DESIGN AND CONSTRUCTION OF MICROCONTROLLER BASED DIGITAL WATTMETER

BY

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SUBMITTED TO

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DEDICATION

I Dedicate this project to Almighty God the source of all Wisdom, Understanding, Knowledge and Energy.

DECLARATION OF ORIGINALITY

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CERTIFICATION

This is to certify that the design and construction of this energy measuring device for home appliances was carried out by OLABINJO EBENEZER TOPE of the department of Electrical and Electronics Engineering. Federal university Oye Ekiti, Nigeria.

The project is my own work and has not been submitted to any other university or higher education institution, or for any other academic award in this university. Where other people's work has been used, it has been fully acknowledged and fully referenced.

....

Engr. S. O. Sanni

(supervisor) **Date**

....

Engr. Dr. J.T. Oricha

(H.O.D) **Date**

ABSTRACT

The purpose of this project is to design and implement a digital wattmeter that can measure wattage of a circuit. The design is implemented using the microcontroller ATMEGA 8, based on the principle of calculating power mathematically two ATMEGA8 were used, one for measuring current while the other for measuring voltage, the multiplication of the voltage and current values gives the wattage reading. At the end of the process the LCD displays the voltage, current and wattage readings. The wattmeter is able to take both AC and DC measurements.

ACKNOWLEDGEMENTS

First of all, I will like to give thanks to God who kept me in His infinite mercies and helped me during the course of my project.

Special thanks to *Engr. S.O Sanni,* my project supervisor, for overseeing and coordinating the project, as it would not have been a success without his support, guidance and fatherly advice. His constructive scrutiny and criticisms were really helpful throughout the course of the project God bless and continue to be with you in everything you do.

I will also like to thank the Head of Department, *Engr. Dr, Orichai*, my special thanks to *Prof. B. A. Alabadan, Prof. A.O Akinsanmi, Prof. Y.A. Adediran, Engr. G. K. Ijemaru, Engr. H. U. Ezea, Engr. Olusuyi, Engr. Ofusori, Engr. Adebusuyi, Engr. A.K Babarinde, Engr. Amoran, Mr Ajibola* and a host of other lecturers and staff for their support throughout my degree program.

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My sincere gratitude to my father in the lord *Prophet Samson Oluwamodede* for his spiritual support. Many thanks to everyone that assisted me in my journey of 5years, God bless you all.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The Rating of an electrical system plays a very important role in the world of electrical and electronics, its enables an effective knowledge of the amount of power an electrical system or circuit consumes. To measure this power wattmeter is used.

Dated back to 1889, wattmeter has featured in so many applications till this present date. Either coupled inside a system or outside a particular circuit, wattmeter form a vital instrument in measuring the power a system consumes. in applications such as energy meters, mobile phones, motorbikes among others its goal and purpose remains the same.

Basically a Wattmeter is used mainly for checking the power an appliance or a power system is consuming. It can also be referred to an instrument used in determining the electrical power or supply rate of electrical power. The unit of power is watt.

Over the years several approach have been implemented in terms of making a wattmeter today it principle had been changed, due to revolutions and drift change in technology Digital Wattmeter have been now introduced and its been used across the globe with several purpose such as :-

1. Measuring instrument for electrical circuit measurement and debugging
2. They are also used in industries to check the power rating and consumption of electrical appliances.
3. Electromagnetic Wattmeter are used to measure utility frequencies.
4. They are used with electric heaters, refrigerators and other equipment to measure their power ratings.

Today as technology advances and mid-high tech devices become more readily available to engineering and technology students as well as researchers now have increasing need for reliable, cost effective testing equipment. Digital Wattmeters are one of these increasingly useful pieces of equipment.

J. Res. Natl. Inst. Stand. Technol, (1992) many of the Wattmeters used in laboratories are less efficient, its seen that several Wattmeters where tested under same conditions and many of them yielded several results. From a deep research it was discovered that part of the cause of the variation in the results from these Wattmeter are due to the environment in which they are calibrated and the conditions they pass through during shipping, J. Res. Natl. Inst. Stand. Technol, (1992).

This brought about the initiative of creating a Wattmeter for the school laboratory, with the use of microcontroller ATMEGA8 the Wattmeter is realized which is believed to be more efficient and reliable and will provide a uniform reading for any material brought to the laboratory for test.

1.2. PROBLEM STATEMENT

There are currently many models of Digital Wattmeters available and being used in industrial settings. Most industrial Wattmeters have better measuring capability, advanced data logging capability and functionality but are not affordable for students. The less expensive versions of these Wattmeters are permanently embedded to their system/application. Being permanently affixed to their application makes them impractical for students, hobbyists and electronics vehement. The goal is to produce a suitable Wattmeter that will help students, and electronics vehement meet their electrical and electronics need.

1.3 MOTIVATION

Today most laboratories have physically large meters like the Wattmeter and other laboratory equipment to measure the value of power. With a vast world of new inventions and innovations I decided to focus on fundamentals of the measuring equipment because it serves as a base line for many electrical circuit & equipments.

Apart from the urge to making a tangible contribution in the world of electronics I worked on a wattmeter that makes use of Microcontroller as its mean for measurement, in order to design and implement a wattmeter that will be optimally useful in the Fuoye Electrical Electronics laboratory.

1.4 SIGNIFICANCE OF STUDY

The Micro-controller Based digital Watt Meter will essential improve the laboratory, as earlier stated Watt Meter is one of the most important measuring instrument in the growing world of technological equipment. It will provide a very reliable power readings and defined aesthetic and portability.

Watt Meters are not limited to meauring the laboratory equipments it can also be used to check the power an inverter generates into building among other functional use of watt meter.

1.5 AIM AND OBJECTIVES

The aim is to design and implement a microcontroller Based Digital Wattmeter, that is capable of measuring the power flowing through a electrical power circuit.

The objectives of this project are:

1. To design a power capacitive system for the wattmeter.
2. To design a voltage and current sensing circuit
3. To make adequate selection of components
4. To design and implement a fully functional micro controller based digital wattmeter.
5. To test and analyze the optimum performance of the wattmeter

1.6 SCOPE OF STUDY

The research aim is to design and implement a wattmeter that uses a microcontroller as its mean of measurement, comprising of the voltage sensing part and the current sensing part. It measures the power of a particular electrical circuit by multiplying the voltage and current in the microcontroller. Conforming to the theoretical formula for power.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORY OF WATTMETER

Wattmeter has been in existence for more than 100 years dating back to the development in the field of electrical engineering. Wattmeter comes in form of voltmeter and ammeter which are devices used for measuring the voltage and current consumed by a piece of electrical equipment or its electrical output discharge.

The great invention comes into limelight around the nineteenth century. The great philosopher Alfred North Whitehead can be regarded as the pioneer father of what we call wattmeter today when he developed this idea around (1891-1941).

Wattmeter was developed earlier into simple watt-hour meter. Oliver B. Shallenberger was the founding father of this native invention in Pittsburgh. He used this device to measure the amount of A.C current and made possible the business model of the electric utility.

Gardiner (1872), developed a wattmeter design in the form of lamp-hour meter. He uses this invention to measure, during which energy was supplied to the load, as the lamps connected to this meter were controlled by one switch.

Thomas Alva Edison (1847-1931), developed an electrolytic meter where he uses the current passing the coil or filament of a lamp coupled with the meter to the rate of energy consumed by the lamp.

German Siemens-Shuckert Hygrogen meter is another form of wattmeter that was developed to measure the ampere-hours consumed by electrical equipment. This device was developed to tackle the basic challenge faced when required to measure the power consumed by electrical machines.

Edward Aryton and John Perry (1881), developed a wattmeter called Pendulum meter. In this invention, two pendulums with a coil on both pendulums connected to the voltage, also below the two pendulums were two current coils winding in opposite directions. They developed these pendulums to swing slower and faster without load. The difference between the oscillations was used to measure the rate of energy consumed by an electrical device.

Another form of wattmeter is motor meters. Thomas Elihu Thomson (1853-1937), made the motor meters to record the energy consumed by a device. This device consists of an iron-less motor, with the rotor excited by the voltage through a coil and a resistor, using a commutator. Elihu measured the current and the voltage drop across this device through the knowledge of electromagnetic induction produced by the electric field.

2.2 LITERATURE SURVEY OF RELATED WORKS

Scherrer (2012), analyze the use of digital radio frequency wattmeter to measure and show the peak values of energy consumed by an electrical and electronic appliance inform power levels. The protégé research made use of various passive and active electronic components to achieve the aim of measuring power digitally. Additionally to use an analogue to digital converter to transform the product level of voltage and current levels measured from the device into discrete values of power level, and later make use of another converter to change the discrete values into radio frequency voltage levels and power levels respectively. The work was accompanied by a list of major challenges which includes the design prototype been too heavy and cumbersome to use, not considering other countries with voltage variation, the design prototype could not be afforded by an average student to use and the design does not encourage its use in a simple or a developing environment. The aforementioned challenges are tackled by this project in a simple and modest manner of approach by providing a simple and mobile design.

Polash (2013), describe the measurement of power with the use of a current sensing shunt resistor. It wad proposed to use a shunt resistor to measure the power consumed by a device when it senses a temperature change from the ambient environment, when there is a variation between the ambient environment temperature and the preset or standardized temperature limits within the system, the change in temperature or difference in temperature is sent to the brain of the system for immediate analysis, and the later information from the microcontroller is displayed on the liquid crystal display (LCD). Eventually a universal meter was designed using a current sensing shunt resistor, IC LTC1050, Arduino nano(ATMEGA328) and a 20x4 LCD display as the major building blocks of the design. The real power, reactive power, apparent power, frequency and energy information conveyed by the output signal from LTC1050 and its extracted by necessary calibration process and finally displayed to LCD display using microcontroller coding. Additionally the resistive value of resistors is subject to temperature changes not only by the ambient temperature but also by self-heating. To reduce the self-heating of the shunt resistor, the allowable power dissipation must be quite over-dimensioned. The specified power dissipation must be approximately 10 times higher than the real maximum dissipation.

One of the challenges faced by this invention is that a large amount of heat is dissipated by this design prototype which can cause smoke, fire, and large destruction of the design circuit which is risky for laboratories and electronics enthusiast because they tend to spend a lot of times working or testing electrical circuits. Also, accurate measurement or reading cannot be deduced from this prototype design, because it's based on temperature changes.

This project has immensely looked into this limitation of this work as an improvement by blending in modern day technology with relevant components to achieve a better result, making use of electronic component with low or less amount of heat dissipation to tackle its predecessor's challenges.

Dietrich (2011), analyze the use of digital A.C wattmeter to measure the rate of energy consumed across a load. The aim of the work was achieved by making use of similar electronics component interfaced with a microcontroller as the brain of his design. Analogue voltage levels are transformed into a sinusoidal waveform that has peak levels. These peak levels are shown on the liquid crystal display as the output power consumed by the device or load. This design has a major challenge which includes the idea of its calibration which is meant for a single use i.e. it can be used only for A.C power measurement, It ability to function well with other forms of current is ill making it not useful for our laboratory.

This project will take the critical and professional approach by solving the aforementioned challenges by providing a system that can be used in our laboratories for both A.C and D.C analysis of power consumed by any electrical or electronic equipment, providing a wattmeter that can help to bring down the cost of testing in our environment.

Jack (2012), worked on the design and implementation of digital wattmeter using a current sensing device. Using several electronic components with various units and a microcontroller to implement and achieve the required aim, which was to measure the power dissipated across a load when it's been supplied with alternating current and alternating voltage. The work suggests the use of a shunt resistor to measure the current flowing through the load or electrical device and also make use of voltage divider to capture the voltage drop across the load. It further takes the reading from these sensors and sends it to the microcontroller, the microcontroller which serves as the brain of the system send the processed information to the LCD for immediate visualization.

This design has a major challenge which includes the high cost of testing and implementation while its only calibrated for A.C power analysis. Apart from the fact that it's not suitable for research purpose and learning, there is a high level of heat and self-heating of the shunt resistor may lead to total destruction of the system.

Mayori (2014), worked on the use of EPMD to measure power consumed by an electrical device. Maryori suggested the use of his device as a metering device for measuring power consumed by the water pumping machine in our domestic homes. This work has a major challenge which is in the area of application it can only be used for domestic purpose. i.e. it cannot be used for research purpose. This project will approach by solving the aforementioned challenges by providing a system that can be used in our laboratories.

CHAPTER THREE

3.0 METHODOLOGY

This project "microcontroller based digital watt-meter" is built around a powerful microcontroller which helps to coordinate the entire activity within the circuitry. Two ATMEGA8 microcontrollers are devised to measure the voltage and current from either an inductive load or resistive load. Also, an OPTO isolator is used to perform the multiplication of the two parameters measured and transfer it to the liquid crystal display for effective visualization. The parameters that will be displayed on the LCD include measured voltage, measured current, and measured wattage.

3.1 REQUIREMENT SPECIFICATION

The Microcontroller digital based wattmeter is designed to enhance a portability nature and relatively maintenance free. This device will be relatively easy to operate, requiring no special expertise or technical know-how to operate. The device was also made from locally sourced materials and designed to be relatively safe to operate under the school laboratory conditions.

SYSTEM DESCRIPTION

The microcontroller based digital wattmeter has several branches embedd inside its system the branches includes the current sensing unit, voltage sensing unit, the power supply unit and the display unit as shown in Figure 3.1. The voltage sensing unit uses the principle of voltage divider rule, similarly the current sensing unit uses the principle of current divider. The readings are then sent to the microcontroller for multiplication. Making reference to figure 3.1 its seen that the microcontroller then sends the result to the LCD for display.

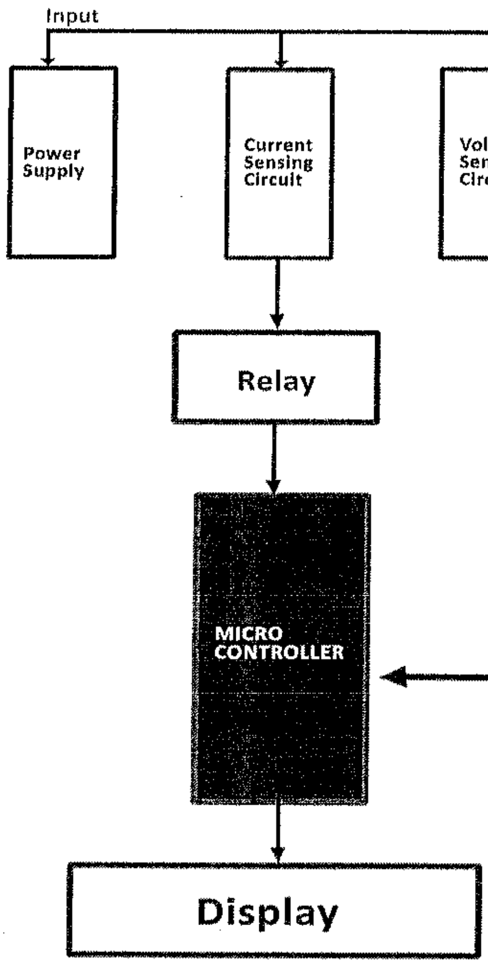
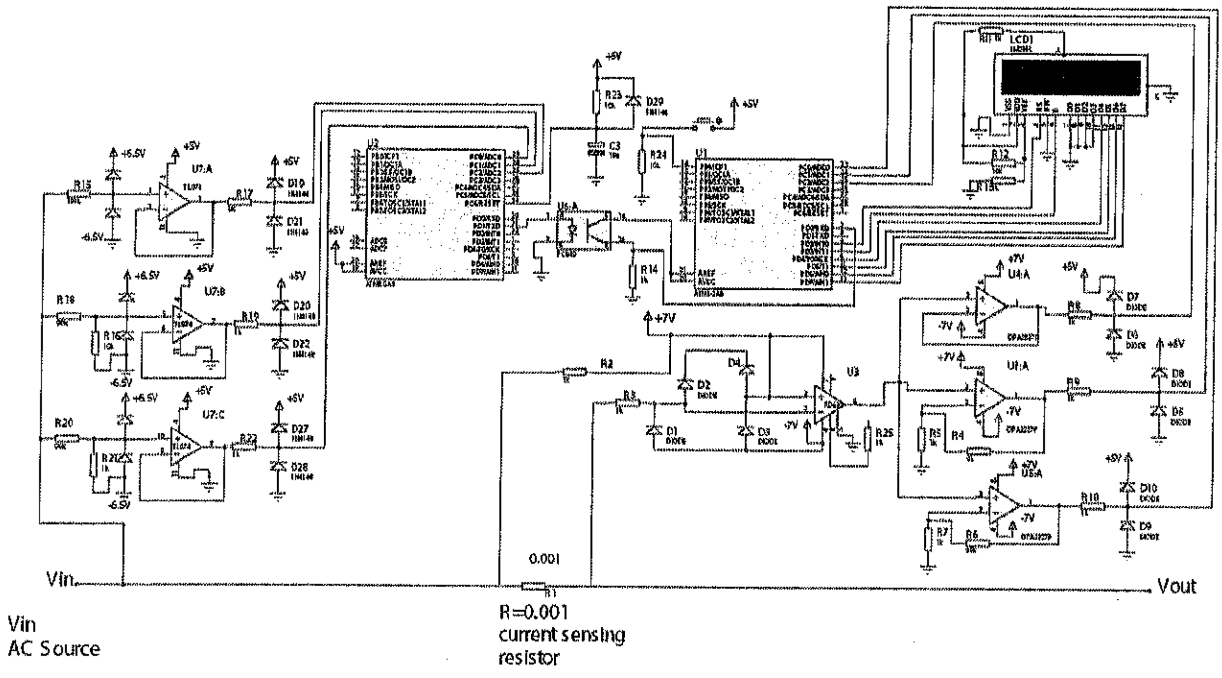


Figure 3.1 Block Diagram of the microcontroller based digital wattmeter

The circuit design of the hardware was made and simulated using the Proteus design suite 8 by lab center Electronics as shown in figure 3.2. Each section of the device was designed and simulated and necessary adjustment made to ensure conformance to desired device objectives. With the aid of this graphical representation of the circuit diagram the circuit comprise of two ATmega8 each of which is in charge of the voltage sensing unit and current sensing unit respectively



Circuit Diagram of microcontroller digital wattmeter

Figure 3.2 Circuit diagram of the microcontroller digital wattmeter.

CIRCUIT ANALYSIS

This project circuit is sectioned into three major parts;

1. Voltage Sensing Unit
2. Current Sensing Unit
3. Display Unit
4. Power supply

VOLTAGE SENSING UNIT

The voltage section comprises of three unity gain amplifier whose functions are defined to boost the input voltage from a low device. Each amplifier has a potential divider that helps to subdue and calculate the voltage that will be getting to the amplifiers respectively.

Just like the voltage divider rule, this potential divider follows similar principles. The voltage section has a microcontroller that does the arithmetic of the measured voltage. Each amplifier has its own saturation level as the case may be, when the first unity gain amplifier measure its **input voltage, the** voltage divider calculate the maximum voltage that can get to its output, and if this amplifier has reach its saturation level, it transfer the remaining voltage to the next amplifier that has high saturation level.

To demonstrate the voltage divider a series circuit in figure 3.2, each resistance varies with its voltage drop as the same current flows through them. In this project, voltage divider rule has been adopted to calculate for the maximum voltage that will reach each amplifier before assuming its saturation level.

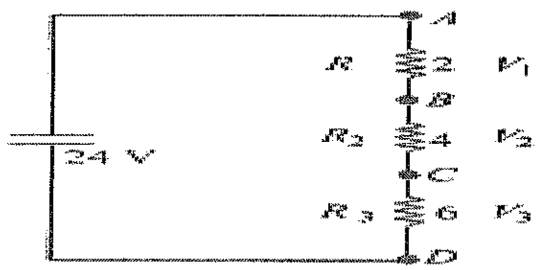


Figure 3.3 Illustration of the voltage divider rule

Mathematically, voltage divider rule can be given with this formula below:

Total resistance = equivalent resistance = $R_{equivalent}$

Input voltage = V_1

$$V_1 = \frac{R_1}{R_{equivalent}} * \text{total voltage or input voltage } V_1$$

The voltage sensing unit consist of an amplifier TL074, diodes and resistors. From figure 3.2 the first unity gain amplifier circuit connection has a range of 0 - 5v, any voltage above is termed as saturated, hence does passes to the output, the other two diodes are the protecting diode, they protect the amplifier form the Vin source while the last two diode are also to protect and stop any voltage beyond the set voltage range.

The second ampliflier circuit has a voltage range of 6 - 50V

The third amplifier circuit has a voltage range of 51 - 500V.

CURRENT SENSING SECTION

The current section comprises of three unity gain amplifier whose function are defined to increase the input current. The current section also includes the current sensing device that enables the measurement of a very small amount of input current from a device and later sends its impulse signal to an instrumental amplifier that helps to increase impulse signal to desirable level.

The reverse case of the voltage divider is done at the current divider section of the current section, where the current divider calculates the maximum current that can reach each amplifier. On the current section, there is an ATMEGA microcontroller that helps to process the measured current from the amplifiers and later send its impulse signal to the LCD screen.

The multiplier circuit is also located on the current section of this project in order to perform algebraic function. Using the formula

P = VI

Where P= Power (Watts)

V= Voltage (Volts)

I= Current (Amp).

Current divider rule has been adopted in this project work to calculate the maximum current that each amplifier will reach at the current section of the circuit before entering saturation level. The current that flows is sensed with the aid of current sensing resistor.

The current section consist of AD620, resistors and jumper wires. The AD620 has a voltage gain of 25V. The diodes connected to the AD620 are protective diodes.

The current resisting device is a device used in this project to measure a two points potential with a small resistance value of 0.001ohms.

To attestate this mathematically

R = 0.001V If we have a current of 1A

I= 1A the voltage will be 0.001V

For I = 10A V= 0.001 * 10 = 0.01v

I = 100A V= 0.001 * 10 = 0.1v

for this values, the voltage are almost negligible.

Hence, the output of AD620 is fed into a low noise operational amplifier OPA22277P having a unit gain connector of each multiplier of 1, 10 and 100 respectively.

The first amplifier OPA2227 has a current range of 0 - 1A

The second amplifier has a current range of 1A - 10A

The third amplifier has a current range of 10A - 100A

Additionally the current sensing device could be a coil or strand of wire that can allow current to move within it. The current sensing device measures a small amount of current and sends its signal to the instrumentation amplifier for further amplification. A pictorial image of this current sensing resistor is given below for clarification.

VISUALIZATION AND POWER SUPPLY SECTION

The visualization section consists of only the liquid crystal display that helps to visualize all the measured parameters such as the wattage, current and the voltage.

The Power supply section provides the supply of electrical power into the circuit.

The complete project design architecture was designed with the use of proteus simulator software as given below in Figure 3.2. The input source to the digital wattmeter is an A.C source with a common ground. The liquid crystal display module is interconnected with microcontroller controlling the current section of the circuit. The purpose of the capacitor is to store charges and retain charges i.e protecting the microcontroller against flash current and surge current. The AD620 used served the purpose of converting analogue readings taking from the amplifiers into streams of digital output for the microcontroller to process. The instrumental amplifier used served the purpose of amplifying small current from the current sensing resistor and feeding it to the unity amplifier for further amplification. The switch interconnected with the microcontrollers helps to power the entire circuitry.

3.2 DESIGN

3.2.1 HARDWARE DESIGN

SELECTION OF MICROCONTROLLER

For effective development and ease of programming, ATmega8 microcontroller was used as the heartbeat of this project. The ATmega8 helps in coordinating the entire process within the circuitry of the digital wattmeter. The ATmega8 have high performance and low power consumption capabilities, it also has the capability of writing and erasing memories stores into its memories. The ATmega8 block diagram is illustrated below in figure

Two ATMEGA8 was used this was done in order to have two different ground for the two sensing part. The microcontroller pins used in U1 (Microcontroller 1) as shown in figure 3.2 includes PIN 23 (PC0/ADC) PIN 24 (PCI/ADC1) PIN 25 (PC2/ADC2) PIN 29(PC6/RESET) PIN31(PDI/TXD) PIN 20(AREF) PIN 18(AVCC).

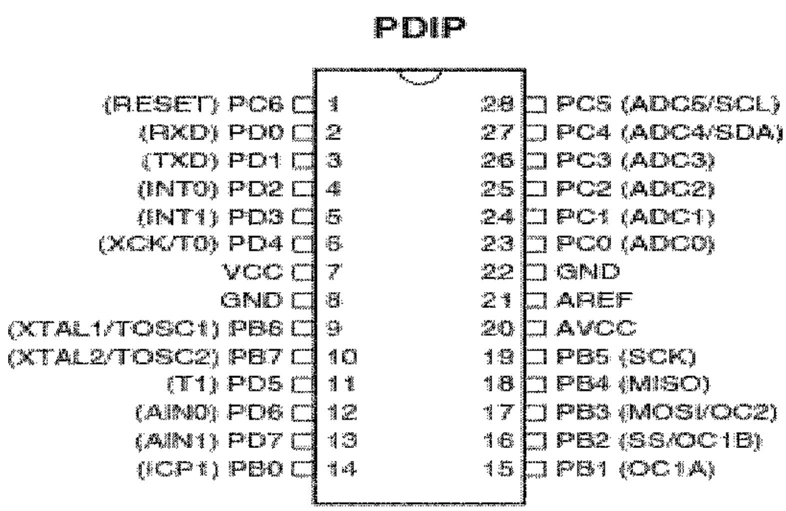


Figure 3.4 Schematic diagram of ATmega8 showing its configuration pins

THE MICROCONTROLLER PROGRAMMER

The microcontroller ATmega8 was programmed using MikroProg. The MikroProg has 40 pins ZIF sockets that are used for holding the pins of the microcontroller chip. MikroProg is a fast and reliable

USB programmer and hardware debugger that transfers the source code from the computer into its hardware components using a USB cable. The source code of this project was written with C language and was later converted into machine language (hex file). AVR programmer software can also be used as an alternative for MikroProg software. The MikroProg programmer was adopted due to its effectiveness, ease of use, friendly user interface, and also ease of debugging error in program codes. The figure 3.5 shows the pictorial look of the MikroProg programmer.

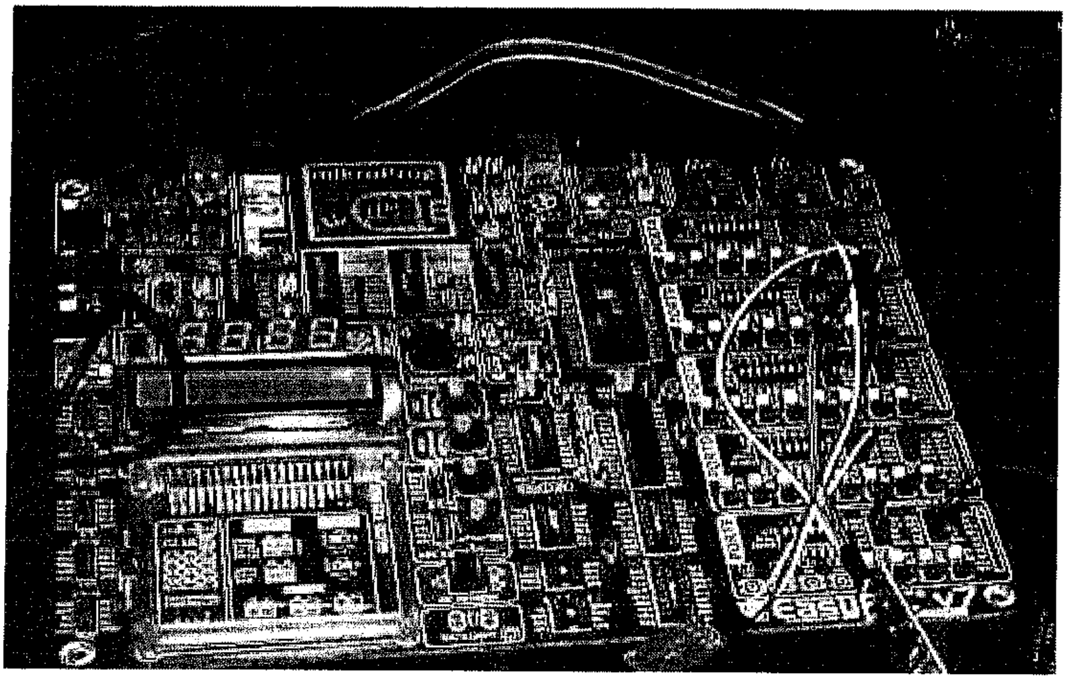


Figure 3.5 MikroProg Programmer

AD620 INSTRUMENTATION AMPLIFIER

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of1 to 10,000.The need for the amplifier arise due to the very small current charge sensed. With the incorporation of the instrumentational amplifier the small current charge is amplified to a more noticable value/ signal. The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 μV max, and offset drift of 0.6 μV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. The AD620 instrumentation amplifier was used in this project works in order to amplify small potential difference and current waveform into a reasonable level that can be used by other unity amplifier to work upon. The supply voltage into this AD620 is $\pm 18v$ and the power dissipation is around $650mW$ making suitable for its application in this project work. As shown in figure 3.6 the amplifier has 8 configurative pins.

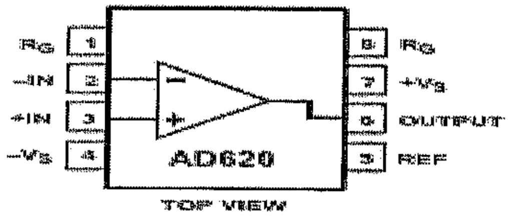


Figure 3.6 Top view of AD620 instrumentation amplifier

TLP250 ANALOG TO DIGITAL CONVERTER (ADC)

The TLP250 as shown in figure 3.7 is an industrial inverter which consist of GaAlAs light emitting diode and an integrated photodetector. The TLP250 ADC has 8 configurative pins as in figure 3.7. The purpose of the TLP250 is to transport all information received from the first ATMEGA8 microcontroller located on the voltage section of the circuit using its transport pin TxD (pin 31) (Analogue Signal) and convert it to digital signal which is to be received by the second ATMEGA 8 for further processing before being displayed on the LCD.

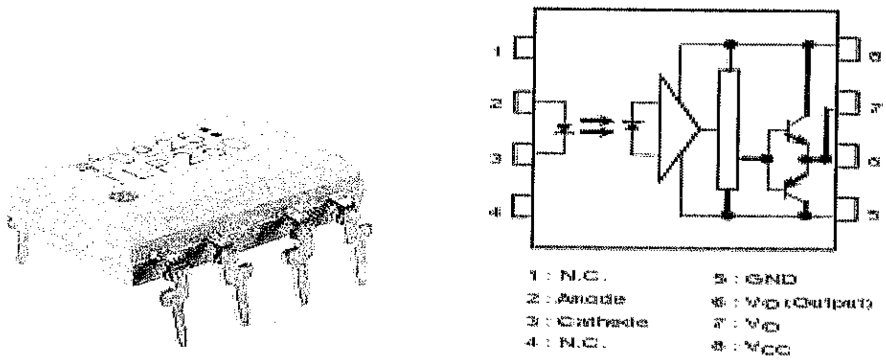


Figure 3.7 Top view of TLP250 showing its configuration pin

TL074 OPERATIONAL AMPLIFIER

The TL074 is high speed J–FET (junction field effect transistor) input quad operational amplifiers incorporating well matched, high voltage J–FET, low noise amplifier and bipolar transistors in a monolithic integrated circuit. The TL074 operational amplifier was used in this project to check for the voltage coming input source with the help of the potential divider and the current divider. Each TL074 placed at the voltage section has different saturation level as applied for use in this project. When the first operational amplifier reaches its saturation level, it transfers the remaining current or voltage left unhandled to the next operational amplifier for effective measurement. The figure 3.8 helps to illustrate the pictorial image of the amplifier. The voltage ranges (maximum voltage each amplifier can handle before saturation) for the operational amplifiers are listed below:

First unity gain operational amplifier OP 1: 0 – 5 volts

Second unity gain operational amplifier OP 2: 6 – 50 volts

Third unity gain operational amplifier OP 3: 51 – 500 volts

Figure 3.8 TL074

OPA2277 LOW NOISE AMPLIFIER

The opa2277 is a low noise amplifier with a unity gain. The OPA2277 op amp operates from ±2V to ±18V supplies with excellent performance. It offers improved noise, wider output voltage swing, and are twice as fast with half the quiescent current. The opa2277 operational amplifier was used in this project circuit to amplify signals coming from the instrumentational amplifier located above the current sensing resistor. The opa2277 operational amplifier checks the current level coming from the Instrumentational amplifier with the use of its current divider. The opa2277 operational is located at the current section of the circuit., Figure 3.9 shows the graphical representation of the Instrumentational amplifier.

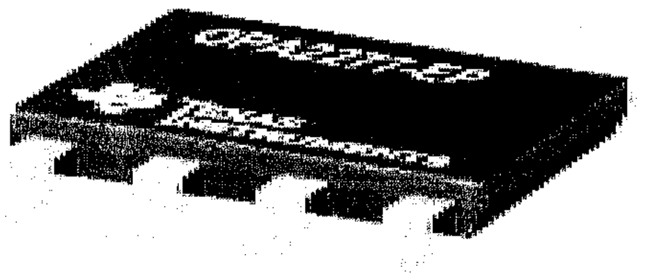


Fig 3.9 Graphical representation of the OPA2277

The opa2277 has different current ranges they are

First op -Amp: 0 - 1A

Second op-Amp: 1 – 10A

Third op-Amp: 10 – 100A

16X2 LIQUID CRYSTAL DISPLAY

The 16x2 LCD displays information on its interface as received from the ATmega8 microcontroller. The 16x2 LCD gives information like the wattage level, current measured and also the voltage measured. Figure 3.10 shows its pictorial illustration.

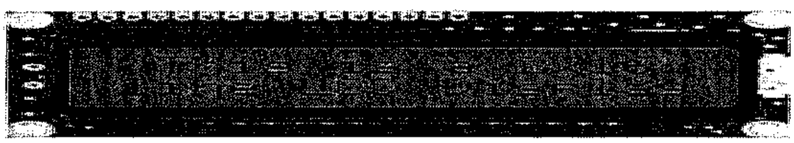


Figure 3.10 Liquid Crystal Display

PROTECTIVE DIODES

The protective diode was used in this project to limit the output voltage of each operational amplifier. This protective diode ensure that the output voltage does not surpass the saturation level voltage in other words protecting the amplifier from damage resulting excess heating, overcurrent and so on. Figure 3.11 shows the graphical representation of the protective diode..

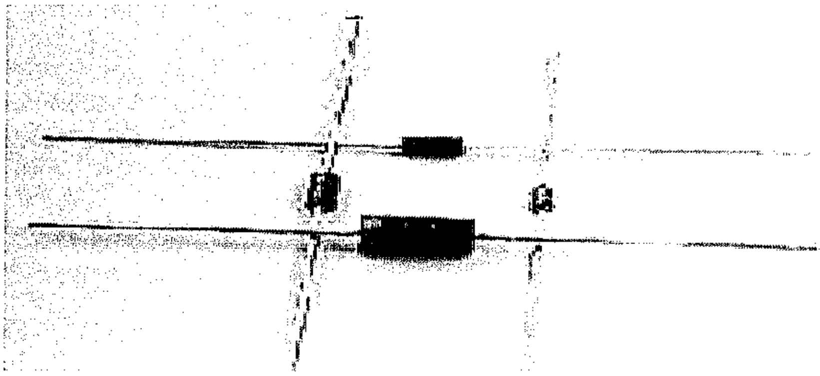


Fig 3.11 Protective diode

RESISTOR, CAPACITORS AND JUMPER WIRES

Various resistor with variety of resistance values were used in this project such as 100kilo-ohm, 50kilo-ohm. Resistor was used in this project as a current divider and also as voltage divider. It was also used to limit the flow of current to restricted component of the circuitry in order to avoid overcurrent and excess heating.

Capacitor were used in this project to the filter noise and other distortion from the microcontroller. Capacitor also helps to store charges in this project.

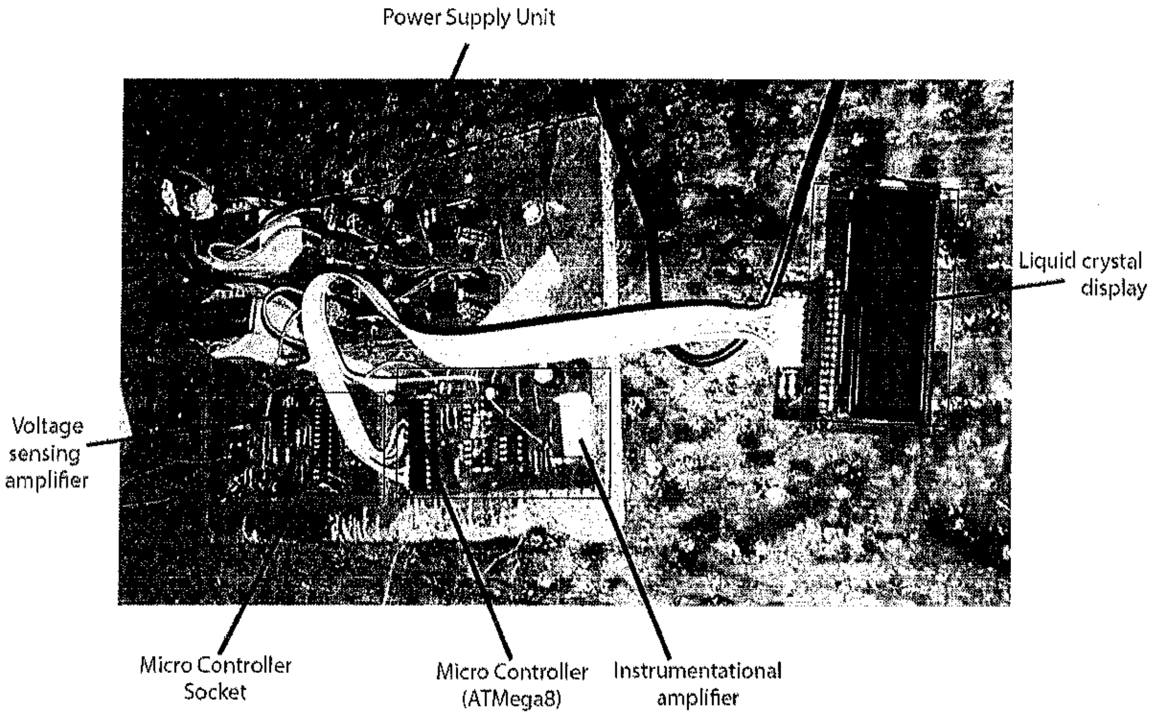


Fig 3.12 The hardware at a glance

3.2.2 SOFTWARE DESIGN

The software part were thouroghly design and tested working with the use of visual studio IDE, Dev Cpp 5.1.3 software and also with dreamwaver program software. The source code containing C language codes was fetched into the computer and later compiled using all the afore-mentioned softwares. This testing was done in order to have a perfect and a working program codes before transferring the codes to the programmer software that will configure the microcontroller. Software testing was carried out by debugging every single error found during compilation of the codes.

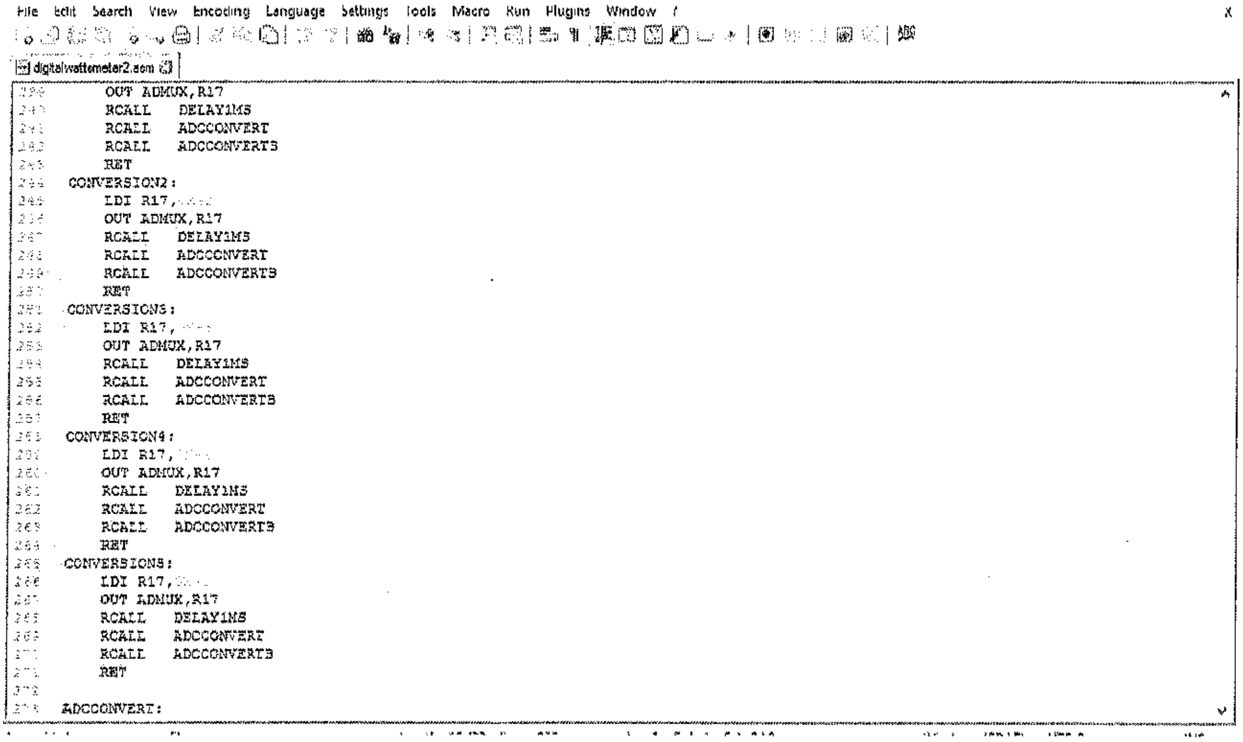


Figure 4.6 Software Coding Interface

ENCODING PROGRAMMING LANGUAGE

There are various programming language that can be used to program or encode the microcontroller. Various high level language such as C language, C#, visual basic and the likes of them are readily to use for programming microcontroller to perform its function. In this project C language was used to program the ATmega microcontroller in order to perform the required task.

CHAPTER FOUR

4.0 TESTING, ANALYSIS OF RESULTS AND DISCUSSIONS

4.1 TESTING

The implementation of this project was carried out in four development stages. Firstly, the project circuit design was done using proteus simulator in order to visualize and optimize the working condition of all the circuit component before going into the full hardware implementation. Secondly, the circuit component was transferred to the breadboard. During this stage, the whole circuitry was powered with four 9v battery connected in series connection. Thirdly, the circuit component was transferred to veroboard and was equally soldered firmly. The last stage entails the packaging of the veroboards into a casing designed for the project. A full list of circuit component used for this project will be attached to the bill of engineering and evaluation of this report under the appendix section.

TESTING OF THE MICROCONTROLLER BASED DIGITAL WATTMETER

The Microcontroller based digital wattmeter was tested for efficiency and attestation to the following objectives:

- Ability to Measure the voltage from both DC and AC circuits
- Ability to measure the current a circuit consumes
- Ability to perform the task of multiplying the value of the voltage and current to give the wattage readings
- Display the wattage readings on the Liquid Crystal Display.
- Ability to switch from the AC mode to the DC mode

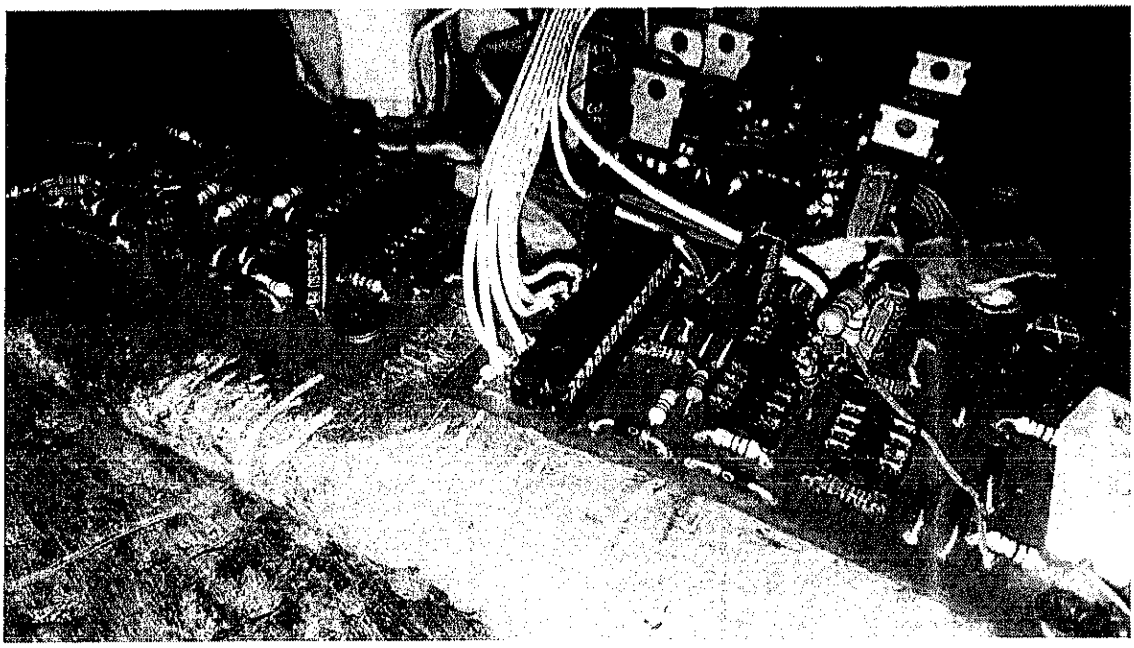


Figure 4.1 Fully assembled just before packaging

TESTING OF THE VOLTAGE SENSING UNIT

The wattmeter was designed to measure and display voltage readings on the LCD. The voltage sensing unit was arranged separately on a breadboard this was done in order to test the efficiency of the voltage sensing unit. Each the amplifer circuit were tested for continuity and accuracy

Figure 4.2 Testing of the voltage sensing unit separately

TESTING OF THE CURRENT SENSING UNIT

The current sensing unit was tested just as the voltage sensing unit arranged. As shown in figure 4.3 the reason for this testing strategy was to make sure the readings from the current sensing unit is accurate and efficient, hence conforming to the simulations done via proteus.

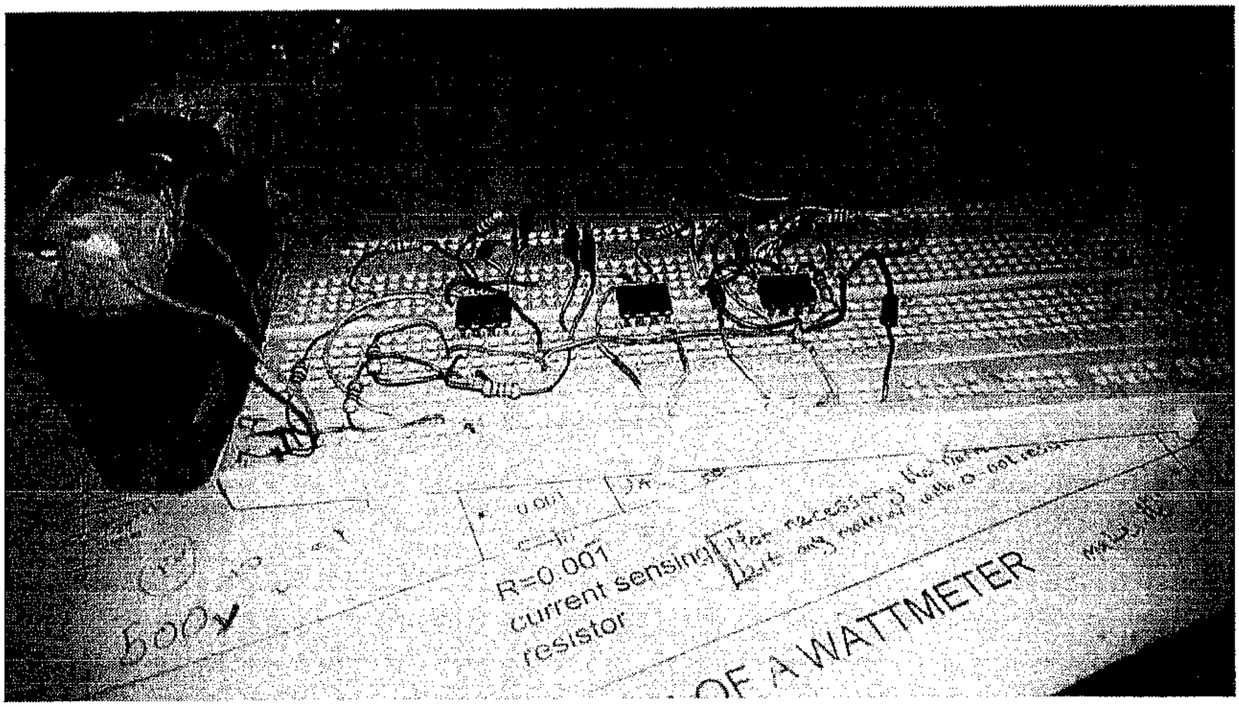


Figure 4.3 Testing of the current sensing unit separately

TESTING ENTIRE CIRCUIT WITH BREADBOARD

At this stage all entire circuit was assembled on a temporary site called "breadboard". After transferring program codes into the microcontroller using the MikroProg, the microcontrollers were inserted into the breadboard pin socket firmly and every other circuit was inserted into the breadboard pin sockets. Interconnections of these circuit components was done using jumper wires. It was later tested and it showed efficient readings and it exhibited a functional performance

When it was discovered that it conform to the required functionality then the assembly of circuit component on a veroboard began. The microcontroller socket was inserted into the veroboard holes firmly and was later soldered to the shining part of the veroboard. After the soldering of the microcontrollers socket to the board, the microcontrollers were fixed into it firmly. Likewise, every other circuit component was inserted into the veroboard according to the circuit diagram and the breadboard . The figure 4.4 shows the components all transfered into the veroboard.

TOOLS USED DURING THE IMPLEMENTATION OF THIS PROJECT

Boring tool: Used for creating holes into the casing of the project work.

Soldering iron: Used for soldering components to the veroboard and also used for drilling holes into plastic parts within the project work.

Screw driver: Used for driving screws into the metallic casing of the project and also for tightening of component that are loose.

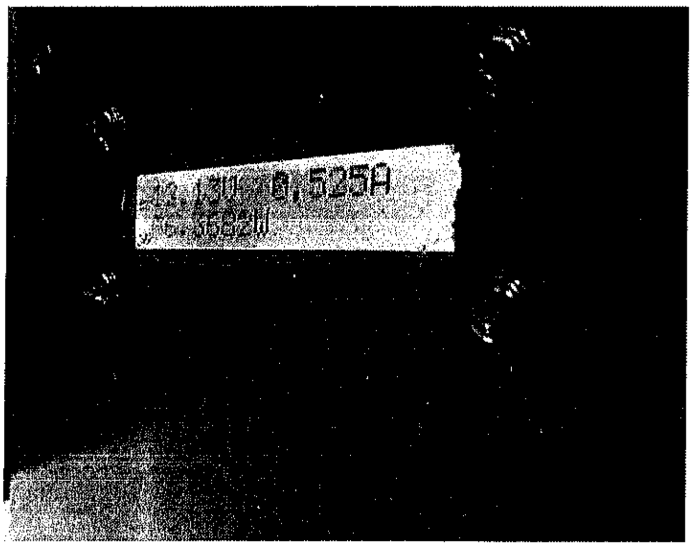
Lead: Used to bind metallic junctions together in order ensure electrical continuity within the circuit.

Cutting pliers: Used for cutting wires and other remaining pin legs that are unwanted.

Multimeter: Used for voltage, current, resistance and continuity readings.

TESTING OF THE ENTIRE WORK

After circuit implementation on the veroboard was done, a full check of the entire circuitry was carried out before testing the work. This testing was done using a digital multimeter in order to check if there is no short circuiting or open circuit of circuit components on the board and also to check for continuity within the circuit. After carrying out the circuit testing, the entire circuit was package into a casing that has been design for it with proper care to avoid damaging of components. The packaging of the entire project is shown in figure 4.4. After the packaging was done the wattmeter was tested in the laboratory alongside the wattmeter used in the lab some of the appliance tested include a fan, buzzer and a charging phone.



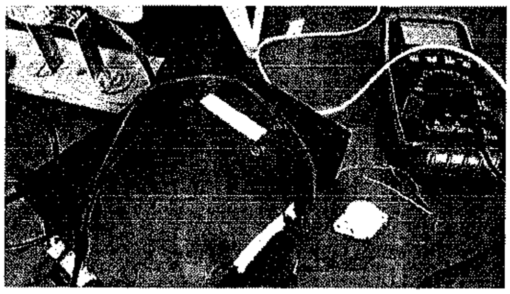


Figure 4.4 testing of the packaged work

4.2 PROJECT MANAGEMENT

4.2.1 SCHEDULE/PROJECT MANAGEMENT

Table 4.1 Schedule/project management

Week 1	**Monday June 25, 2018**	**Friday June 29, 2018**	**Submission and review of proposal**
Week 2	**Monday July 2, 2018**	**Friday July 6, 2018**	**Simulation on proteus**
Week 3	**Monday July 9, 2018**	**Monday July 13, 2018**	**Purchase of components**
Week 4	**Monday July 16, 2018**	**Friday July 20, 2018**	**Testing of circuit and assembling of components**
Week 5	**Monday July 23, 2018**	**Friday July 27, 2018**	**System programming**
Week 6	**Monday July 30, 2018**	**Friday August 3, 2018**	**System programming**
Week 7	**Monday August 6, 2018**	**Friday August 10, 2018**	**System programming**

Week 8	**Monday August 13, 2018**	**Friday August 17, 2018**	**Report writing**
Week 9	**Monday August 20, 2018**	**Friday August 24, 2018**	**Report writing**
Week 10	**Monday August 27, 2018**	**Friday August 31, 2018**	**Report Writing**
Week11	**Monday September 3, 2018**	**Friday September 7, 2018**	**Report Writing**
Week 12	**Monday September 10, 2018**	**Friday September 14, 2018**	**Report Writing**

4.2.2 RISK MANAGEMENT

Various risk was encountered during the process of this project work which eventually led to the success. Risk are inevitable in any work; the listed risk was recorded during the implementation of this project.

- Inhaling of soldering iron smokes during soldering of component parts.
- Excess expenditure incurred on component parts when they fail due long distance delivery.
- Risk of travelling to get component part that are not easily available.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

The Microcontroller based digital wattmeter comprises of the ATmega8 microcontroller, the voltage sensing part of the circuit, current sensing part, and the display unit, coupled with other components. In this project a microcontroller based wattmeter is designed and implemented to be Portable, accurate, simple to use and relatively cheap to fabricate. The user interface is quite simple and the user can select the mode of the meter easily as either AC or DC

To realize the wattmeter two ATMEGA8 were used, one for measuring current why the other for measuring voltage, the two must have different ground to ensure this, An OPTO isolator is also used, (TLP250). The multiplication of the voltage readings and the current readings gives the wattage, so the LCD displays both voltage, current and wattage readings.

5.1 CONTRIBUTION TO KNOWLEDGE

In the course of the implementation of this project I began to develop a special attachment to the fabrication of innovative electrical designs and equipment. I also was able to develop my understanding of the microcontroller and how I can manipulate its functionality to perform tasks and meet different requirements.

5.2 FUTURE WORKS

More portable electronic products could also be integrated into the design. If large component are replaced with smaller ones or more sophisticated ones, this will make these products cheap, and more energy efficient.

Its also believed that a time differentiation sensor could be used as the current sensing circuit because it will enhance electrical isolation and it consumes low power.

5.3 CRITICAL APPRAISAL

The future implications of the project are very great considering the usefulness and practical contribution to the laboratory. This system can be used as a reference or as a base for realizing a scheme to be implemented in other projects of greater levels example are energy saving, and measuring projects.

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https://www.academia.edu/33147416/Design_and_Hardware_Implementation_of_an_Universal_Meter

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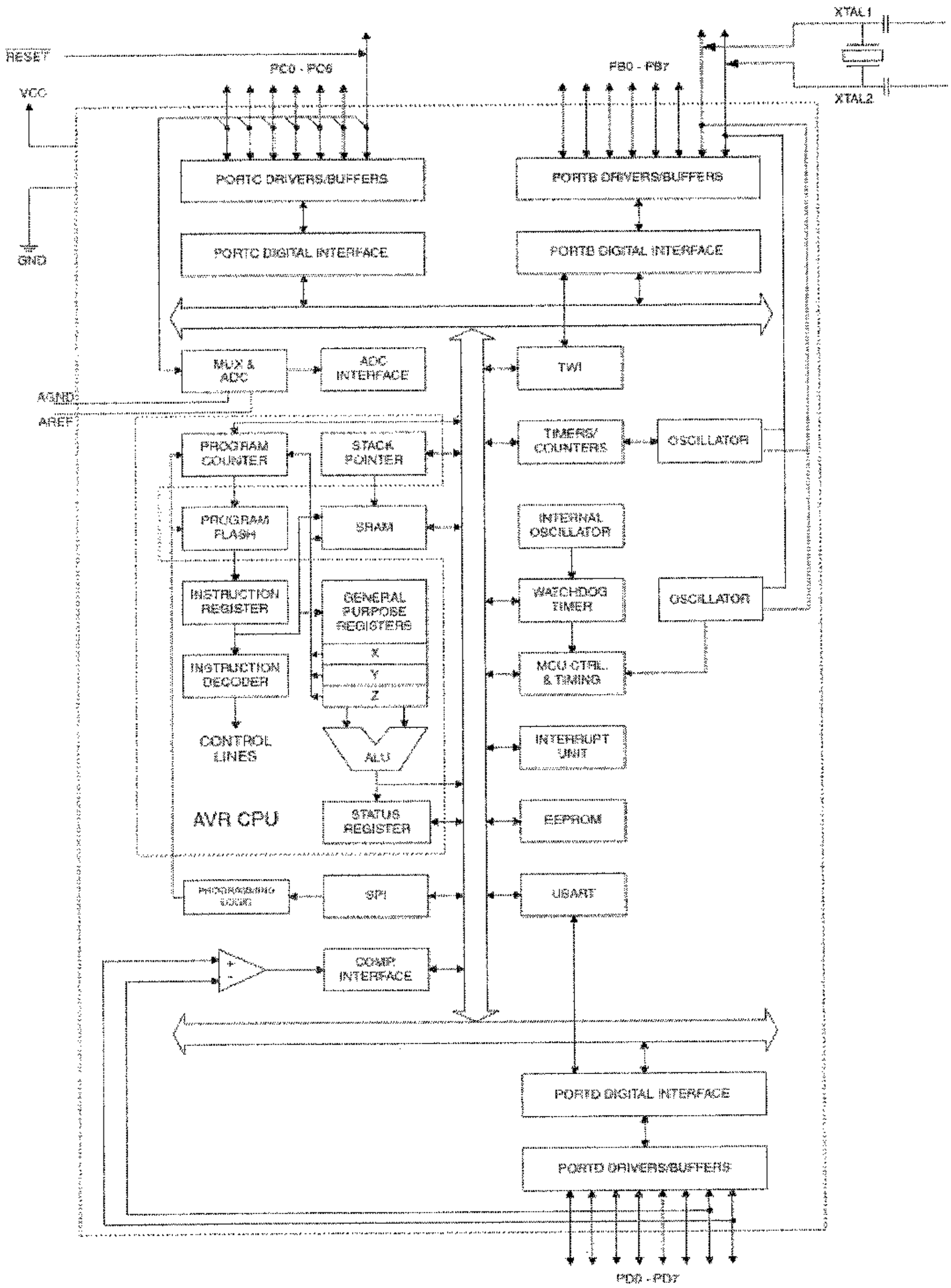
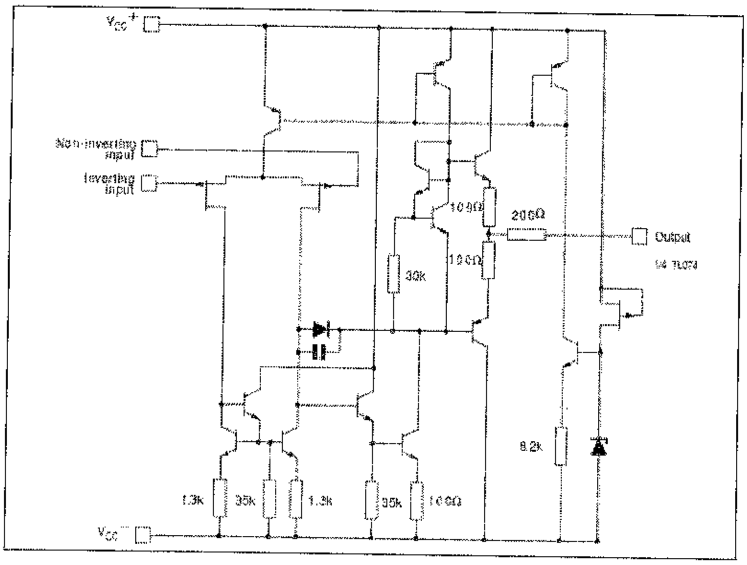
APPENDIX I

Schematic of the ATMEGA8



APPENDIX II

Schematic diagram of TL074 amplifier



APPENDIX III

Design Title	**Design and implementation of a Microcontroller digital based wattmeter**
Author	**Olabinjo Ebenezer Tope**
Document Number	
Design Created	**Thursday, March 30, 2017**
Design Last Modified	**Monday, October 30, 2017**
Total Parts in the Design	**59**

Category	Quantity	Value/Reference	Price (#)
Resistor	25	1k,10k,99k,100k, 0.001 ohms	#1500
Diode	24		#1200
Amplifier	4		#4000
Instrumentational Amplifier	1		#300
Opto Isolator	1		#450
Microcontroller	2	ATMEGA8	#5,000
Capacitor	1		#100
LCD	1		#650
Total	61		#13,200

APPENDIX IV

Program Code

```
.EQU   PORTB = 0X18

..EQU  PORTB = 0X18

.EQU   DDRB = 0X17

.EQU   PINB = 0X16

.EQU   PORTC = 0X15

.EQU   DDRC = 0X14

.EQU   PINC   = 0X13

.EQU   PORTD          = 0X12

.EQU   DDRD  = 0X11

.EQU   PIND   = 0X10

.EQU   SPH            = 0X3E

.EQU   SPL            = 0X3D

.EQU   UBRRH          = 0X20

.EQU   UCSRC          = 0X20

.EQU   UBRRL          = 0X09

.EQU   UCSRB= 0X0A

.EQU   UCSRA          = 0X0B

.EQU   UDR   = 0X0C

.EQU   ADMUX          = 0X07

.EQU   ADCSRA         = 0X06

.EQU   ADCH  = 0X05

.EQU   ADCL  = 0X04

.EQU   TCCR0= 0X33

.EQU   TCNT0=         0X32
```

```
.EQU   TIMSK= 0X39
.EQU   TIFR   = 0X38
.EQU   SREG   = 0X3F
.EQU   TCCR1A        = 0X2F
.EQU   TCCR1B        = 0X2E
.EQU   TCNT1H        = 0X2D
.EQU   TCNT1L        = 0X2C
.EQU   OCR1AH        = 0X2B
.EQU   OCR1AL        = 0X2A
.EQU   OCR1BH        = 0X29
.EQU   OCR1BL        = 0X28
.EQU   SFIOR = 0X30
.EQU   TCCR2= 0X25
.EQU   TCNT2 = 0X24
.EQU   GICR   = 0X3B
.EQU   MCUCR         = 0X35
.EQU   ASSR   = 0X22
.EQU   EEARH         = 0X1F
.EQU   EEARL         = 0X1E
.EQU   EEDR   = 0X1D
.EQU   EECR   = 0X1C
.EQU   OSCCAL        =        0X31

.EQU   ADRES1        = 0X60
.EQU   ADRES2        = 0X61
.EQU   ADRES3 = 0X62
```

```
.EQU   ADCCOUNT = 0X63

.ORG   0X00

START:
        LDI    R17,0XA5
        OUT    OSCCAL,R17

        LDI    R17,0X5F
        OUT    SPL,R17

        LDI    R17,0X04
        OUT    SPH,R17

        CLR    R17

        OUT    PORTB,R17
        OUT    PORTC,R17
        OUT    PORTD,R17

        LDI    R17,0XFF
        OUT    DDRB,R17

        CLR    R17
        OUT    DDRC,R17
```

```
LDI    R17,0XFC
OUT    DDRD,R17

LDI    R17,0X04
OUT    SFIOR,R17

;USART
LDI    R17,0X01
OUT    UBRRH,R17

LDI    R17,0XA1 ;  1200  (8MHZ / 16 / (01A1(HEX) + 1)
OUT    UBRRL,R17

LDI    R17,0X18
OUT    UCSRB,R17

LDI    R17,0X86
OUT    UCSRC,R17

;for adc use

LDI    R17,0X40
OUT    ADMUX,R17
```

```
        LDI     R17,0X86
        OUT     ADCSRA,R17

        RCALL       DELAY5SEC
        RCALL       DELAY5SEC

REDO:
        RCALL CONVERSION0

        LDS     R16,ADRES2
        LDS     R17,ADRES3

        RCALL       GEN

        ORI     R16,0X20

        RCALL       SERIAL2A
        RCALL       SERIAL2B

        RCALL CONVERSION1

        LDS     R16,ADRES2
```

```
LDS     R17,ADRES3

RCALL       GEN

ORI     R16,0X60
ORI     R17,0X40

RCALL       SERIAL2A
RCALL       SERIAL2B

RCALL CONVERSION2

LDS     R16,ADRES2
LDS     R17,ADRES3

RCALL       GEN

ORI     R16,0XA0
ORI     R17,0X80

RCALL       SERIAL2A
RCALL       SERIAL2B
```

```
        RJMP  REDO

GEN:
        ROL   R16
        ROL   R17
        ROL   R16
        ROL   R17
        ROL   R16
        ROL   R17

        CLC
        ROR   R16
        CLC
        ROR   R16
        CLC
        ROR   R16

        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS

        RET
```

```
;transmit content of r17
SERIAL2A:
        SBIS UCSRA,5
        RJMP SERIAL2A
        OUT   UDR,R17
        RET

;transmit content of r16
SERIAL2B:
        SBIS UCSRA,5
        RJMP SERIAL2B
        OUT   UDR,R16
        RET

CONVERSION0:
        LDI   R17,0X40
        OUT   ADMUX,R17
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET
CONVERSION1:
        LDI   R17,0X41
        OUT   ADMUX,R17
```

```
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET
CONVERSION2:
        LDI     R17,0X42
        OUT     ADMUX,R17
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET
CONVERSION3:
        LDI     R17,0X43
        OUT     ADMUX,R17
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET
CONVERSION4:
        LDI     R17,0X44
        OUT     ADMUX,R17
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET
CONVERSION5:
```

```
        LDI     R17,0X45
        OUT     ADMUX,R17
        RCALL       DELAY1MS
        RCALL       ADCCONVERT
        RCALL       ADCCONVERTB
        RET

ADCCONVERT:
        CLR     R17
        STS     ADRES1,R17
        STS     ADRES2,R17
        STS     ADRES3,R17
        STS     ADCCOUNT,R17
        RET

ADCCONVERTB:
        SBI     ADCSRA,6
ADCCONVERTC:
        SBIC    ADCSRA,6
        RJMP    ADCCONVERTC
        IN      R17,ADCL
        LDS     R16,ADRES1
        ADD     R16,R17
        STS     ADRES1,R16
        IN      R17,ADCH
        LDS     R16,ADRES2
```

```
        ADC   R16,R17
        STS   ADRES2,R16
        BRCC  ADCCONVERTD
        LDS   R17,ADRES3
        INC   R17
        STS   ADRES3,R17
ADCCONVERTD:
        LDS   R17,ADCCOUNT
        INC   R17
        STS   ADCCOUNT,R17
        CPI   R17,0X00
        BRNE  ADCCONVERTB
        RET
```

```
;THESE DELAY DOES NOT USE TIMERS AND INTERRUPT
;ADJUST AS NEEDED FOR OTHER CRYSTALS
; FOR 16MHZ ADD 8 NOPS TO EACH INCIDENT OF 1 NOP  OR CREATE A SUB AND PUT 1 NOP
;FOR 20MHZ  ADD 12 NOPS TO EACH INCIDENT OF 1 NOP OR CREATE A SUB AND PUT 5 NOP

SUB16:
        NOP
```

```
        RET

SUB20:
        NOP
        NOP
        NOP
        NOP
        NOP
        RET

;THERE ARE 8 INCIDENCE OF RCALL SUB16/20 IF THE NEED ARISES FOR ADJUSTMENT

DELAY1US:  ; IF 8MHZ THEN EACH NOP IS 0.125US REQUIRES 8 NOPS TO MAKE 1US
        NOP    ; RET = 4 , RCALL = 3 HENCE ONLY ONE NOP NEEDED
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAY10US: ; CALLS DELAY1US 9 TIMES WITH COMPENSATION FOR THE 10TH
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
```

```
        RCALL           DELAY1US
        RCALL           DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAY100US: ; CALLS DELAY10US 9 TIMES WITH COMPENSATION FOR THE 10TH
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY10US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
        RCALL           DELAY1US
```

```
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAY500US:
DELAY:  ; UPDATED TO 500US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US  ;400US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US  ;490US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
```

```
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAYMX:
        RCALL       DELAY
        RET

DELAY1MS:
DELAY1000US:
DELAYM3X:  ;UPDATED TO 1000US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US
        RCALL       DELAY100US  ;900US
        RCALL       DELAY10US
        RCALL       DELAY10US
```

```
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US ;990US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAYM: ;APPROXIMATELY 2MS
        RCALL       DELAY1MS
        RCALL       DELAY1MS
        RET
```

```
DELAY10MS:
DELAYM2: ; UPDATED TO 10MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS
        RCALL   DELAY1MS  ; 9MS
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US
        RCALL   DELAY100US ;9.900MS
        RCALL   DELAY10US
        RCALL   DELAY10US
        RCALL   DELAY10US
        RCALL   DELAY10US
        RCALL   DELAY10US
        RCALL   DELAY10US
```

```
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US  ;9.990MS
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAY100MS:
DELAYM3:  ; UPDATED TO 100MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
```

```
RCALL    DELAY10MS
RCALL    DELAY10MS ;90MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS
RCALL    DELAY1MS  ; 99MS
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US
RCALL    DELAY100US ;99.90MS
RCALL    DELAY10US
RCALL    DELAY10US
RCALL    DELAY10US
RCALL    DELAY10US
RCALL    DELAY10US
RCALL    DELAY10US
```

```
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US  ;99.990MS
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET

DELAY500MS:
DELAYM4:    ; UPDATED TO 500MS
        RCALL       DELAY100MS
        RCALL       DELAY100MS
        RCALL       DELAY100MS
        RCALL       DELAY100MS  ;400MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
        RCALL       DELAY10MS
```

```
RCALL       DELAY10MS
RCALL       DELAY10MS
RCALL       DELAY10MS
RCALL       DELAY10MS
RCALL       DELAY10MS
RCALL       DELAY10MS ;490MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS
RCALL       DELAY1MS  ; 499MS
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US
RCALL       DELAY100US ;499.900MS
RCALL       DELAY10US
RCALL       DELAY10US
```

```
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US
        RCALL       DELAY10US  ;499.990MS
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        RCALL       DELAY1US
        NOP
        ;RCALL SUB16
        ;RCALL SUB20
        RET
SEC1:
DELAY1SEC:   ; 1.000 000 875 SEC
        RCALL       DELAYM4
        RCALL       DELAYM4
        RET
```

```
SEC5:  ; 5.000 000 875 SEC
DELAY5SEC:
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RET

SEC10: ; 10.000 000 875 SEC
DELAY10SEC:
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
```

```
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RET
SEC20:
DELAY20SEC: ; 20.000 000 875 SEC
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
        RCALL       DELAYM4
```