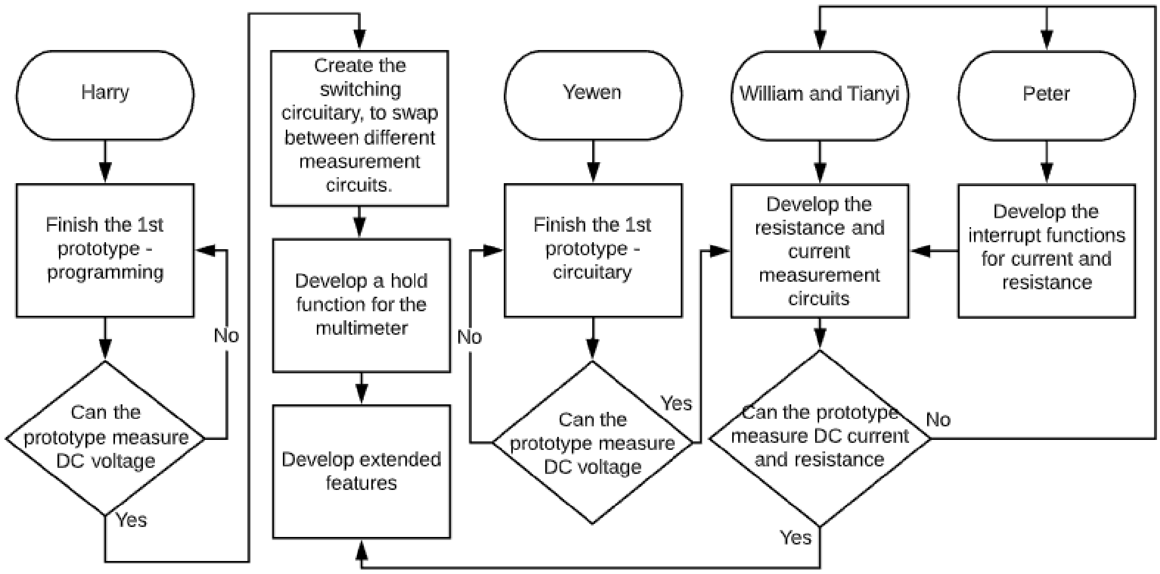

Figure 9 – The proposed future group structure

Testing

The product would be tested using the voltage generator or a random resistor. One member of the group would select a value and another would measure it. The accuracy of the measurment can then be determined by compairing this value to the one given by the digital multimeters in the laboratory. Testing should be performed when the relevant point on the flowchart is reached.

8- Description of Future Individual Contribution

In order to complete the first prototype, I will need to finish the ADC and tie the entire program together, this includes:

- Programming the ADC, from setting it up to handling the conversion between V_{ADC} and V_{True}
- Completing and optimising the main program.
- Setting up an averaging function to improve the accuracy of the measurements taken.

Firstly, the interrupt functions will be developed. Using the requirements as a reference, the following flowchart (figure 10) was produced:

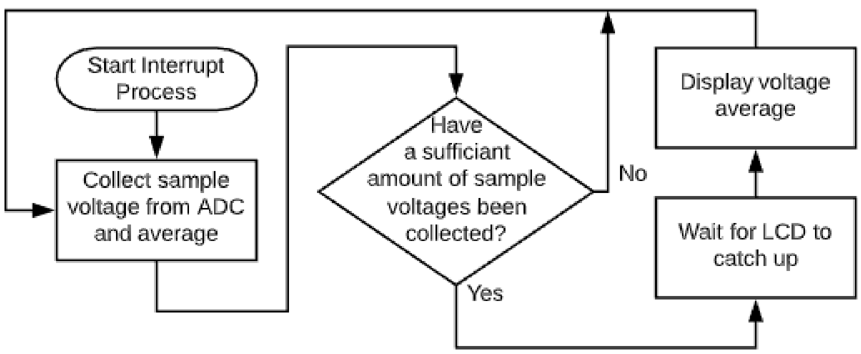

Figure 10 – A flowchart of the interrupt process

As the analogue to digital converter was configured using the CubeMX generation tool, it is controlled using the functions created by CubeMX. Functions are provided for starting, stopping and converting the value from the ADC input. Should the program be redeveloped without the use of CubeMX, the value provided by the ADC can be found in the regular data register. Another issue requiring attention is the LCD screen’s refresh rate. If values are written to the LCD too quickly, it will not display the data properly. The limits of the LCD will have to be found through testing. The clock will also have to be assigned to the ADC pin when the program is generated.

The ADC functions provided by CubeMX will return a value as a 12-bit number, this will need converting to decimal before it can be converted to its true value using the equations provided by the electronics team. This is done using:

$$V_{Input} = V_{ADC} \div \frac{ADC\ Resolution}{System\ Voltage}$$

This value can then be put through the voltage conversion equation and turned into code. Any code will need to be tested when the laboratory reopens. The while loop from the interrupt function for voltage measurement becomes:

```
while (1) {

    for(double i = 1; 1 <= 5; i++) {

        //Start the ADC
        HAL_ADC_Start(&hadc1);

        //Specify how long the ADC should spend converting the data,
        //The CPU will be unable to do anything else for this time.
        HAL_ADC_PollForConversion(&hadc1, 100);

        //Get the result from the ADC
        adcResult = HAL_ADC_GetValue(&hadc1);

        //Stop the ADC
        HAL_ADC_Stop(&hadc1);

        //Calculates the true voltage using a combination of the electronics
        //team's equation and the ADC input equation.
        averageResult = ((adcResult / (4095/3.3)) - 1.5 / 0.15);

    }

    //Calculates the average result from the sum of the voltages.
    averageResult = sumOfTrueResults / 5;

    //Clears the previous value from the screen.
    dispClear();

    //Displays the voltage on the LCD
    dispVoltage(averageResult);

}
```

Figure 11– The new voltage measurement while loop.

The loop will take 5 readings and display the average of those readings. A wait function will need to be included if the LCD cannot handle the speed at which it is being updated. Alternatively, this time could be used to average more readings by increasing the number of iterations performed by the for loop.

My next responsibility would be to develop the switching circuit which takes the 3-bit output from the discovery board and uses it to select the correct measurement circuit. This can be done using a multiplexer or MUX. The multiplexers available in the laboratory are the DG408 and the DG409. As the DG409 has 8 inputs it would provide some extra space for extended features so is preferred.

Because the laboratory is unavailable at the moment, I have made a circuit diagram using circuit wizard, which does not have a DG409 chip, so a similar one has been used. The connectors on the motherboard are also stated, so the circuit can be wired to the discovery board. The only missing connection is the enable pin, which should be connected to a +5v connection which can be found at J4.1 on the breadboard connector. This will enable the MUX whenever the discovery board is powered up.

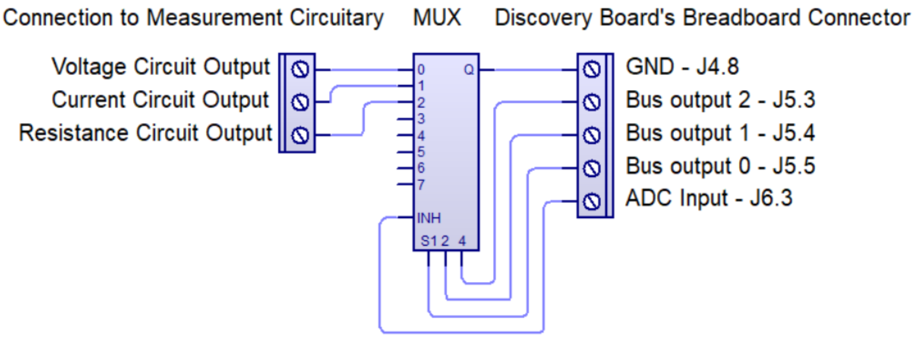

Figure 12– A wiring diagram for the MUX circuit.

Finally, I would need to develop a hold function. The LCD mounted to the discovery board will hold its current state unless it is given a new one. Therefore, a hold function would simply need to be an interrupt that makes the processor idle as this would prevent the LCD from receiving new values. This can be achieved using an infinite while loop. When the user wants to break the hold, they can then press any other button, triggering a new interrupt and running a new measurement function. The hold function would be assigned to the rightmost button, with the leftmost being DC voltage measurement, making it easy to find.

```
//Runs if an interrupt is detected
void EXTI15_10_IRQHandler(void)
{
    //Turns off all LEDS
    deactivateLEDs();

    HAL_GPIO_EXTI_IRQHandler(GPIO_PIN_15);

    //Checks if GPIO pin 15 was the cause of the interrupt
    if (GPIOE -> IDR & GPIO_PIN_15) {

            //Turns on the LED above the button.
            GPIOD -> ODR |= GPIO_PIN_15;

            //Creates an infinite while loop.
            while(1){}

        }
}
```

Figure 13 – The hold functions code

At this stage, I believe time would run out, but the main specifications would have been met. Time permitting, the CubeMX generated drivers should be re-written. This would involve setting up all the registers relating to the GPIOs in use and the ADC. However, this is a large task and I highly doubt there would be time to complete this process.

The Final Product & the Design Specification

Provided the steps outlined in sections 7 and 8 were carried out successfully, the final product would be a digital multimeter capable of reading DC voltage, DC current and resistance as well as holding the current value onscreen until the user resumes normal operation.

This would mean the product meets the design specification entirely, including the request for an extended feature. The accuracy of readings would determine how well the specification had been met. However, without testing facilities there is no way to know how accurate the final product would be.

8- Analysis of Sustainability

In order to negate the environmental impact of a product, its impact must be analysed, understood and reduced. This is done by performing a life cycle analysis which evaluates each step of the product's life and looks for any opportunities to reduce its environmental impact.

The first step to be analysed is the manufacturing of the product. Any electronic product is made up of components, which are often sourced from a third party. All components bought, sold or manufactured in the EU must meet RoHS standards, meaning they do not contain any of the substances banned under these regulations. Although it should be verified that this is the case, this will mean that any of the components that are bought and used in the manufacture of the multimeter will have to meet this requirement. Every effort must be made to ensure these components are made using as many recycled materials as possible, perhaps even a supplier of components removed from waste products could be found. When the components arrive, they will need to be assembled onto a printed circuit board or PCB. This should be done using as many recycled materials as possible, such as the copper, which will make up the tracks on the PCB. The size of the PCB, casing and LCD should be minimised as far as possible to reduce the amount of materials required. A smaller product will mean shipping it will have less of an environmental impact.

Secondly, the packaging of the product should be analysed. As this is a product which would be bought in bulk and cased in a tough material, the packaging should be minimal, perhaps 10 units could be boxed together in one box, ready for shipping. As the unit itself would be stackable, no storage solution, such as a case, would be required either.

The third step of the analysis is to examine how the product will be used during its life. Fortunately, the device requires very little power, with the discovery board needing only 5 volts and the LCD 12 volts. However, power consumption could be lessened with a 5v LCD. This would also remove the need for a 12-volt power supply, as the entire system could be powered off a 5v USB slot in an ICT classroom or likewise. Not only would this reduce manufacturing costs, it would mean that less material would be used in the manufacturing of the device and thus, less weight to ship.

The fourth step of the analysis, is deciding how the product will be shipped. Rather than the manufacturer providing a dedicated service, a postal service should be used as this means that one large vehicle is carrying a larger load, rather than several smaller ones producing more pollutants. DHL are currently trialling the use of electric vehicles in their supply chain, making them a prime candidate for an environmentally conscious delivery solution.

Finally, an end-of-life analysis will be performed. Usually, when a device such as a mobile phone reaches the end of its life, the internal technology is outdated. This makes reusing the device near impossible. Because of this, much e-waste ends up in landfill. To combat this, the EU introduced the waste electrical and electronic equipment (WEEE) directive. WEEE makes manufacturers financially responsible for the reuse or recycling of their product. The business model proposed in section 2 was to offer the product in bulk to schools and colleges, part of the package could be a recycling scheme, much like the one offered by Apple. The customer would return the product for a small discount on their next purchase. In the case of the multimeter schools should be able to return their product, for a discount on future purchases. This financial incentive will ensure the product is returned to the manufacturer at the end of its life for recycling.

Potentially, the system could be reconditioned and resold, saving the company the full manufacturing costs to produce a new system. An ARM chip with an ADC also has some potential for reuse. Rather than using energy to melt the metals used to make the multimeter the main components could be reprogrammed, put in a new case and sold as a low cost multimeter in DIY stores. As a last resort, the product would be broken down into its original materials and used for the manufacture of another product. Should a unit break, every effort should be made to repair it. Even if every electronic system is replaced and the case reused, the environmental impact would still be less than if the device was replaced with a band new unit.

9- Reflective Summary of Group Work

Initially, the group worked well as a team. The task was split into several components with similar difficulty. Tasks were then assigned to group members who felt that they were best equipped for that task. Deadlines were set and the work began with everyone in agreement. However, the group began to run into problems.

Tianyi did not ask for help with his individual task even though he seems to have been struggling with it. Therefore, while the rest of the project progressed well, the analogue to digital converter did not progress. By the time the group discovered that the development of the ADC hadn't begun, it was too late for another group member to learn how to create an ADC, which is why the CubeMX generation tool was used instead. I feel that, had regular progress reports been required, possibly every week or every few days, then this issue would have been discovered sooner.

Secondly, while writing this report I only had access to a very limited amount of technical data. The group worked off a shared Google drive and a GitHub repository. The most recent version of the multimeter code, including the UI functions were on the Google drive. However, no data was provided by the electronics group, despite the fact that simulations and real-life testing were performed during the laboratory sessions. Again, this issue could have been resolved through regular progress reports. If every member of the group had been required to upload their work to the shared Google drive on a weekly basis, then working from home would not have affected the content of this report.

The third issue concerns how the work was distributed. Two group members managed to almost create the all code necessary to build the prototype and this could have been achieved had we been researching the ADC from the beginning. This was while two other members struggled to create the voltage measurement circuit in time. I believe that one of the programming group members should have been assigned to the electronics team, that way they could have spread the task more evenly and met the deadline.

The deadlines themselves would have been met had every task been worked on during the allotted time. This is proved by the fact that the deadline was still very nearly met, despite the fact that too many group members were working on programming and the ADC was not developed properly.

Peer review

William gets 30 of the 100 marks available. He was punctual and did the vast majority of the work on the measurement circuits. William also led group discussions and was very good at explaining to Yewen when she didn't understand a concept they were working on.

Yewen gets 10 marks as she was often late or not present at all. William was often seen to be working alone.

Peter gets 25 marks as he was the only other group member to complete his allotted task. After completing his task, Peter also intended to work with me on the ADC. However, the laboratory was shut before he got the chance.

Tianyi gets 10 marks as he rarely did any work. He was punctual, but he did not complete his task. If he had problems with the task, I feel that he should have asked for help, which we would have gladly given. There could also have been a language barrier. However, if this was the case Tianyi did not attempt to convey that he did not understand his task.

I have given myself 25 marks. I completed my task good standard despite having to miss two laboratory sessions due to an unforeseen leave of absence at the start of the project. I also chose to program the ADC towards the end of the project, freeing Peter up to complete his UI.

Conclusion

Had the labs remained open for the 3rd term, I believe that our group would have a functional prototype which met the design specification. However, we would most definitely have needed to reorganise the group and ensure that every member was comfortable with their task. If any more issues then arose I feel that meeting the deadline would have become an issue.