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November 2, 2009

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Dear: Dr. Bird and Mr. Whitmore,

The attached document presents the design specification for the wireless single phase power monitoring system, which is being implemented in the ENSC 440 course. The product that is being designed is a home power monitoring system which will assist the user in measuring the power consumption of various appliances in their home. Moreover, this device will be able to simultaneously transmit the measured data through a wireless connection to a computer and plot a graph of energy and power consumption for the appliances under test.

The design specification document is intended to describe how the product achieves the required tasks. This report includes the overall system design, component design for the analog circuit, MCU, wireless module and PC interface as well as the system test plan.

Watt Smart Inc. consists of five enthusiastic, dedicated upper-year engineering students: Glen Nogayev, Kamyar Ghomi Osgoei, Wenqi Sun, Babak Sobhani, and Titus Cheung. If you have any questions or concerns about our proposal, please feel free to contact Titus at tcc11@sfu.ca.

Sincerely,

Watt Smart Inc.

Enclosure: Design Specification for Wireless Single Phase Power Monitoring System



School of Engineering Science • Burnaby, BC • V5A 1S6

Design Specification for Wireless Single Phase Power Monitoring System

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Executive Summary

The design specification document for the Wireless Single Phase Power Monitoring System (WPMS) provides a complete description for the design and implementation of the prototype device. Since this document describes exclusively the design specifications for the prototype model, only the requirements with priority I and II, according to the Functional Specification for Wireless Single Phase Power Monitoring System [1], will be discussed.

The purpose of this document is to outline the design of the WPMS product and provide explanations as to why this particular design was chosen. First, the overall system design is described with particular focus on mechanical, high-level, electronic and wireless communications design. Following that, the design of all the system components is discussed. These include the analog circuit, MCU, wireless module and PC interface. The analog circuit section explains how voltage and current waveforms are captured. The next section describes the MCU operation as well as the ADC implementation and the SPI communication with the wireless module. Following that, the function of the wireless module is explained together with the network configuration parameters. Finally, PC interface design is analyzed, focusing on the data acquisition, power calculations and the graphing tool used to display the real-time power and energy consumption charts.

In the end of the document, a detailed description of the product test plan is included. The test plan is broken down into component testing and integrated testing sections. In other words, the functionality of all the components and the system as a whole are tested.

As the development of the product is progressing, the first stage, as specified by the Functional Specification for Wireless Single Phase Power Monitoring System has been completed. The completion deadline for the working prototype is still anticipated for December 3rd, 2009.



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Glossary

AC	Alternating Current
ADC	Analog to Digital Converter
CT	Current Transformer
DC	Direct Current
DFT	Discrete Fourier Transform
DMM	Digital Multi Meter
FFT	Fast Fourier Transform
GUI	Graphical User Interface
I/O	Input/Output
MCU	Microcontroller Unit
MDI	Multiple Document Interface
Op-Amp	Operational Amplifier
PCB	Printer Circuit Board
RS-232	Recommended Standard 232 (computer serial port)
SPI	Serial Peripheral Interface Bus
UART/USART	Universal (Synchronous) Asynchronous Receiver Transmitter
WPMS	Wireless Power Monitoring System

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1. Introduction

Wireless Power Monitoring System (WPMS) is a device that measures the power consumption of various household appliances. It is designed to precisely calculate the input voltage, drawn current, power factor, and energy usage. Our aim in this project is to create a system that not only measures the required data, but also calculates and analyses them with highest accuracy possible. In addition, the system is capable of transmitting the data through XBee 802.15.4 wireless module to a PC where the data will be collected, analyzed, and graphed for users to view. The project is developed in three stages: MCU sensing unit, wireless module, and PC illustration. This report describes the technical details for the design of each stage of WPMS.

1.1. Scope

This document explains the design of the WPMS and is intended to describe how the functional requirements stated in functional Specification report work. It also includes all the requirements for a proof-of-concept system as well as some partial set of requirements for a production model. As we are focusing only on the proof-of-concept system, only design considerations relevant to the functional requirements with priority I and II will be explicitly discussed.

1.2. Intended Audience

The design Specification is intended for use by the members of WattSmart Inc. as well as design engineers. Test engineers can also use this document to implement the test plan for measurement accuracy.



2. Overall System Design

This section provides the design description of the whole system. It is broken down into mechanical design, high-level system design, electronic design and wireless communications design.

2.1. Mechanical Design

The overview of the proposed mechanical design of the WPMS sensing unit is shown in Figure 1. The USB dongle with the wireless receiver is not shown as it is a standard off-the-shelf product.

The sensing unit shown in the figure below consists of the following:

- Signal conditioning circuit
- Microcontroller unit
- RS-232 module
- Wireless module
- Power supply



Figure 1: Overview of the Sensing Unit (from top left to bottom right): top view, front view, side view, trimetric view

The signal conditioning circuit with a CT and a voltage transformer as well as the power supply unit and the MCU are placed on a single PCB board to conserve space. The wireless module is on a separate PCB board, which is connected to the MCU using wires. There is also an RS-232 port on the side of the box, which can be connected to a computer for calibration and debugging purposes. According to the physical requirements of the product, the sensing unit has a three-pronged plug which is connected to a wall outlet and it also has a corresponding socket for an appliance to plug in to.

2.2. High-level System Design

This section provides a high-level overview of the system as a whole. Figure 2 provides a system block diagram with appropriate inputs and outputs as well as the relationship between the components.

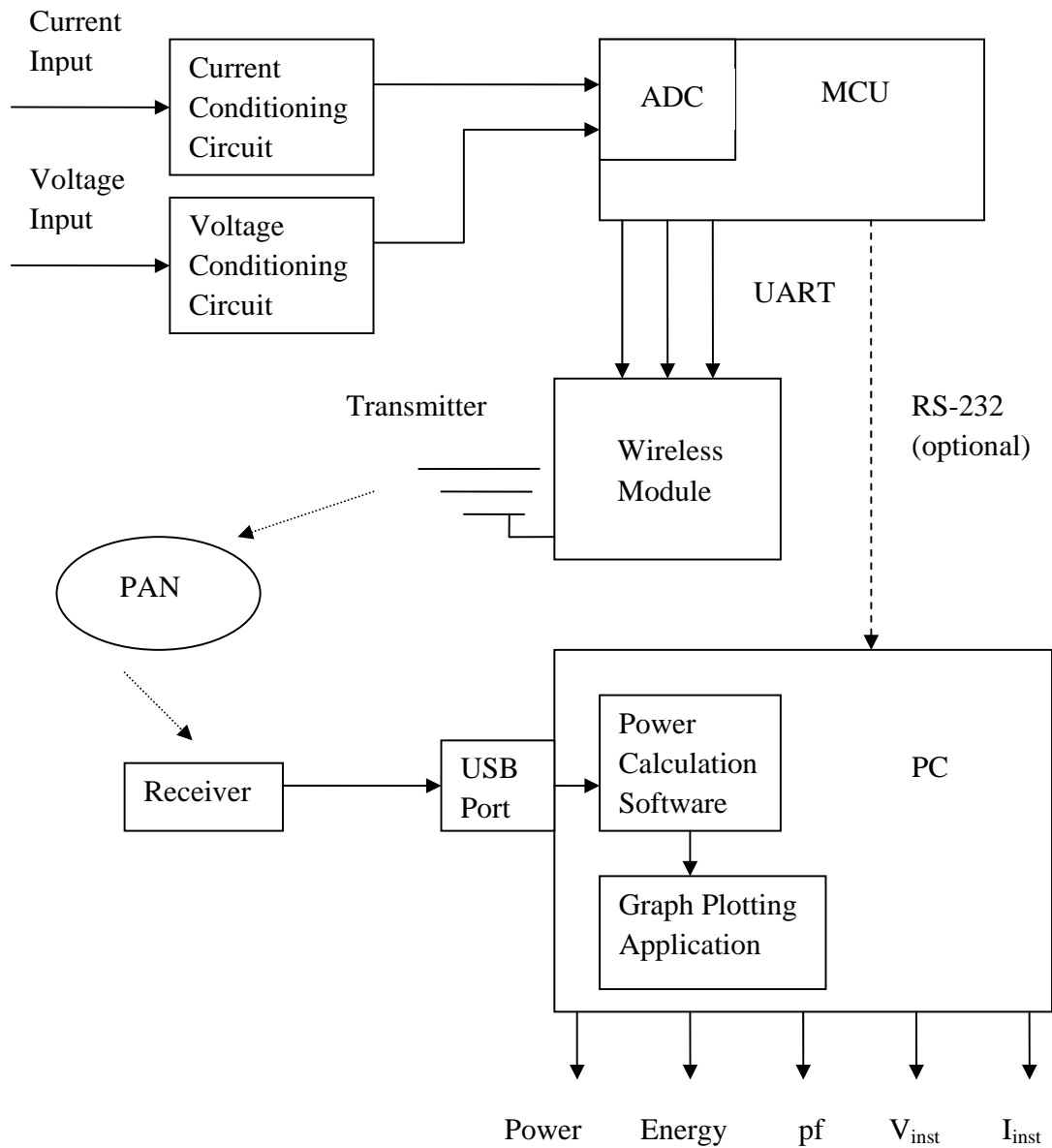


Figure 2: System Block Diagram

As can be seen from the figure above, the system inputs are the current and voltage waveforms from the outlet. Before they are passed to the ADC inside the MCU, the two signals are fed through their respective conditioning circuits. After the ADC, the digital signals are transferred to the PC through a wireless module. On the PC, power calculations are performed using the acquired data. The resulting outputs are the power and energy consumption graphs as well as the appliance power factor, instantaneous voltage and current values and the cost in dollars for various time intervals (not shown in figure).

2.3. Electric Design

The sensing unit requires two power supply voltages to power the system. A 5V supply is needed to run the MCU and the op-amp and a 3.3V supply is used to power the wireless module. Both of these supply voltages will be obtained from the wall outlet input when the sensing unit is plugged in. A 120-5V transformer will step the voltage down to a safe level and then two 5V and 3.3V voltage regulators will ensure a constant power supply for their respective modules.

The current transformer is used to capture the current passing through the main line. Together with the shunt resistor, a voltage representation of the current waveform is generated and fed into the MCU. Similarly, for the voltage capture, an AC voltage transformer steps the voltage waveform down to the required level, which is then transferred to the MCU.

2.4. Wireless Communications Design

For the wireless communications module, XBee Series 1 device was chosen due to its simplicity and ease of programming. It can easily communicate with most MCUs using UART controller. XBee uses IEEE 802.15.4 wireless standard, which is a subset of the Zigbee standard. This standard was chosen over others due to its low cost of communication between devices with almost no underlying infrastructure [2]. Moreover, the power consumption of the XBee device is extremely low, which is a requirement for our product. The data transfer rates can vary from 20-250 kbit/s depending on the distance between the receiver and transmitter. However, high data rates are not required in our project since the amount of data that needs to be transferred is very small.

3. Sensing Unit

3.1. General Design

The sensing unit is responsible for current and voltage data acquisition. Target appliance is plugged into this unit from one side and the unit itself is plugged into the wall power outlet from the other side as depicted in Figure 3.

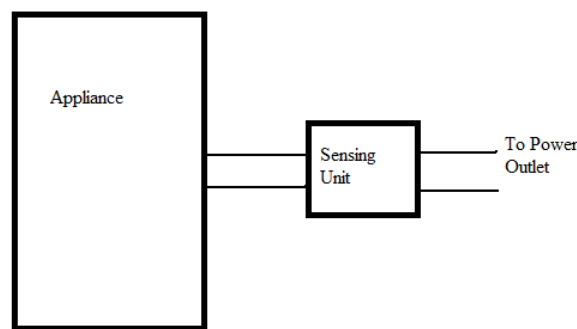


Figure 3: Setup of Sensing Unit

The sensing unit is made up of the following three modules:

1. Signal conditioning module
2. ADC Module
3. Communication Module.

Signal conditioning modules prepares the input voltage and current signals to be fed to the A/D analog channel of the ADC unit. The ADC unit in the MCU converts analog signal into digital data and captures the complete current and voltage waveforms. Then this data is passed to the wireless module in order to be sent to the PC. In addition, an RS-232 module provides the capability of connecting the sensing unit directly to the PC for testing and calibration purposes. A Block diagram of the sensing unit is presented in Figure 4.

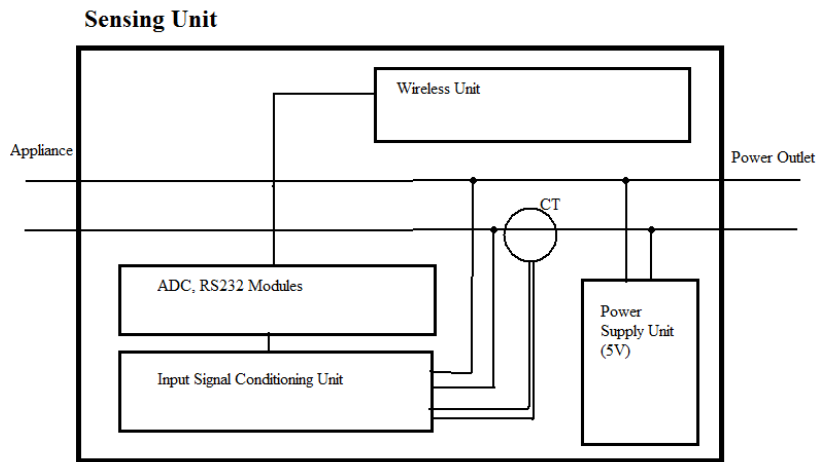


Figure 4: Sensing Unit Block Diagram

3.2. Power Supply Unit

This unit provides a steady 5V supply for the other modules inside the sensing unit. It feeds from the main line (parallel). Output of a bridge rectifier is fed into a 5V regulator to get a steady constant 5V output. The schematic of the power supply module is depicted in Figure 5.

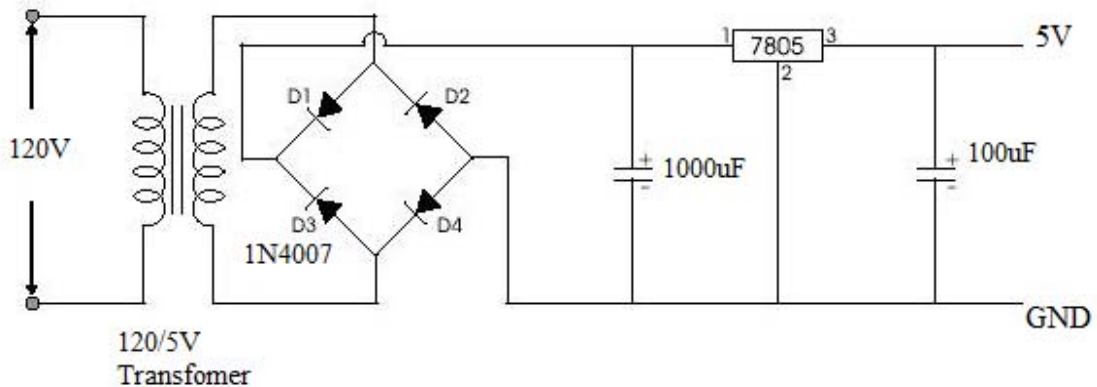


Figure 5: Schematic of the Power Supply Unit

A low supply voltage ($V_{CC} = \pm 1$ to $\pm 2.5V$) op amp has been chosen in the signal conditioning unit such that one power supply unit be able to supply both the ADC and the signal condition units. Therefore, it is not necessary to use an extra transformer, which is beneficial as it would not increase the total power consumption of the device.

3.3. Signal Conditioning Unit

The conditioning unit receives two signals: one coming from the CT (current transformer) and another coming from the voltage clips that are connected to the main line. Both CT and voltage clips are parallel to the main line such that in an unlikely case of a breakdown of the sensing unit, the appliance will not be shut down. This is a necessary safety feature since it would be unacceptable if appliances such as a fridge or computer be turned off without notice when there is a malfunction in the sensing unit.

3.3.1. Current Input Signal Conditioning

An AC1025 CT from Amveco Magnetics Inc. is used to senses the current passing through the main wire. The CT has an output to input ratio of 1:1000. The CT specification table along with output voltage versus input current graph is presented in Figure 6 and Figure 7 [3].

Electrical Specifications @ 20°C ambient

Electrical Specifications	
Primary Current	25A nom., 75A max.
Tums Ratio	1000:1 nominal
Volt per Amp Ratio at 25A for 100 ohm load	0.100 V/A
Volt per Amp Ratio at 2.5A for 100 ohm load	0.098 V/A
DC Resistance at 20°C	48 ohms
Dielectric Withstanding Voltage (Hi-pot)	4KVrms
Mechanical Specifications	
Case	Polycarbonate
Encapsulant	Epoxy
Flammibility	Conforms to UL94-VO
Terminals	Pins Ø 1.0mm
Marking	Date Code (W/Y) AC1025, Dot at start pin
Approximate Weight	35.5 grams
Tolerance	±0.2mm

Figure 6: CT Specifications

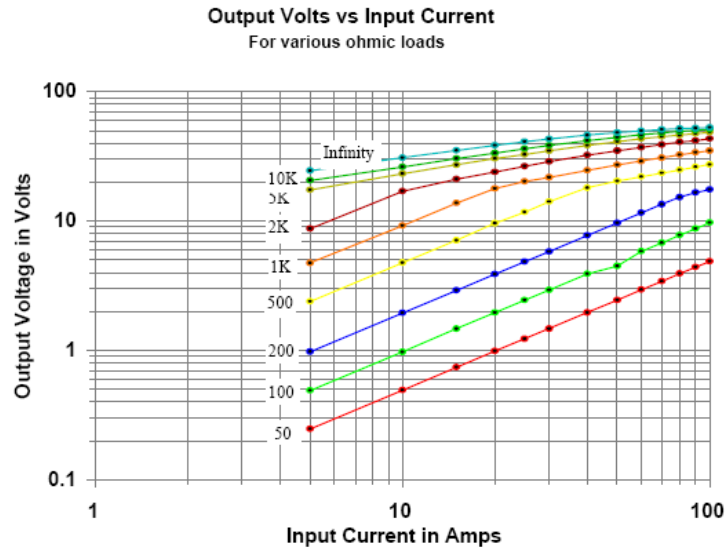


Figure 7: Output Voltage vs Input Current Graph

A 200Ω shunt resistor (blue line in the figure above) connected to the CT generates voltages according to the above graph. The reason why the 200Ω value was chosen is due to the fact that a typical house appliance’s current range (0-20A) generates a linear output voltage. Moreover, a 200Ω resistor gives out higher voltages for lower currents compared to the 100Ω and 50Ω ones and therefore would be easier to process. The schematic of current input signal conditioning circuit is shown in Figure 8.

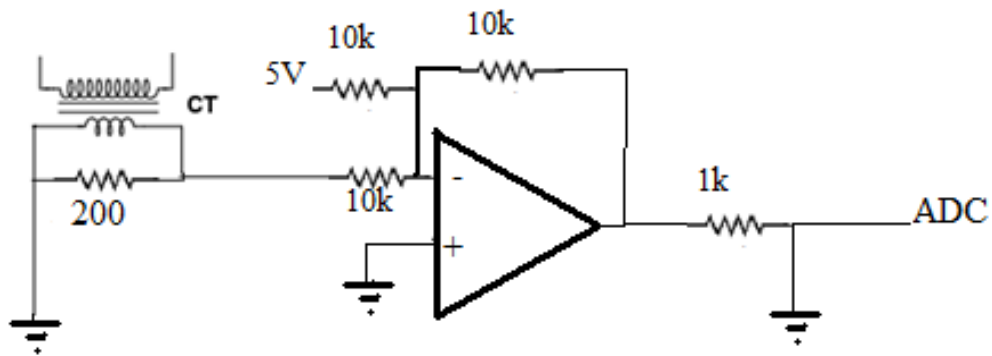


Figure 8: Current Conditioning Circuit

The voltage generated across the 200Ω resistor is level shifted through the summing amplifier. The level shifted voltage is passed to the ADC unit. The graph in Figure 9 demonstrates the signal conditioning process (level shifting).

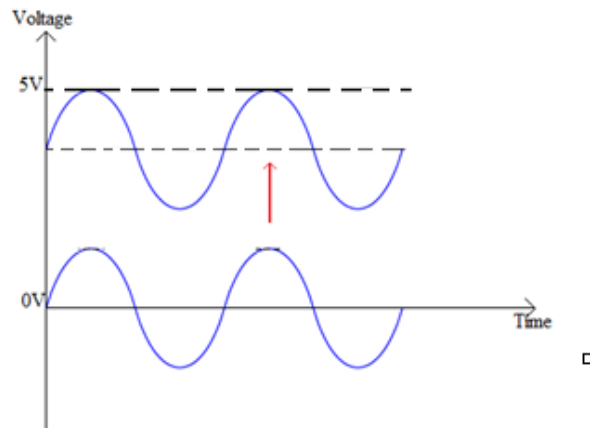


Figure 9: Level Shifting

There exists an alternative solution, which does not make use of an op-amp. The schematic for this solution is presented in Figure 10.

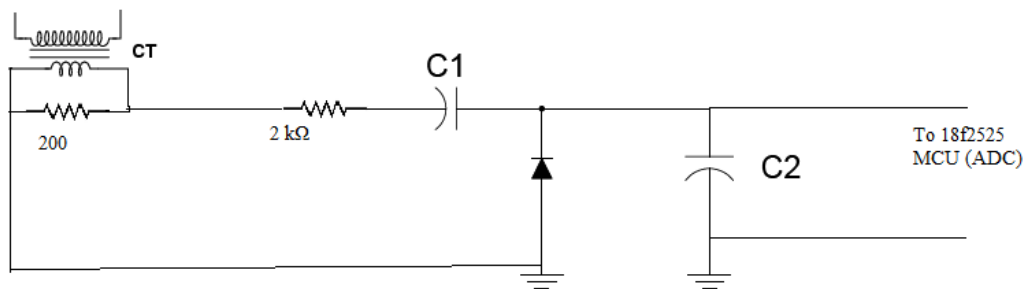


Figure 10: Alternative Current Conditioning Circuit

As can be seen from the figure above, capacitors C1 and C2 together with the diode shift the wave up so that the minimum becomes zero (theoretically). The only issue with the above design is that the minimum voltage is never exactly zero, but rather a value close to -0.3V, which corresponds to the diode forward bias voltage drop. The graph in Figure 11 illustrates this issue.

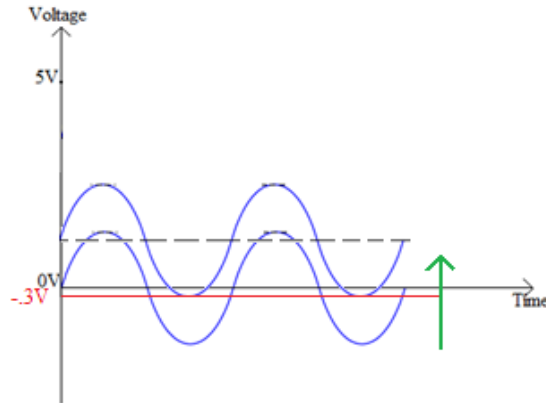


Figure 11: Graph of Waveform with Alternative Design

3.3.2. Voltage Input Signal Conditioning

The input voltage signal is conditioned almost the same way as the current signal. The difference is that voltage is stepped down using an AC transformer and also there is no shunt resistor in this configuration. The schematic of the voltage input signal conditioning circuit is shown in Figure 12.

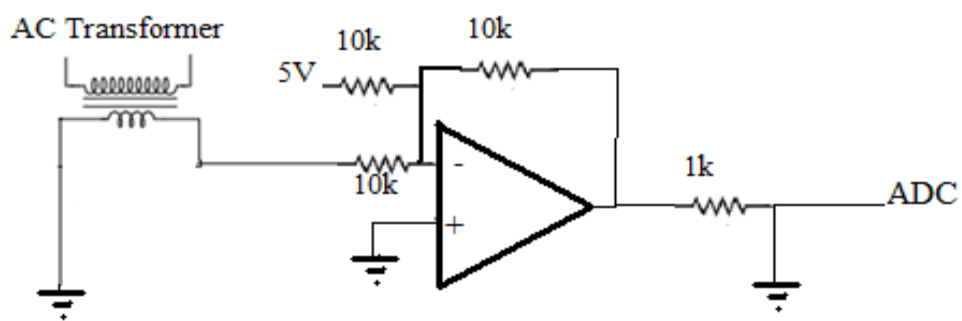


Figure 12: Voltage Conditioning Circuit

As can be seen from the figure above, the stepped down voltage waveform is fed into the negative terminal of the op-amp. The output is then passed to the analog pin of the ADC.

3.4. ADC Module

The conditioned current and voltage waveforms coming from the signal conditioning unit are fed into the ADC module. This module is part of the PIC18F2525 microcontroller. The following are the main reasons why this microcontroller was chosen:

1. Large RAM size (1024Bytes), which is enough for storing captured data (full waveform of current and voltage)
2. Supports UART for RS232 to be connected directly to PC.
3. Capability for SPI communication to wireless unit.
4. Has appropriate number of ADC channels (of which we need only 2).

PIC18F2525 microcontroller ADC block diagram is outlined in Figure 13 [4].

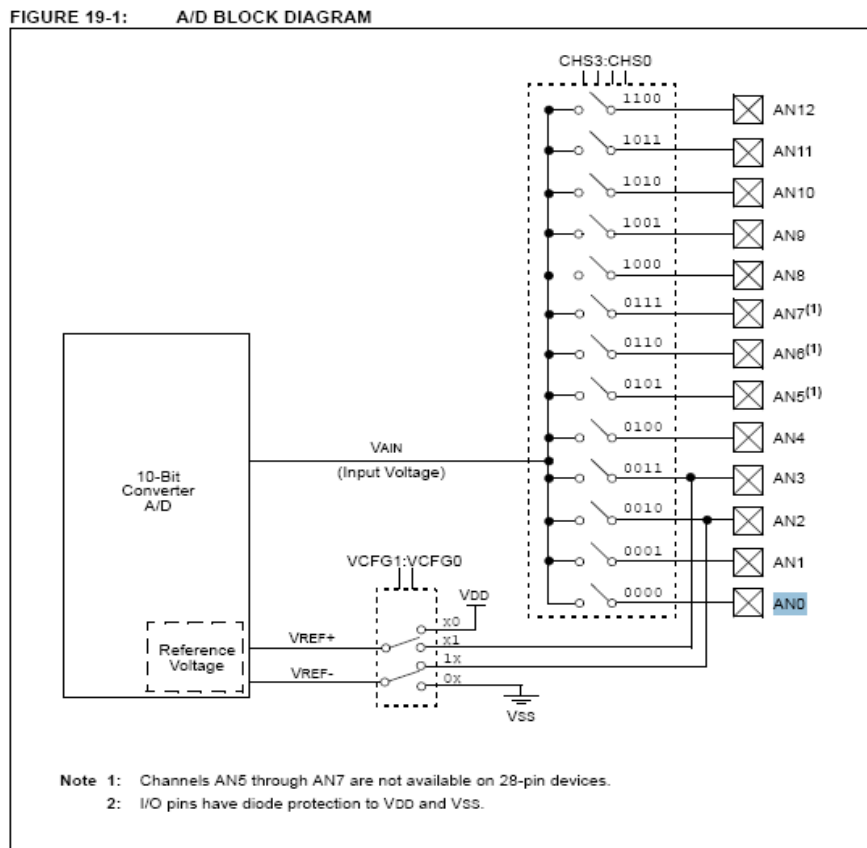


Figure 13: ADC Block Diagram

Analog signals are fed to A/D channel 0 and 1 or RA0 and RA1 pins. ADC has been setup to store data in the 10-bit register (which gives the accuracy 0-3FF hex). Voltage and current signals are captured alternatively for a full period of both the voltage and current waveforms, which is equal to 1/60 s.

Timer1 (which runs on internal clock) has been set up to measure the timing between captures and the total capture time. This timer is set to run on internal clock FOSC/4 which gives the accuracy of 4µs based on the 1MHZ internal clock. The block diagram of timer1 is shown in Figure 14 [4].

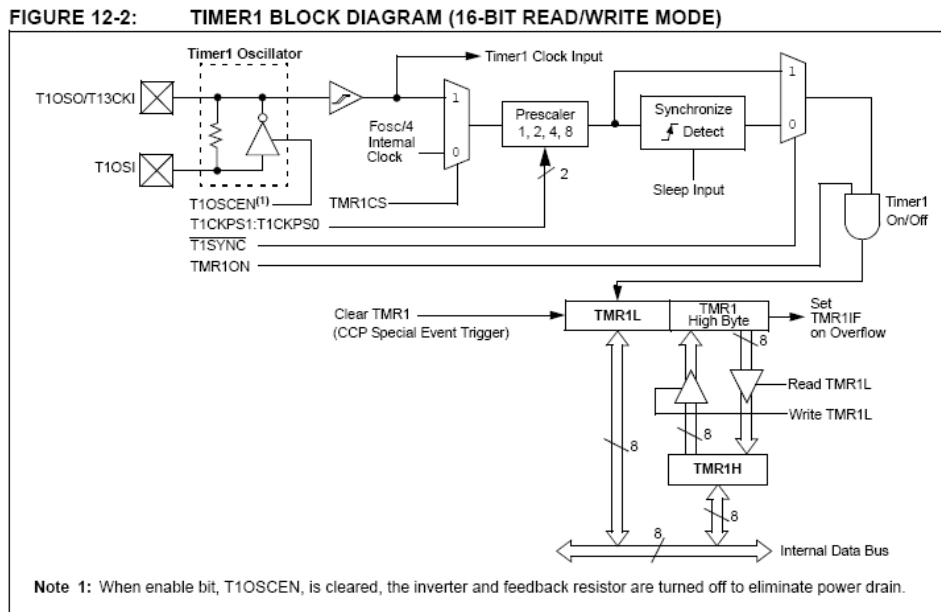


Figure 14: Timer1 Block Diagram

Samples captured for a full period of the voltage and current waveforms are saved in an array. After the capture is complete, they are sent out to the PC. This process is repeated and the MCU shifts from data capture to data transfer and vice versa.

3.5. RS-232 Module

Using the same micro controller PIC18F2525 and MAX232 chip, the data captured through A/D channels is transferred to the PC through an RS-232 port. The schematic of the RS-232 module is shown in Figure 15.

The communication between the PIC microcontroller and the MAX232 chip is performed through the TX and RX pins (see Appendix for pin layout) of the PIC18F2525 and the T1in and R1out pins on the MAX232 chip (see figure 14). The main function of the MAX232 driver/receiver system is to convert TTL/CMOS input voltage levels into EIA-232 levels and vice versa [5]. In other words, the driver provides RS-232 voltage level outputs, which are approximately $\pm 7.5V$ from a +5V MCU supply and the receiver reduces RS-232 inputs, which can be as high as $\pm 25V$ to standard 5V level suitable for the MCU [6].

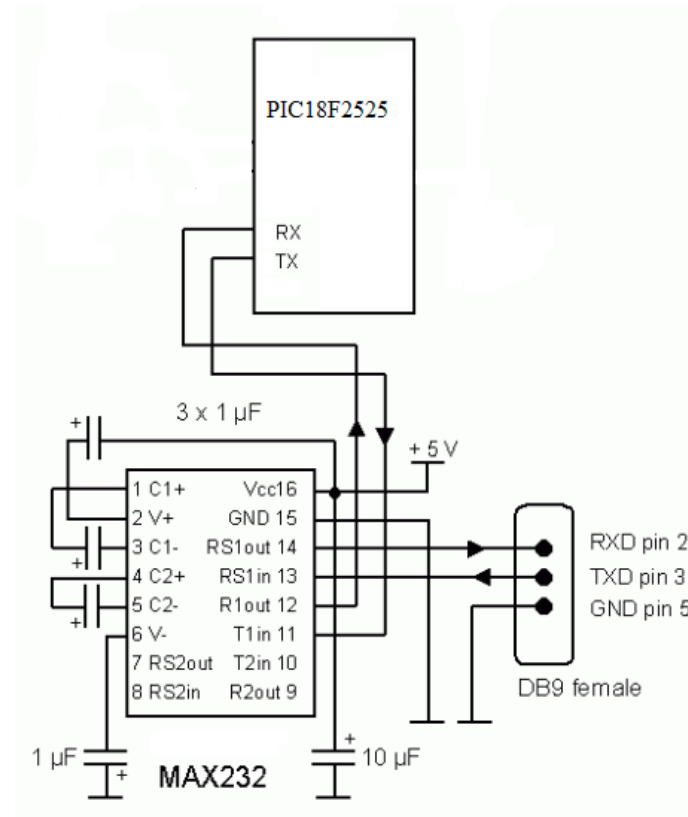


Figure 15: RS-232 Module

The following are the default parameters for RS-232 communication:

- Baud rate = 1200
- Data bits = 8
- Parity = Odd
- Stop bits = 1

With this RS-232 module, the sensing unit can directly be connected to the PC for testing and calibration purposes. An alternative communication method is through the USB port. The reason that RS-232 was chosen over USB was because of its simplicity and the fact that the RS-232 port communication, unlike the USB method, does not require the user to install any drivers.

3.6. PIC18F2525 Dedication Time to Different Modules

Since PIC18F2525 is used in common between the RS-232 and ADC modules, its time is divided between these two modules in a series type of format as depicted in Figure 16.



Figure 16: Time Division between Modules

In other words, the MCU alternates between capturing data and sending out data. This will not cause a problem in accuracy of the data because the transfer time is very small compared to the data acquisition time.

4. Wireless Module Unit

In this section, the wireless module unit is described. The main function of this unit is to receive data from the MCU and transmit it to the PC through a wireless connection. This section is broken down into four parts. The first part provides a general description of the XBee module. The second part describes the IEEE 802.15.4 wireless standard used by this module. The third part outlines UART serial communication. The last part talks about how a personal area network is established and configured.

4.1. XBee Description

As outlined in the Functional Specification report, XBee 802.15.4 module was chosen for the wireless communication. The motivation for choosing XBee was mainly based on its simplicity, lower power consumption, lower cost, and larger range compared to other wireless protocols. After IEEE 802.15.4 committee started developing this low data rate standard, they joined ZigBee Alliance and produced the present commercially available module. Because of its low power consumption it can run on battery life as long as several months to several years. XBee 802.15.4 is similar to Bluetooth but it is simpler. The operational range for XBee is 10-75m compared to 10m for Bluetooth (excluding power amplifier), however in terms of data rate Bluetooth is superior. The data rate of XBee is 250kbps at 2.4GHz, 40kbps at 915MHz and

20kbps at 868MHz whereas that of Bluetooth is 1Mbps. Given the fact that a high data rate is not required in our project, XBee is the best candidate for this project.

4.2. IEEE 802.15.4 Standard

IEEE 802.15.4 details the specifications of PHY and MAC layers and has 3 types of topologies: star, peer-to-peer, and cluster tree. These topologies are outlined in Figure 17

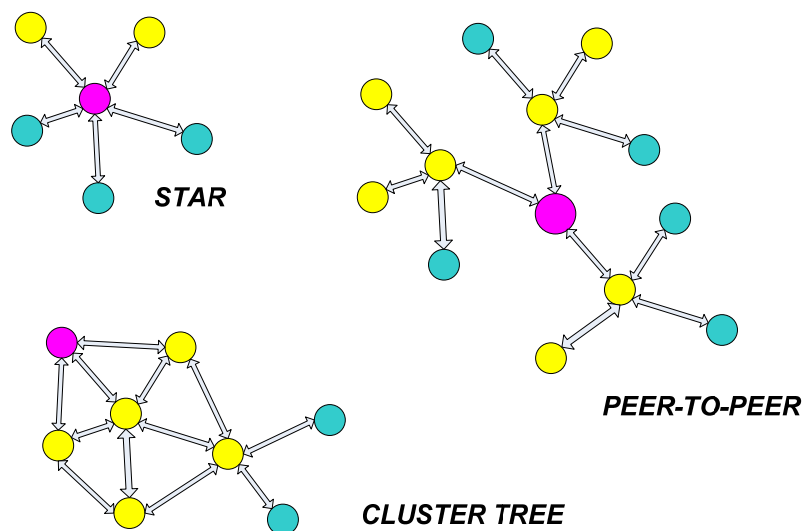


Figure 17: Three Network Topologies

As can be seen from the figure above, star topology communicates between devices and a single central PAN coordinator. On the other hand, devices in the other two topologies have the capability of communicating with each other as long as they are in the range of one another. Cluster-tree network is a subdivision of peer-to-peer network where only a few functional devices are able to communicate directly with each other. For our project we are using a star network.

4.3. UART Configuration

The XBee modules are capable of interfacing to its host device through a serial port. They can communicate with any device that supports UART. The UART is a circuit that translates data between parallel and serial forms [7]. Since the PIC18F2525 microcontroller has a USART

module, it can communicate with the XBee device. Figure 18 shows the connection between the microcontroller and the wireless module.

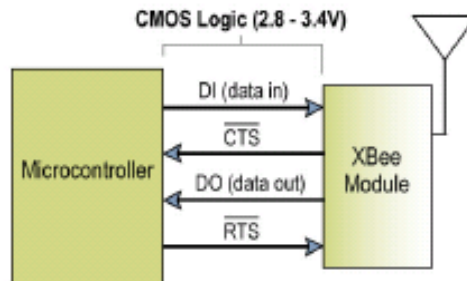


Figure 18: UART Dataflow Diagram

In the figure above, the DI (data in) signal is going from the TX pin on the MCU, and the DO (data out) signal is going into the RX pin on the MCU. The CTS (clear to send) and RTS (request to send) are flow control signals.

Data enters the XBee module through the DI pin as a serial signal. When no data is being transmitted, the signal voltage should be set to high. Each data byte consists of a start bit (low), 8 data bits and a stop bit (high). Figure 19 illustrates the data pattern that is going into the wireless module.

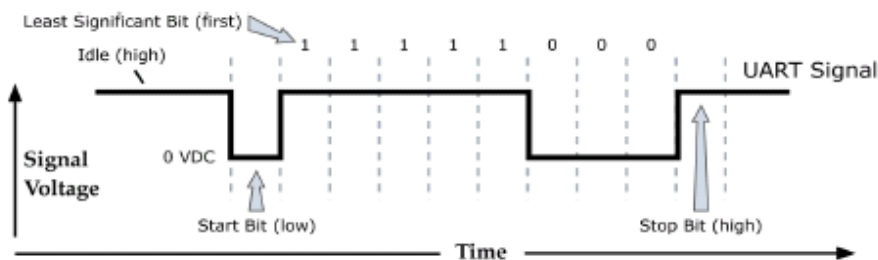


Figure 19: UART Data Packet for XBee

4.4. PAN Configuration

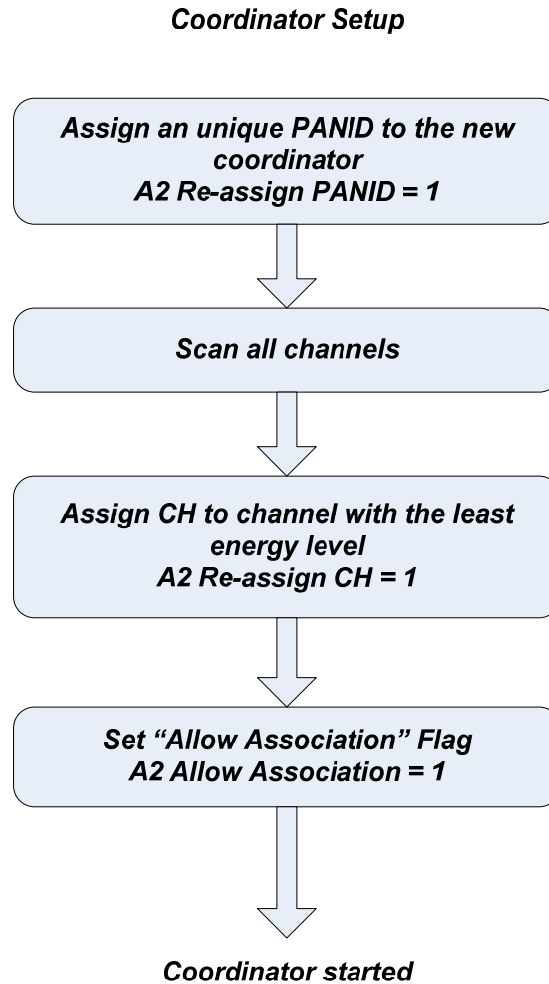


Figure 20 Coordinator Setup

End Device Startup

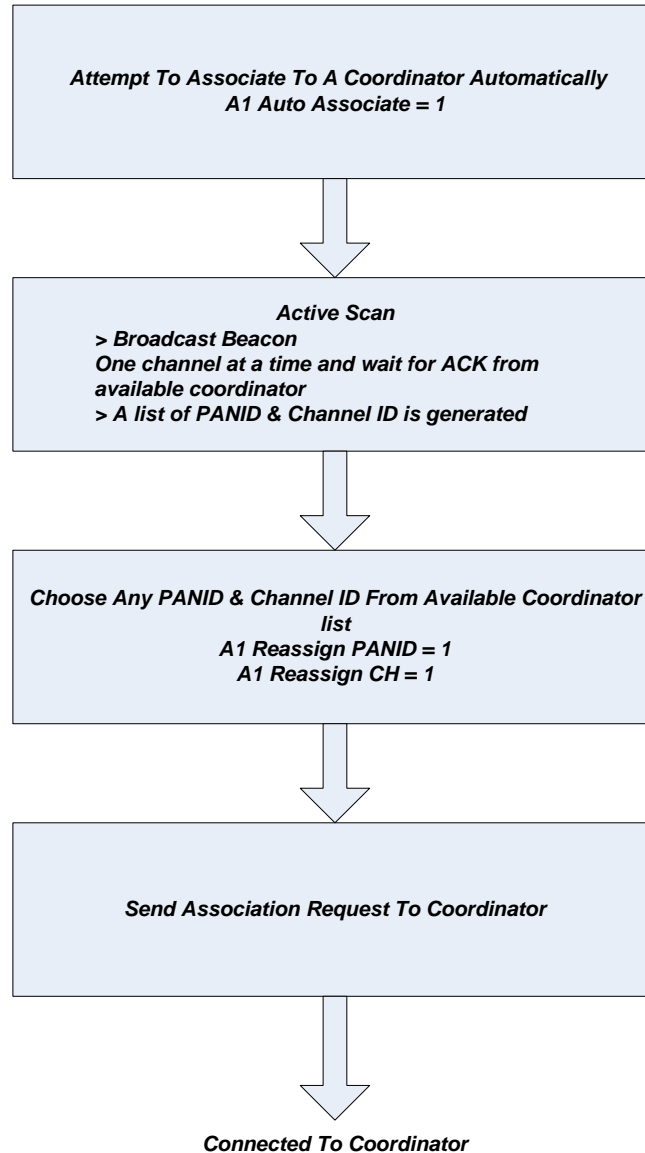


Figure 21 End Device Setup

5. PC Interface Unit

5.1. General Design

Since the MCU is only responsible for data collection, the PC will handle all the calculations and control. Although the functionality that an application provides to users is important, the way in which it is presented is equally important. It is assumed that the end users for this application are not going to have any technical background; therefore the main goal during the design of this application is to make it as simple as possible.

The GUI of the application is based on MDI due to multiple monitoring requirements. Therefore, as many windows can be opened simultaneously as the computer hardware can support. A monitor panel can be opened by going to the menu bar which showed in Figure 22 below. There is also a status bar at the bottom of each panel, which shows information such as: port name, bit rate, parity and the time elapsed since the panel was opened.

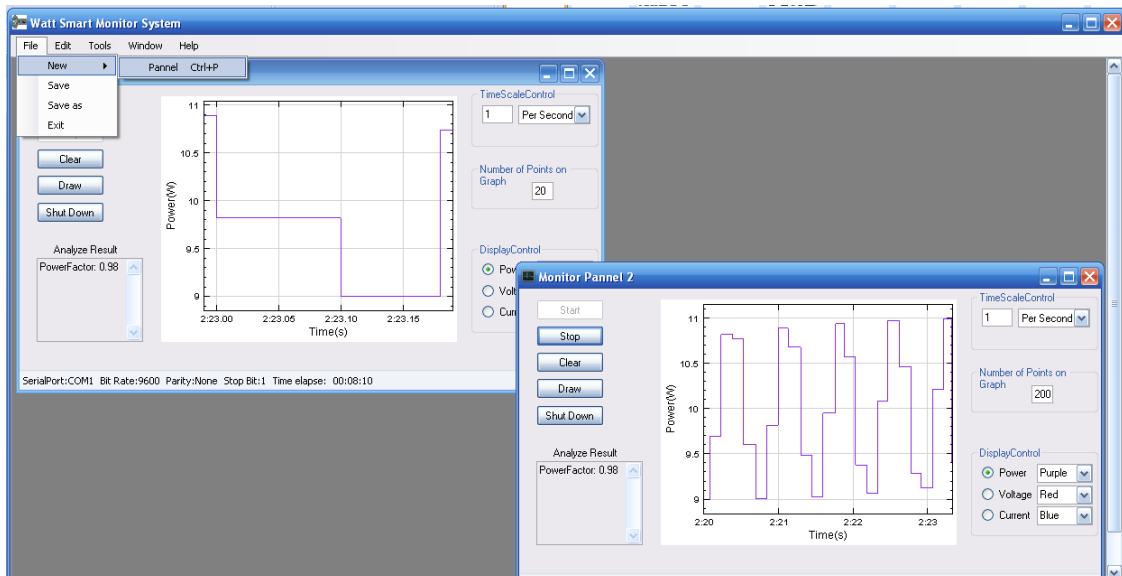


Figure 22: Graphical User Interface (main window)

Before each monitor panel can be opened, the application asks how to connect to the target device, which will be discussed in the following section.

5.2. Data Acquisition

In this application design, there are two ways to acquire the data, one way is directly through the RS-232 serial port and the other one is through a wireless connection using 802.15.4 wireless protocol. Figure 23 shows how the user can select different connections by clicking the corresponding radio buttons at the top of the selection window.

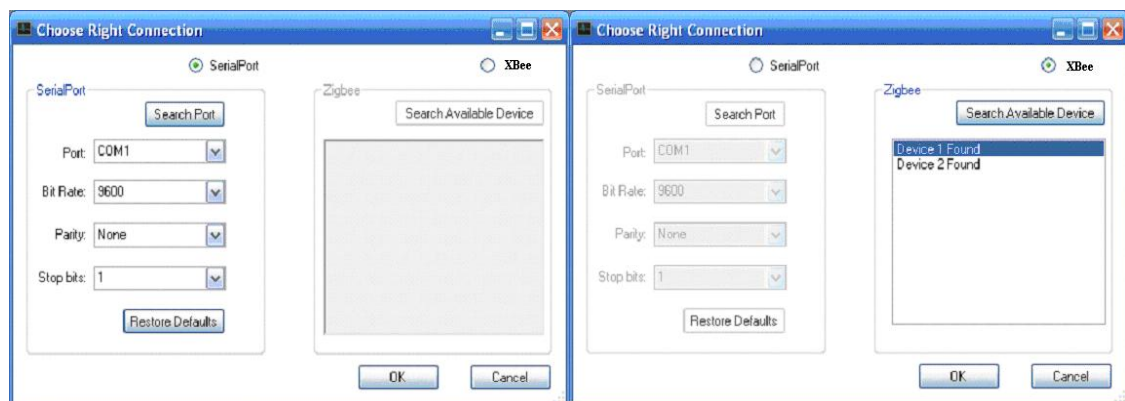


Figure 23: Connection Selection Interface

As can be seen from the figure above, the user can select either the serial port or XBee wireless to communicate with the target device. When a device is connected using RS-232 serial connection, the software will automatically detect the device before this selection window is opened. In the case when this window is opened before the device is plugged in, clicking the “search port” button will find the port that is recognized by the system. This serial port is automatically assigned default values, so that user does not have to change any settings besides choosing the correct port.

The other and more common way to acquire data from the device is using is the XBee wireless connection. This can be achieved by selecting the XBee radio button and then clicking on “Search Available Device” button. The user will be provided with a list of all the available devices in the range. Finally, the user can simply select any of these devices and click OK to open the monitor panel.

5.3. Power Calculations

The general formula for power is shown in Equation 1:

$$P = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i)$$

Equation 1

Since BC hydro only charges for the real power consumption, from the equation above it can be seen that the most important part is to calculating the power factor $PF = \cos(\theta_v - \theta_i)$ in an efficient way. Since only the voltage and current values are received from MCU, there is no way to obtain the time shift directly from this data. However, there are two things that are known: one is the waveform frequency of 60Hz and the other is the approximate sampling rate in ADC in the microcontroller. Based on this information, it has been concluded that the most optimal way to calculate PF is using a part of the DFT. Figure 24 outlines a sample calculation using this transform.

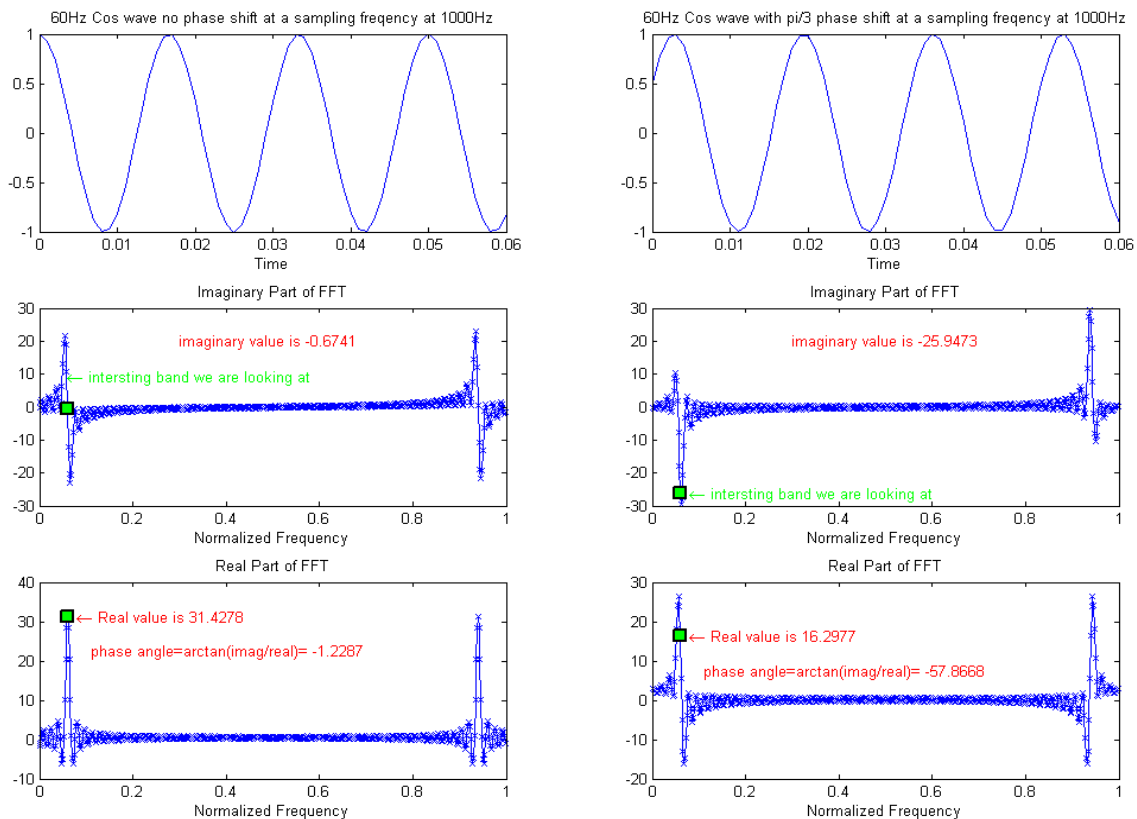


Figure 24: Phase Angle Calculation Using DFT

The figure above is a MATLAB demonstration for a sinusoidal wave with two different phase angles that are determined by the FFT, which is an algorithm to calculate DFT. The function in

left column is $\cos(2\pi 60t)$ and the one in the right column is $\cos(2\pi 60t - \frac{\pi}{3})$. The sampling frequency for both functions is 1000Hz. Therefore, the interesting band in the normalized

frequency is determined to be simply $\frac{60}{1000} = 0.06$. This value is unitless because it is normalized. The green square dot in the bottom two graphs of the figure is exactly at 0.06. Since we are only interested in that one frequency, the calculations for the rest of the bands are no longer necessary. This greatly reduces our workload. In order to directly calculate the band value of interest, the formula from the original Discrete Fourier Transform is used. It is provided in Equation 2.

$$X_K = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} Kn} \quad K = 0, \dots, N - 1$$

Equation 2

In the equation above, **N** is the number of sequence samples and **K** is the corresponding number in frequency domain. In order to derive the equation, three more variables need to be defined: **F_n** is the normalized frequency which needs to be determined, **f₀** is the AC frequency, which is 60Hz and **T_s** is the sampling time of the ADC. The relationship between these variables is shown in Equation 3.

$$F_n = \frac{f_0}{1/T_s} = f_0 * T_s$$

Equation 3

Moreover, **K** can be expressed in terms of **f₀**, **T_s** and **N** as can be seen from Equation 4.

$$K = F_n * N = f_0 * T_s * N$$

Equation 4

Then, **K** is substituted back into the DFT equation to obtain Equation 5.

$$X_K = \sum_{n=0}^{N-1} x_n e^{-j2\pi n f_0 T_s}$$

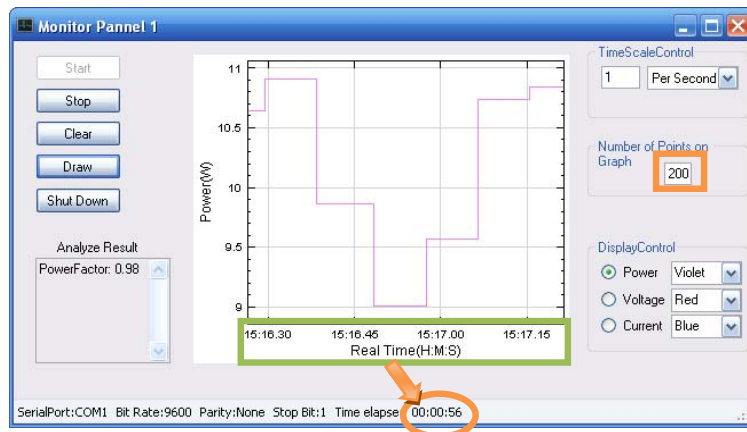
Equation 5

It is important to note that K can be adjusted to be an integer by changing the sampling time T_s . Since f_0 , N and T_s are all known values, the complex number, X_K , can be easily found. By using

this formula to calculate X_K of the two cosine functions $\cos(2\pi 60t)$ and $\cos(2\pi 60t - \frac{\pi}{3})$ from the previous example, two complex numbers $31.4278 - 0.6741i$ and $16.2977 - 25.9473i$ are obtained. Their corresponding phase angles are -1.2287° and -57.8669° . These values are exactly same as in Figure 24. As can be seen, this example demonstrates the accuracy of the power calculation method used in the application.

5.4. Graphing Application

One of the best ways to interpret data is to provide a visual graph for the user. In order to achieve this goal, an analysis tool was built which is able to plot the real-time power usage of an appliance with respect to time. After pressing the start button, the panel will acquire the data from the communication channel, which has been previously set up and will plot the results in the window. The time scale of the graph can be adjusted, so that the user can see the older data as well as the real-time data. A sample graph is shown in Figure 25.



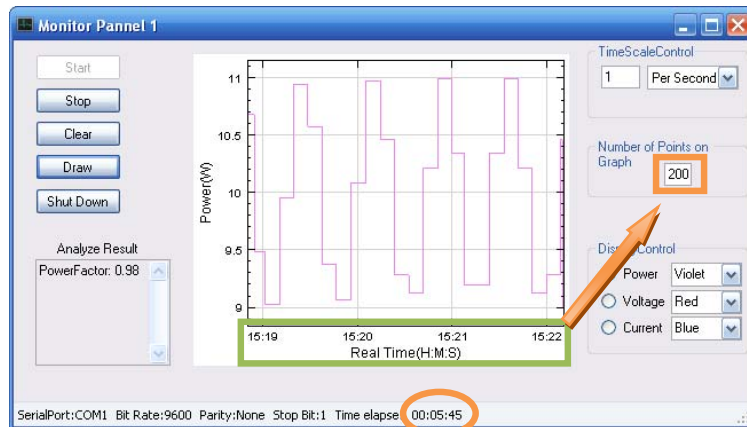


Figure 25: Sample Graph in PC Application

The figure above contains a sample sinusoidal wave with an average power of 10 Watts. The top graph in the figure has only been running for 56 seconds and therefore has fewer points than the required 200. In this case, only the existing points are plotted. The bottom graph has been running for over 5 minutes, so it has more than 200 points. In this case, only the last 200 points will be plotted.

The graphical controls of the monitor panel are outlined in Figure 26.

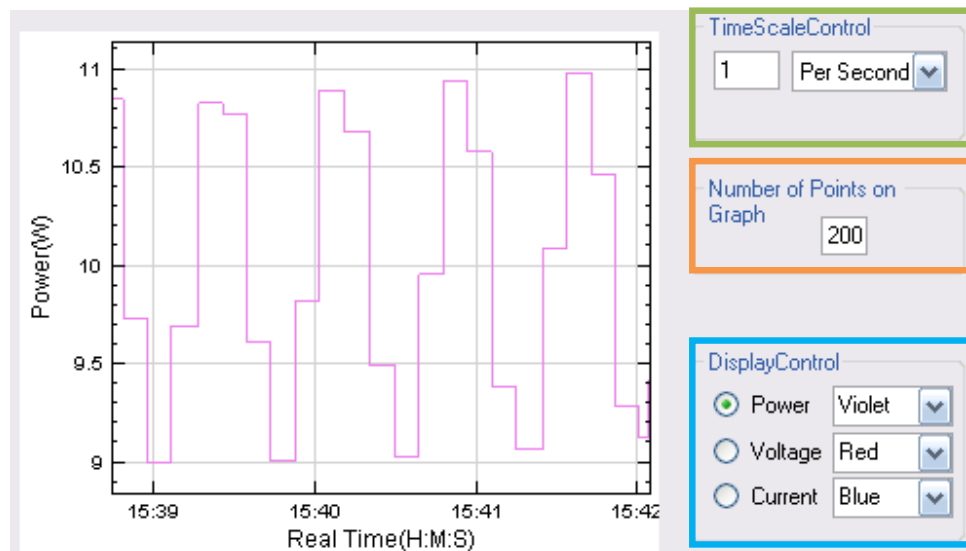


Figure 26: Graphical Controls



As can be seen from the figure above, three control units are provided to user on the right side of the panel. The green square is time scale control, the orange square is graph points control and the blue square is display control.

Time scale control enables the user to adjust the time scale of the graph either per number of seconds or minutes. The user can only input an integer into the scale box; any illegal input will be ignored.

Graph points control allows the user to set the number of points to be displayed in the graph. In Figure 26, it is set to 200 points in graph and the time scale is set to 1 per second. Therefore, the graph should display the results for the last 200 seconds. This is equivalent to 3 minutes and 20 seconds which indeed corresponds to Figure 26.

Display control lets the user select among Power VS Time, Voltage VS Time, and Current VS Time graphs to view.

Figure 27 is an example, which shows four Power VS Time graphs with various settings as well as a Voltage VS Time graph and a Current VS Time graph.

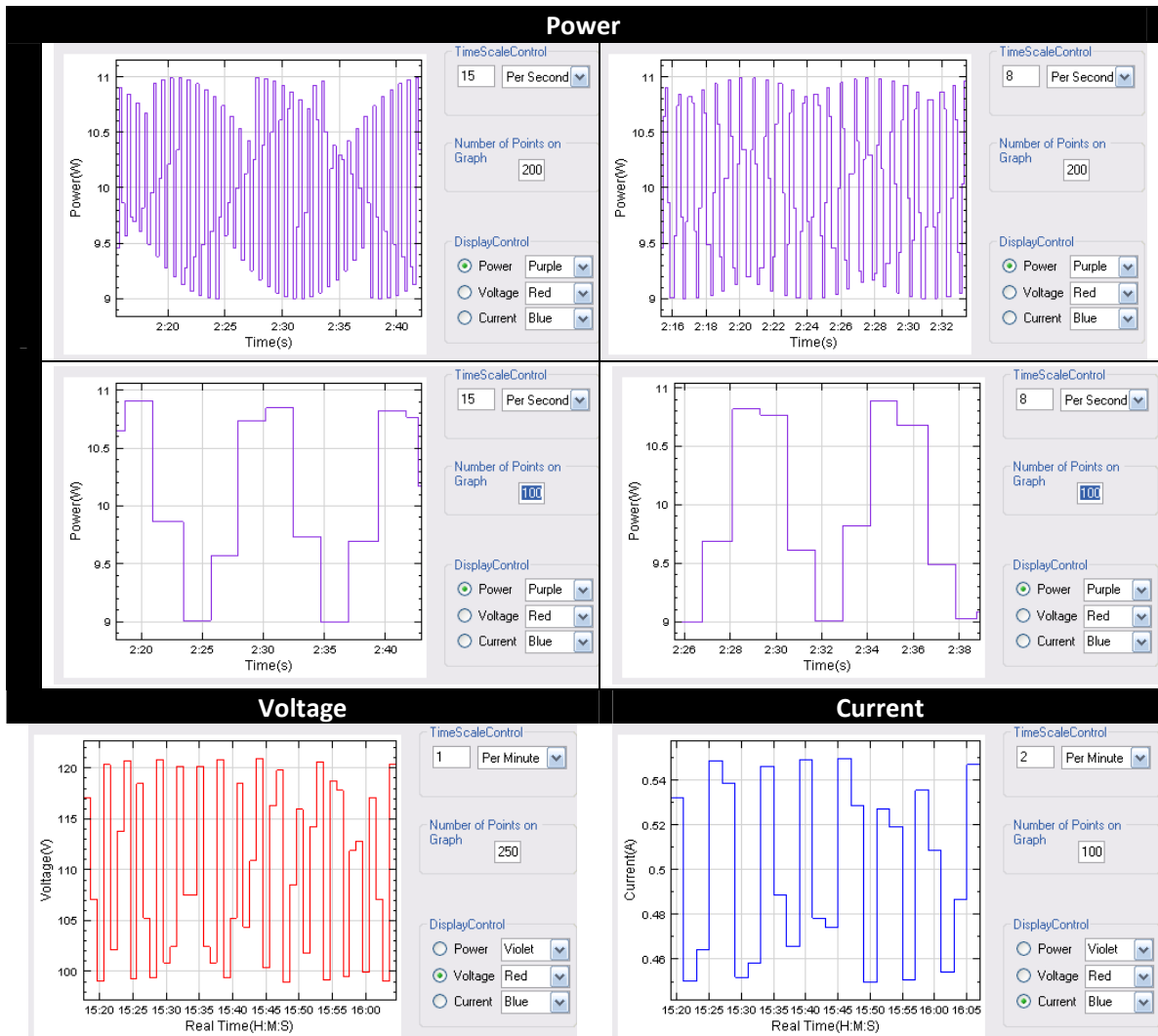


Figure 27: Graphs with Different Graph Control Settings

6. Test Plan

Component Testing

Analog Circuit Test

The analog circuit will be tested by plugging it into the outlet and using the DMM and the oscilloscope to measure and display the resulting voltage and current waveforms. The expected result will be a sinusoidal scaled down version of the original signals. The circuit will also be tested to ensure that it provides a 5VDC power supply for the MCU and the wireless module.

MCU Test

To insure accuracy and the functionality of the MCU, it will be tested before it is connected to the wireless module. A sinusoidal signal from a function generator will be applied to the analog inputs of the microcontroller. The MCU should be able to convert the input analog waveform to digital samples proportional to the magnitude of the input signal. The output signals will be checked using an oscilloscope. Moreover, an LCD display has been incorporated into the first level prototype design so that MCU readings and calculations can be viewed directly on the LCD without the need to send them to the PC. This will ensure that the MCU is fully tested and it is working properly before it is added to the rest of the system.

Finally, before connecting the MCU to the wireless module, it will first be connected to the PC directly to validate the MCU/wireless module communication signals.

Wireless Module Test

The wireless module is developed and tested separately from the analog, MCU, and PC sections. It functions as a drop-in replacement for the wired connection between the MCU and the PC. The wireless transmitter will be connected to another MCU. A known data packet will be assembled and sent out. The receiver must be able to receive the data packet. An error correction in the protocol will be used to identify whether or not there is an error.

PC Application Test

The PC module testing is done without connectivity to the wireless module or the MCU first. The PC application will simulate a received data packet by reading in data of same byte length from a file. The application will calculate the power factor and subsequently the energy consumed. Since the data used is fictitious, the expected power factor and the energy usage are known. The calculated values are tested against these known values.

Integrated System Testing

RS-232 System Test

This integration test will involve connecting the analog circuit and the MCU directly to the PC using the RS-232 port. The test will determine whether or not the analog circuit and the MCU are functioning correctly by analyzing the MCU output on the computer. This will be done by applying different voltage and current waveforms to the circuit input and checking the calculated values on the PC.

Wireless System Test

In this integration test, the wireless module will be added to the system. This test will involve combine the elements of the RS-232 system test and the wireless module test and ensure that the whole system is functioning correctly. After the signal is passed through the analog circuit and the MCU, it will be transmitted to the PC through the wireless module. On the PC, the acquired data will be analyzed for validity by comparing the expected and measured results.

7. Conclusion

In this document, the proposed design solutions for the functional requirements of the product have been discussed. The design that was chosen for the prototype device has been described in detail and the design choices for each component were justified. Until the end of the development cycle, the design and functional specification documents will act as reference documents and will be gone through on a weekly basis to ensure that all the appropriate requirements have been included in the prototype device.



8. References

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9. Appendix

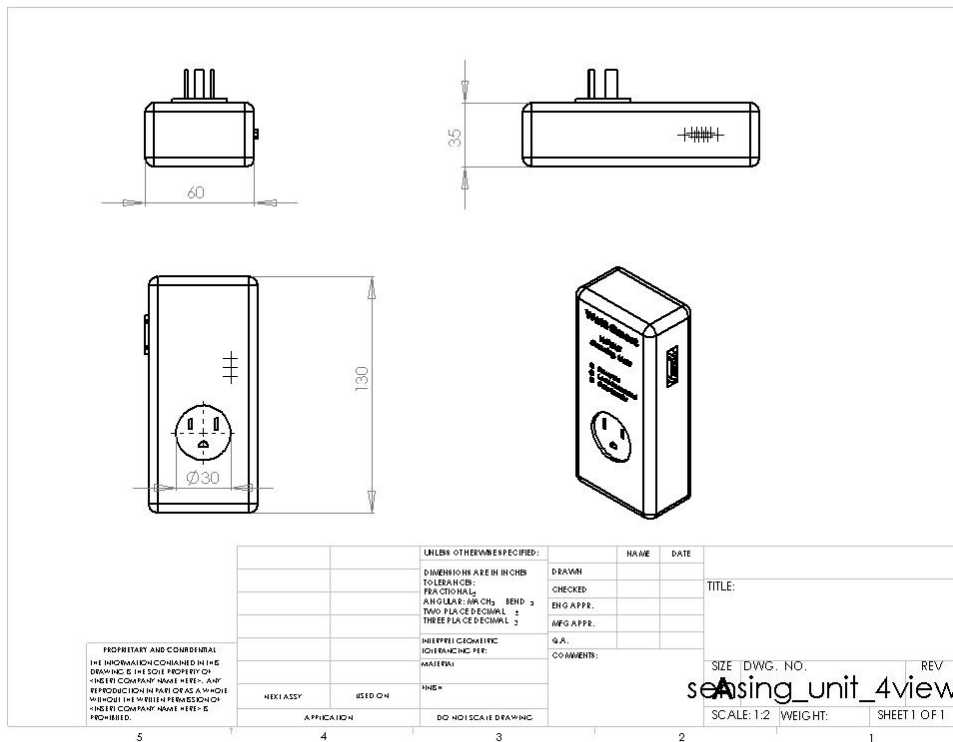


Figure 28: 4 Views of the Sensing Unit

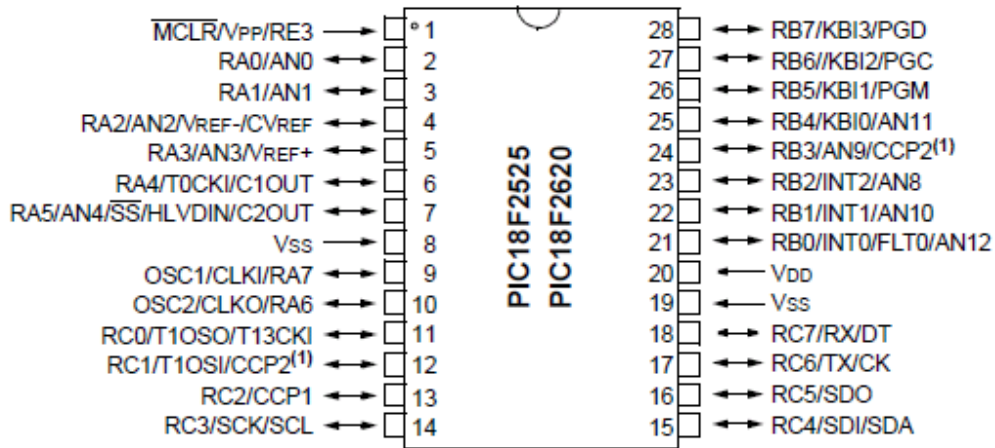


Figure 29: PIC18F2525 Pin Diagram [4]