Design Document

May13-06

Logging DC Wattmeter

Team Member:

Ailing Mei

Andrew Kom

Chongli Cai

David Hoffman

Qiaoya Cui

Advisor :

Collin Christy

Client:

Garmin International

Table of Contents

EXECUTIVE SUMMARY

Power consumption has become an important issue in designing electronic devices. When designing analog circuits and precise devices, people always need to measure the DC power consumed on those devices accurately. Most of the traditional analog wattmeter measure the power based on Electrodynamics. This kind of wattmeter has good performance in larger power measurement. However, the traditional analog wattmeter has a significant error in measuring the contemporary electronic devices because most of these devices are running on DC with small power consumption. In addition, since the traditional analog wattmeter works based on electrodynamics, it is easy to be disturbed by an external magnetic field. Our project is aimed at developing a prototype of digital DC wattmeter working based on the microcontroller to accurately measure the power consumed by other devices running on DC. This device will be used for measurement the power usage of any electronic device in a vehicle, the output of solar arrays overtime, or charging devices like cell phones/pads/laptops.

SYSTEM DESIGN

- **System Requirements**

I. Functional Requirements

Compliance Requirements:

- The system shall accept as close to a 1-24 VDC range
- Source the same 1-24V out the other side with a minimal voltage drop through the device
- Need the resolution to measure currents from 0.5mA to 3A
- Logs voltage, current, time ,temperature
- Have a programmable logging time ideally from 100ms to 10min
- Log the saved data to a removable SD card in a format easy to import with MS Excel
- The device needs the ability to run on battery power so that it doesn't distort the measurement being made.

Interface Requirements:

- For user to easy use device, need an interface
- Interface display the data
- Have buttons easy turn on/off

II. Non-functional Requirements

Tools Requirements:

- Simulation tools
- Schematic capture
- PCB drawing
- C compiler
- Lab equipment to construct and test the device

Security Requirements:

Before the devices entry the market, it must be passed relative quality and legality test or certification.

Maintainability Requirements:

The device should be encased in a durable shell to protect from the outside environment or accidental damage.

• System description

The system block diagram is shown in Figure 2. Since the device is connect in serious between DC supply and load, our design should satisfy that the watt meter cannot disturb the normal power consumption of the load. In other words, we need to measure the output port voltage and current rather than the input port.

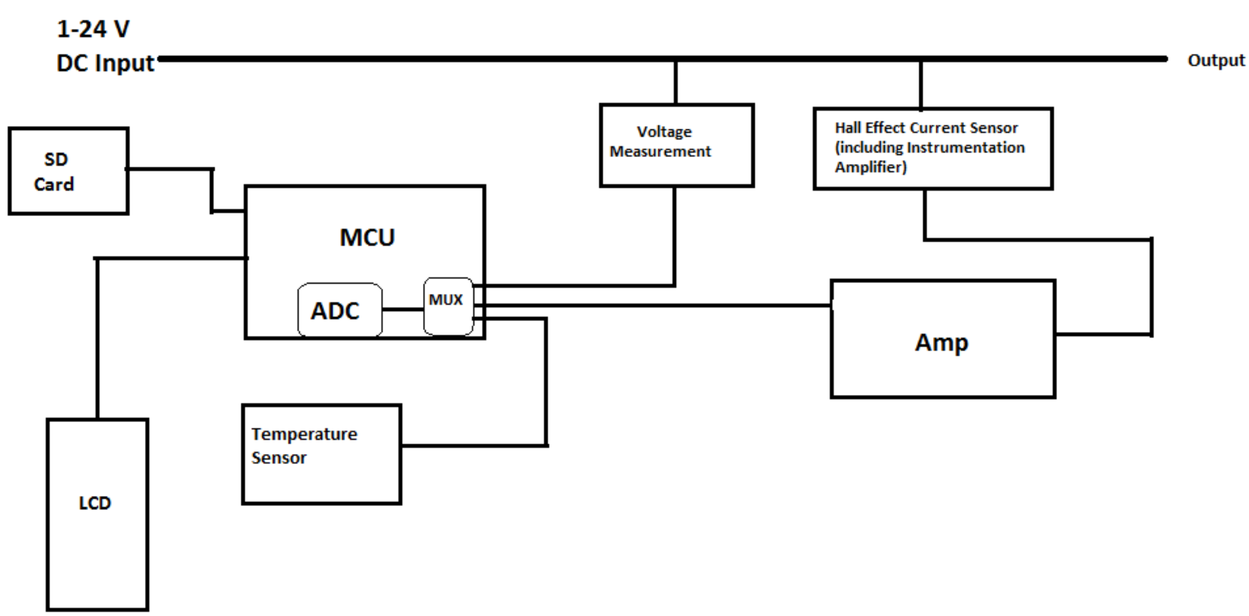


Figure 1: System sketch

- ## Operating System

This device is designed for accurately measuring the power consumed by other devices running on DC. So the device will be used as a measurement instrument widely. In order to make this device more versatile, designer needs to give a larger input/output voltage range and current range to the system. The following is the designed operating environment of the DC wattmeter.

- input/output DC voltage : Minimum value 1V , Maximum 24V
- current measurement range: Minimum value 0.5 mA, Maximum value 3A
- logging time: Minimum value 100ms, Maximum value 10min

In addition, all the measurement data will be stored to SD card automatically.

DETAILED DESIGN

- ## Voltage Measurement

Since the input voltage is in the range of 1-24V, it needs a voltage attenuator to reduce the voltage less than 3V (VCC). For the initial design, this part is a simple voltage divider.

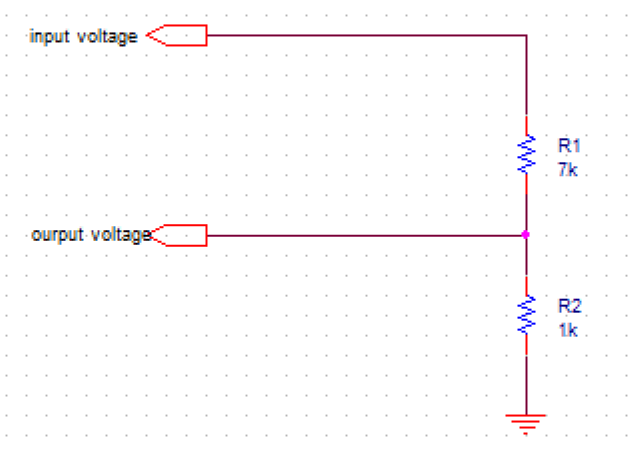
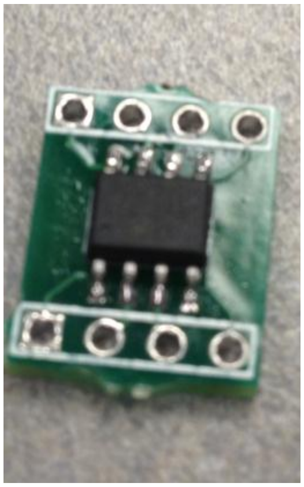


Figure 2: Voltage Attenuator

- ## Current Measurement

Current measurement is based on Hall effect-Base Linear Current Sensor. The output of current sensor is followed by an amplifier to arrange the voltage less than 3V. Allegro System Inc. ACS714 Hall Effect-Base Linear Current Sensor is used for current measurement. Since ACS714 includes an instrumentation amplifier, it does not need to follow another one at the output pin.



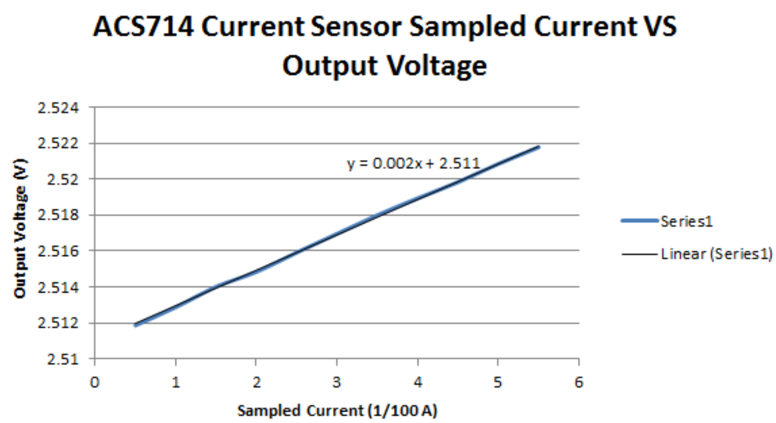


Figure 3: ACS714 Hall-Effect Current Sensor

Figure 4: Test Result for ACS714

- **Temperature measurement**

 The temperature is measured by using LM35 temperature sensor from Taxes Instruments Inc. The output voltage is linearly proportionally to the Celsius Temperature.

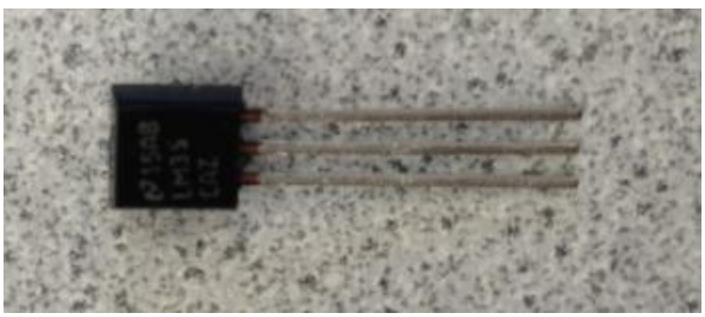


Figure 5: TI LM35 Temperature Sensor

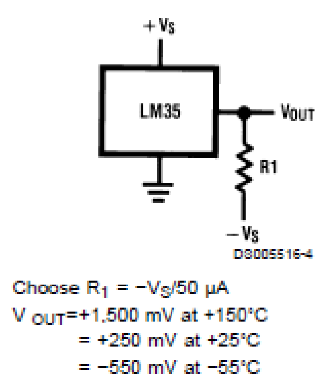


Figure 6: Lab Measurement schematic

 We test the Temperature Sensor in the Lab and find the linear relation between output voltage and temperature. The Matlab result is shown in the Figure 5.

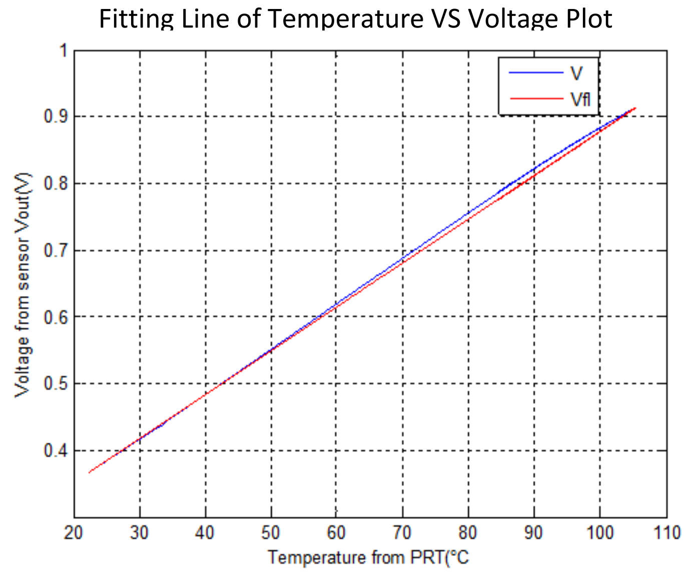


Figure 5: Fitting Line of Temperature VS Voltage Plot

The red line is the measurement result and the blue line is the theoretical result.

• Microcontroller Unit

Our team works on two Microcontrollers. One is the MSP430G2553 from Texas Instruments and another one is dsPIC33FJ256GP710 from Microchip

➢ MSP430G2553

MSP 430G2553 is mainly used to do the ADC for the voltage measurement result and serial communicate with LCD. In addition, it is also use to log time and store the measurement data into SD card.

1. Main function

The flow chart of function is shown in the figure 6. Since using signal-channel-signal-convention mode, ADC10 needs to turn on again after each sampling in order to do the next sampling and convention. All the sampling and convention is based on the interrupt.

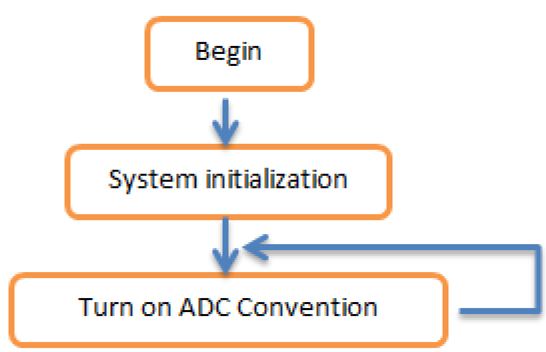


Figure 7: Main Function Flowchart

2. System initialization function

System initialization function is shown in the Figure 7. The purpose of this function is to initialize the watchdog timer, I/O, ADC10 and LED.

3. ADC initialization function

ADC initialization function is shown in the Figure 8. The purpose of the function is to set the ADC10 convention control registers. For ADC10CTL0 it needs to set ADC 10 enable bit, ADC sampling period, reference voltage, ADC10 interrupt; for ADC10CTL1 it needs to select the ADC convention sequence mode and input channel.

4. LCD initialization function

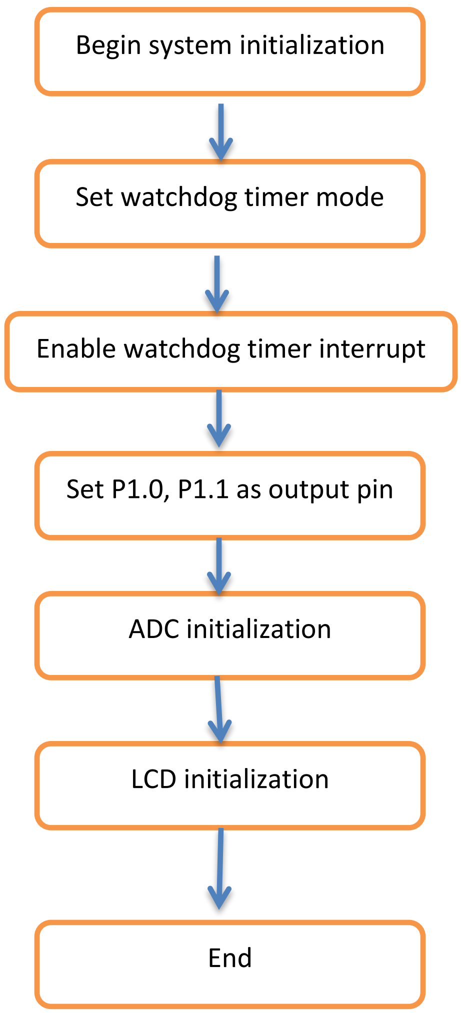


Figure 8: System initialization flowchart

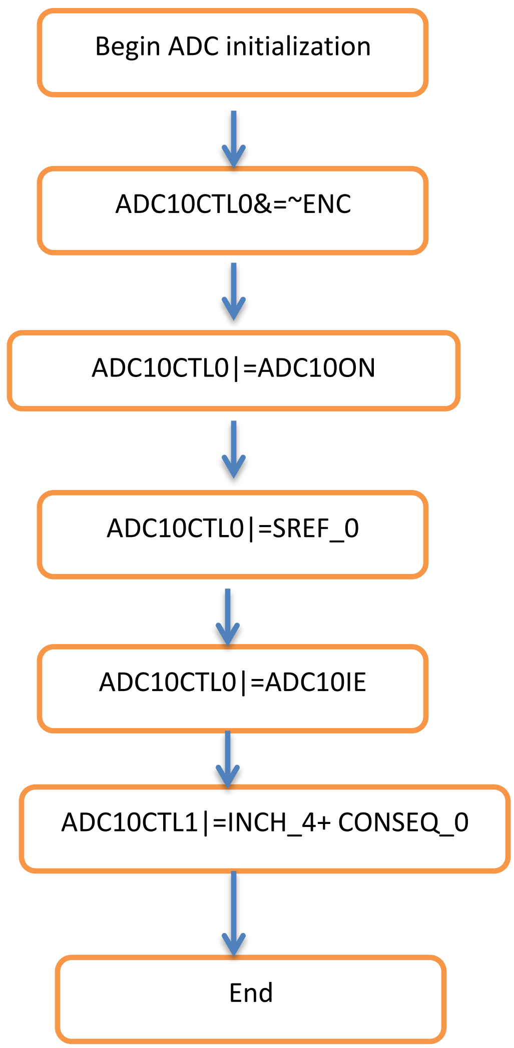


Figure 9: ADC Initialization flowchart

5. Interrupt function

Interrupt function includes ADC interrupt function and watchdog interrupt function. Figure 9 shows the flowchart of ADC interrupt function. The interrupt occurs every 4 ADC10CLKS periods. ADC10 stores the sampled data into register ADC10MEM, which can be read directly and convert into measurement voltage according to a specific formula. The watchdog interrupt function is shown in the Figure 10. Watchdog interrupt occurs every 1 second to update the display voltage value on the LCD.

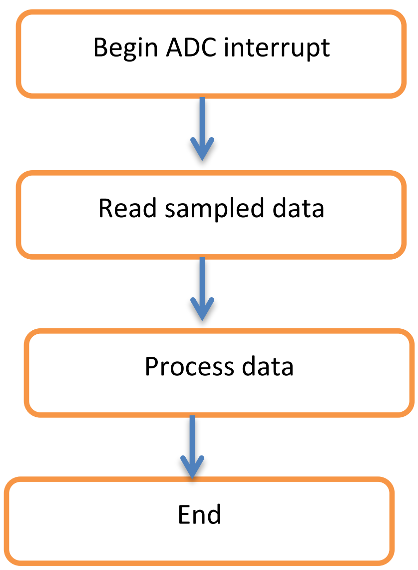


Figure 10: ADC interrupt flowchart

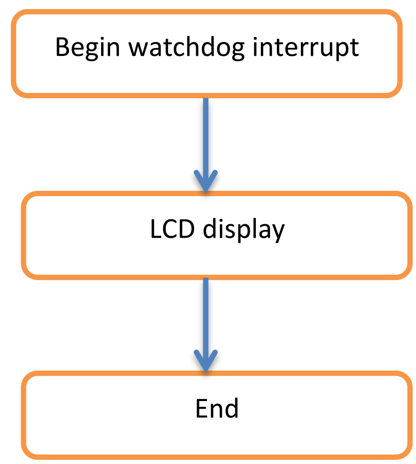


Figure 11: watchdog interrupt flowchart

➢ dsPIC33FJ256GP710

The dsPIC33FJ256GP710 is primarily used to take ADC measurements for the temperature, voltage, and amperage sensors. The project also has a requirement to store the results of these measurements to an SD card for future retrieval and an LCD for current viewing of the data, there will also be 2 UARTs that the dsPIC33FJ256GP710 will have to be configured for sending data to the LCD and SD Card. The chip also has to record the correct time of each measurement which will require a timer or system function call to get that information.

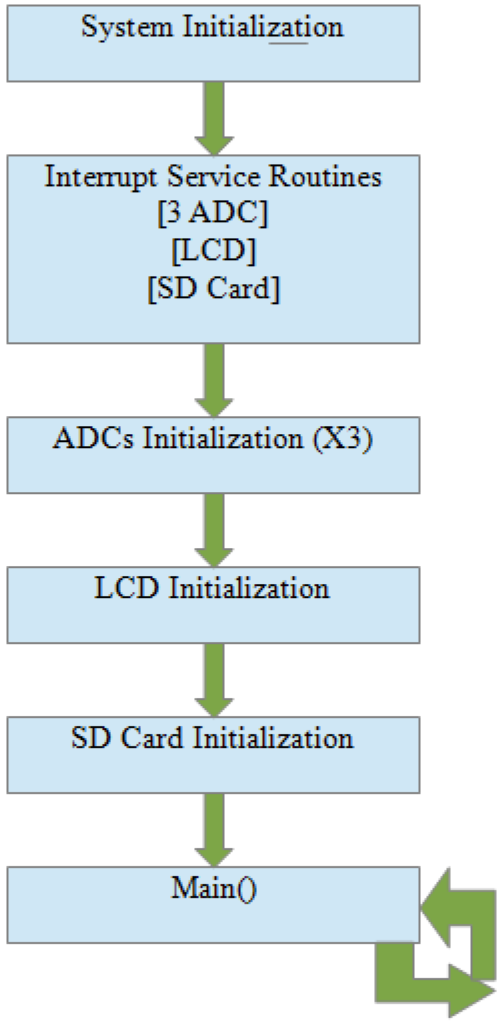


Figure 12: Main Function Flowchart

1. Main function

The Fig 12 shows the Main() function and its prototype functions. All sampling and UART communications is done via the Interrupt Service Routine. The ISR must be properly set up before most other devices. There will be 5 of them, one for each of the three ADCs and one for each of the two UARTs. In order for the ISR to work and the device to perform its function, it must be properly initialized, so each device will get its own initialization, except for the ADC, which will be initialized as a group.

The actual Main() function will be put in a continuous loop. It will have the responsibility of getting the measurement from the ADC once its ISR has triggered. This measurement will then be saved until all 3 ADCs have been scanned. Once this happens, Main() will then format this information for the SD Card and the LCD and send it to both of them using an ISR. The next thing will be to start the loop over. This will be accomplished using the interval the user selected to take these measurements.

ADCs have been scanned. Once this happens, Main() will then format this information for the SD Card and the LCD and send it to both of them using an ISR. The next thing will be to start the loop over. This will be accomplished using the interval the user selected to take these measurements.

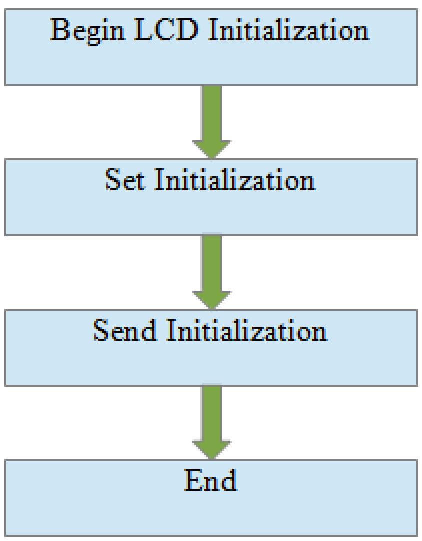


Figure 13: LCD Initialization Flowchart

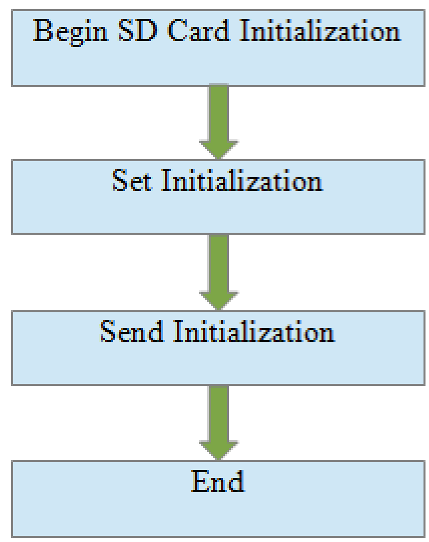


Figure 14: SD Card initialization flowchart

The SD Card initialization is very similar to the LCD initialization. This time we set and then send the initialization to the SD Card via the UART interrupt.

2. ADC initialization function

It is obvious from this flow chart that the initialization for the ADC is longer and more complicated than the initialization for the UARTs. All 3 of these initializations, one for each of the 3 ISRs are done at the same time. The important thing to remember here is that certain features need to be turned on in order for a good measurement to be taken. Those steps are all the steps before Set Interrupt Enable. The Set Interrupt Enable ensures that we can use the ISRs for getting the values from the ADCs while not using a lot of the processor time to get them. And, of course, the last step is to enable the ADC to start taking measurements on its inputs.

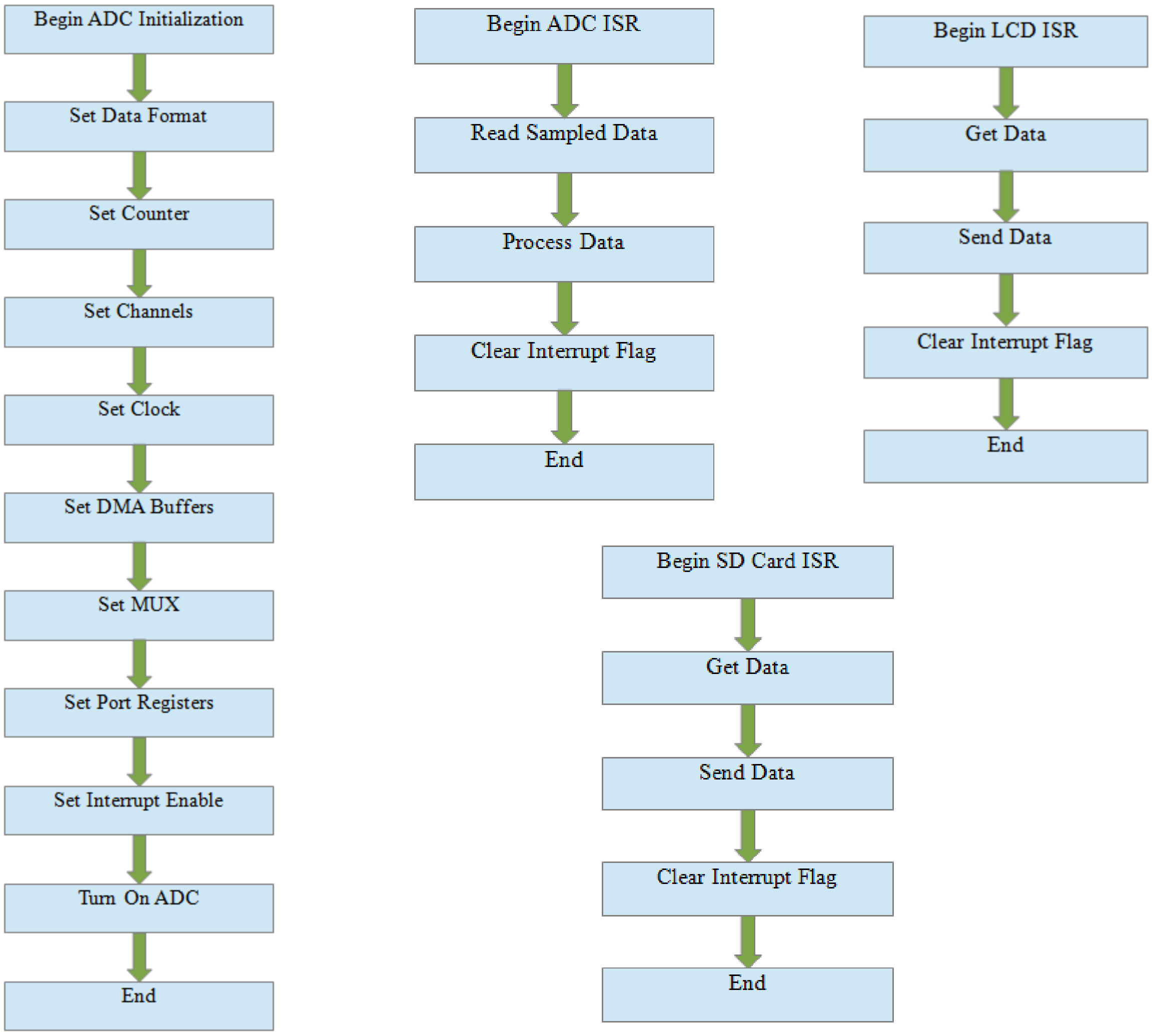


Figure 15: ADC /LCD/SD Interrupt function Flowchart

3. The Interrupt Function

There are 3 ADC Interrupt Service Routines, one for each initialization which are for measuring the temperature, voltage, and amperage. The only thing the ISR does is read the data, process it so it is in a format that is useful, and then it resets the interrupt flag so another interrupt can occur.

The LCD ISR is responsible for only sending data to the LCD when there is data in the buffer to send. It must get that data, process it so the LCD can display it, and then send it to the LCD. The interrupt flag must be reset before data can be sent to the LCD again.

The SD Card ISR is similar to the LCD ISR in the way it operates, except the data does not have to be formated before it is sent, as it should already be in the correct format. The data must however append to the existing file and not overwrite it. That should be a function of the SD Card and not our software.

- **Test Plan**

The test includes two stages: component test part and system test part. For the component test part the current sensor, temperature sensor will be tested respectively. After that we will test the whole current measurement circuit and voltage measurement circuit. Once both of them satisfy the design requirement, we will connect them to the microcontroller to test the whole system. Before doing the system testing we need to make sure every component of the system satisfies the design requirement. Once finishing the first time whole system testing, we will draw the PCB for the system and deliver it to fabricate. After getting the PCB board, we will test the system again to make sure the prototype satisfies the design requirement.

- **Deliverables**

Design Specifications

The design specification document will be used by Garmin to evaluate the plan of action before production of the prototype begins. It will also be used as an outline for how the device should function.

Inside the design specification document the operation of the device will be strictly defined. The document will list different settings that could be changed on the device and their intended uses. Additionally, the design specification will describe how the Watt Meter will function. This will include a listing of expected input power parameters and their ranges.

Operating constraints and performance specifications will also be detailed in this document. These performance specifications will ensure that the Watt Meter has the necessary characteristics that make it compatible with the power source it is measuring. These constraints will be rigidly defined and will include topics such as maximum power usage for any power source, operating temperature range, expected battery life under certain conditions, and cost.

Once a draft of the design specification has been completed, it will be submitted to Garmin for evaluation and revision. In this way, the aspects of the design may be evaluated by the customer before production of the prototype begins. The ultimate goal of this document is to define the characteristics of the design to ensure that the delivered product is successful.

Engineering Report

The Engineering Report document will be used to describe the different methods and techniques used to solve the problems encountered during the design of the Watt Meter. This will include justification and description of the type of implementation chosen. By describing the problem and the approach taken in solving the problems, the document will show the best solution was implemented. This report will refer to the constraints and operations outlined in the design specification document.

The Engineering report will also have a recommended path for improvements that can be made. This will include ways to get better performance out of the device and a direction that further research might take as well. Additionally, suggested ways to lower the cost of production will include in this report.

Operating Prototype

The operating prototype will be a Watt Meter that can operate reliably within a specific temperature range measuring a given power source. It will be some form of integrated circuits and digital logic that will have practical inputs and outputs, and a display for showing the measured characteristics of the power source.

PROJECT SCHEDULE

- **Work Plan**

Work breakdown structure

Research 20%

Research is an important part of design. According to the project goals, first of all is to understand how the DC wattmeter is working and then come up with the structure of the whole project design. Based on the design constraints, it is essential to look for the best technical approaches and tools to accomplish the design such as the test equipment, simulation tools and devices choices. At the same time, the cost of design is also considered in this design.

Design 30%

After identifying the project goals, a device could be designed to perform like a DC wattmeter. This may include current sensor design, voltage senor design, analog to digital converter design, microcontroller implement and PCB drafting. The most important parts of design are current senor circuit and voltage senor circuit. To minimize the error in measurement, it is necessary to figure out the best method to design the circuit.

Implementation 30%

Once obtain the desired circuit, the implementation is to make sure the correctness of design. The first step is to pick up a simulation tool such as Cadence to test circuit. If the circuit is acceptable and practical, the next step is to build circuit by hands. The devices involved in this project depend on the previous research results. The implementation is to combine all of these elements together and then to see if we can get the desired results. After the PCB drafting and fabrication, the last step is to test the final project.

Debugging/validation 20%

In the implementation section, the design should have been evaluated. If there are any errors in the design, they should be revised and then meet the requirements of the design specification.

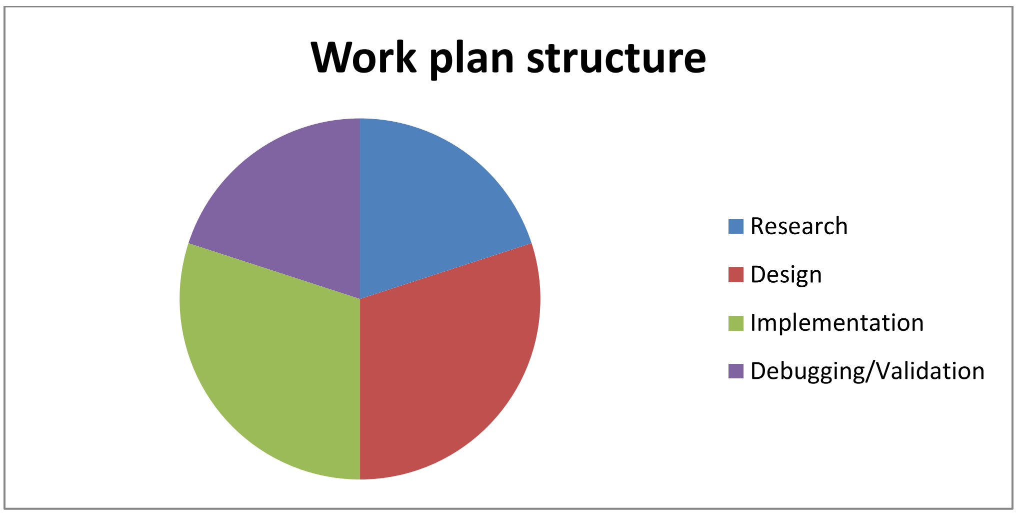


Figure 3: Work Plan Structure

• Schedule

Our schedule is divided up into weekly segments, in which we desire to accomplish the main goal listed below. The timeline is as follows:

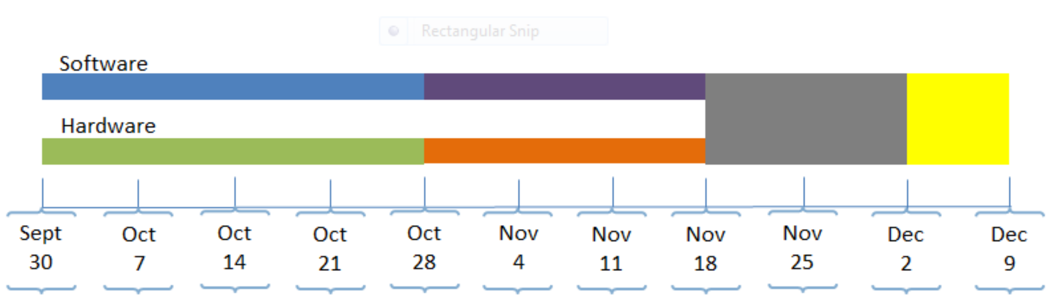


Figure 4: Time Table

During this period of time, the software team will focus on getting a system established by which we can send a voltage to an ADC pin, and have the MCU interpret the data correctly and send it to the SD memory card. This step will include setting up the values tied to each ADC reading, converting it to a digital signal, manipulating it to produce the actual reading we desire, and then sending that value through the UART serial bus to the SD card in a file format that can be read later by excel.

The hardware team will focus on producing a circuit that can be simulated to produce a range transformation for the voltage readings and current readings, into a range that can be read by the ADC. This will be done by utilizing our Cadence Virtuoso simulation software and schematic designer. The plan for the circuits is to use an operational amplifier to convert the range in an accurate manner. For the current reading side of the circuit, we will use a current sensor chip with the voltage range converter to send a reading to the ADC.

At this point, the software team will have completed the ADC to SD card communication. They will then begin focus on the LCD screen implementation into the MCU. This will involve communication to the LCD from the UART serial port of the MCU.

The hardware team will focus on determining real world parts to try implementation of the voltage range circuit. This will include finding the parts that will suit our needs, and running breadboard testing. This will also include implementation of the current measuring sensor as well and confirming that it is accurate enough in measurements for our needs.

This process will combine the hardware and software teams to bring together the components into a working demonstration of the Wattage measurement system. Also included in this time period will be the designing of the GUI, including buttons to turn on/off the system and change modes.

This will be the week in which we finish up our proof-of-concept design and put together our presentation that will be given in “Dead Week”. We would also need to get together documentation that will be required for prototyping in the spring semester, including diagrams, pictures, and schematics.

Reference:

1. MSP430G2553 User Guider
2. MSP430G2553 Data Sheet
3. ACS714 Data Sheet