DIGITAL KWH METER

LILY SURAIYA RAMELY

This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

APRIL, 2009
ABSTRACT

The purpose of this project is to develop a digital KWh meter and display the instantaneous values of current (I), voltage (V), and power (P), and total energy (KWh) consumed by load on liquid crystal display (LCD). The scopes include developing hardware to measure instantaneous current, voltage and power consumed by load and also interfacing the hardware with PIC microcontroller so that energy can be calculated. This research was about the alternative for electromechanical induction meter which is widely used to measure energy consumed by load. First, both current and voltage that is used by load will be measured. Then, both values will be fed to ADE7753. The total energy will be calculated and the output will be in form of pulse. Finally the output from the ADE7753 will send to the PIC microcontroller and will be displayed on LCD. Furthermore, users can choose the desired readings to be displayed using the selection buttons.
ABSTRAK

CHAPTER | TITLE | PAGE
--- | --- | ---

DECLARATION | ii
ACKNOWLEDGEMENT OF SUPERVISOR | iii
DEDICATION | iv
ACKNOWLEDGEMENT | v
ABSTRACT | vi
ABSTRAK | vii
TABLE OF CONTENTS | viii
LIST OF TABLES | xi
LIST OF FIGURES | xii
LIST OF SYMBOLS/ABBREVIATIONS | xiii
LIST OF APPENDICES | xiv

1 | INTRODUCTION | 1
1.1 | Introduction | 1
1.1.1 | Electrical Power and Energy | 1
1.1.2 | Electromechanical Induction Meter | 3
1.2 | Problem Statement | 5
1.3 | Objectives | 6
1.4 | Scopes | 6

2 | LITERATURE REVIEW | 7
2.1 Increasing the capability of the KWh meter
2.2 Solid State Meter
   2.2.1 Introduction
   2.2.2 Technology
   2.2.3 Communication Technology
   2.2.4 Advantages
2.3 Current and Voltage Measuring
2.4 Energy Measuring Circuit
2.5 Electrical energy computation
2.6 Software structure description

3 METHODOLOGY
3.1 Hardware development
   3.1.1 Power supply
   3.1.2 Current and Voltage sensing circuit
   3.1.3 Energy measurement circuit
   3.1.4 Microcontroller
      3.1.4.1 Display Module
      3.1.4.2 Selection Module
3.2 Software development

4 RESULT AND DISCUSSION
4.1 Result
   4.1.1 +5V power supply
   4.1.2 Current and Voltage Sensing Circuit
   4.1.3 Energy measurement circuit
4.1.4 Microcontroller
4.1.5 Full system
4.2 Discussion
  4.2.1 Comparison between Theoretical and measured values of Current and voltage sensor
  4.2.2 Failure to calculate the coefficient value
4.3 Problems encountered and solutions

5 COSTING AND COMMERCIALIZATION, CONCLUSION AND RECOMMENDATION
  5.1 Costing and commercialization
    5.1.1 Costing
    5.1.2 Commercialization
  5.2 Conclusion
  5.3 Recommendation

REFERENCES
APPENDIX
<table>
<thead>
<tr>
<th>TABLE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>LCD's pins Function</td>
<td>20</td>
</tr>
<tr>
<td>4.1</td>
<td>Measured voltage of current and voltage sensor</td>
<td>25</td>
</tr>
<tr>
<td>4.2</td>
<td>Values displayed on LCD</td>
<td>26</td>
</tr>
<tr>
<td>4.3</td>
<td>Comparison of voltage values</td>
<td>28</td>
</tr>
<tr>
<td>5.1</td>
<td>Project costing</td>
<td>32</td>
</tr>
<tr>
<td>FIGURE</td>
<td>TITLE</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1.1</td>
<td>Power triangle-The components of AC power</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Electromechanical Induction Meter</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>Flow chart of the system</td>
<td>11</td>
</tr>
<tr>
<td>3.1</td>
<td>Basic Block Diagram of System</td>
<td>13</td>
</tr>
<tr>
<td>3.2</td>
<td>Power Supply Circuit</td>
<td>14</td>
</tr>
<tr>
<td>3.3</td>
<td>Current and Voltage sensing Circuit</td>
<td>15</td>
</tr>
<tr>
<td>3.4</td>
<td>Energy Measurement Circuit</td>
<td>16</td>
</tr>
<tr>
<td>3.5</td>
<td>Microcontroller Circuit</td>
<td>18</td>
</tr>
<tr>
<td>3.6</td>
<td>LCD Connection</td>
<td>19</td>
</tr>
<tr>
<td>3.7</td>
<td>Selection Button Connection</td>
<td>21</td>
</tr>
<tr>
<td>3.8</td>
<td>Flow Chart of the programme</td>
<td>22</td>
</tr>
<tr>
<td>4.1</td>
<td>+5V power supply</td>
<td>24</td>
</tr>
<tr>
<td>4.2</td>
<td>Current and voltage sensor</td>
<td>25</td>
</tr>
<tr>
<td>4.3</td>
<td>Energy Management</td>
<td>26</td>
</tr>
<tr>
<td>4.4</td>
<td>Microcontroller</td>
<td>27</td>
</tr>
<tr>
<td>4.5</td>
<td>kWh Meter</td>
<td>28</td>
</tr>
<tr>
<td>Symbol</td>
<td>Meaning</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>Alternating Current</td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Energy</td>
<td></td>
</tr>
<tr>
<td>EEC</td>
<td>Electric Energy Computation</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Current</td>
<td></td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt-hour</td>
<td></td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Active power</td>
<td></td>
</tr>
<tr>
<td>PIC</td>
<td>Programmable Integrated Circuit</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Reactive power</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Resistance</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Apparent power</td>
<td></td>
</tr>
<tr>
<td>TIDA</td>
<td>Timing-Interruption Data Acquisition</td>
<td></td>
</tr>
</tbody>
</table>
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Data Sheets</td>
<td>38</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Electrical Power and Energy

Electrical power is defined as the rate at which electrical energy is transferred by electrical circuit. In direct current, instantaneous electrical power is calculated using Joule's Law. Joule's Law is

\[ P = V \cdot I \]

Where,

\( P \) is the electric power,

\( V \) the potential difference,

\( I \) is the electric current.

If Joule's law is combined with Ohm's law \((V = RI)\) two more equations, two more equations are produced:
$$P = IR$$

and

$$P = V^2/R$$

Where,

$R$ is the electric resistance.

In alternating current circuits may result in there are periodic reversals of the direction of energy flow due to energy storage elements such as inductance and capacitance. Figure 1.1 below shows the components of AC power.

![Power triangle-The components of AC power](image)

**Figure 1.1:** Power triangle-The components of AC power

The relationship among real, reactive and apparent power is:

$$S^2 = P^2 + Q^2$$

Real and reactive powers can also be calculated directly from the apparent power, when the current and voltage are both sinusoids with a known phase angle between them:

$$P = S \cdot \cos \theta$$
\[ Q = S \times \sin \theta \]

Energy in kilowatt-hour is the product of power in the unit of kilowatts multiplied by the times (hour). So, as a result, the SI unit is Kilowatt-hour. As example, there are a water heater with 100W power rating that has been used for 10 hour, the total energy the heater consumed is:

\[ E = P \times h \]

\[ E = 100 \times 10 \]

\[ E = 1 \text{kWh} \]

KWh is measured using a meter that is located at every household so that users can easily pay for the energy they used every month. There are a few type of meter are used for this purpose, but the most common one which is still in used is electromechanical induction meter.

1.1.2 Electromechanical Induction Meter

KWh meter is the most common meter that can be found at every household. The function of this meter is to determine the amount of energy consumed by the users of the household, so that the cost of the energy can be calculated. The most popular type of meter that is still used by many is electromechanical induction meter, which is illustrated by figure 1.2 below.

Electromechanical induction meter operates by counting the revolution of the aluminum disc that rotates at the speed proportional to the power consumed by load. The aluminum disc acted upon to coils that are voltage coil and current coil. Voltage coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and current coil produces a magnetic flux proportion to the current. Next, eddy current produced in the aluminum disc and a force is exerted on the disc proportional to the product of instantaneous current and voltage.
The aluminum disc is supported by a spindle which has a worm gear that drives the register. The dials may be of the cyclometer type, an odometer-like display that is easy to read where for each dial a single digit is shown through a window in the face of the meter, or of the pointer type where a pointer indicates each digit. It should be noted that with the dial pointer type, adjacent pointers generally rotate in opposite directions due to the gearing mechanism.

The amount of energy presented by one revolution of the disc denoted by the symbol KWh which is given in units of watt-hours per revolution. The value 7.2 is commonly seen. Using the value of KWh, one can determine their power consumption at any given time by timing the disc with a stopwatch. If the time in seconds taken by the disc to complete one revolution is t, then the power in watts is

\[ P = \frac{3600 \times \text{KWh}}{t} \]

For example, if KWh = 7.2, and one revolution took place in 14.4 seconds,

\[
\begin{align*}
\text{KWh} & = 7.2 \\
t & = 14.4\text{s} \\
P & = \frac{3600 \times 7.2}{14.4} \\
P & = 1800\text{W}
\end{align*}
\]

This method can be used to determine the power consumption of household devices by switching them one by one. Most domestic electricity meters must be read manually. [1]
1.2 Problems statement

Due to all the rotations, electromechanical induction meter consumes a small amount of power, typically around 2 watts. [4] So, the customers have to pay not only the energy used to operate all the house appliances, but they also have to pay for energy used in calculating the energy used. Moreover, the accuracy of the electromechanical induction meter also can be questioned. This is because the accuracy of this particular type of meter is depends on the quality of the material used in designing the meter.

Thus, because of these two main problems that arise when the electromechanical induction meter is used, digital KWh meter is introduced. Digital KWh meter consumes relatively smaller power than electromechanical induction meter. Not only that, the accuracy of digital KWh meter also reliable because the calculation will be done by microcontroller.

1.3 Objective
The objective of this project is to develop a digital KWh meter and display the instantaneous values of current, voltage, power and total energy consumed by load on liquid crystal display (LCD).

1.4 Scopes

There are two scopes of this project:

i. To develop hardware to measure instantaneous current and voltage consumed by load.

ii. To interface the hardware with PIC microcontroller so that the total power and energy can be calculated.
CHAPTER 2

LITERATURE REVIEW

2.1 Increasing the capability of the KWh meter

For monitoring electrical energy, the instrument for measuring electrical energy are moving coil meters which could be seen in every home in the type of KWh meter. When considering on accuracy of these meters which will depend on the quality of material such as the saturated properties of magnetic field on moving plate and coil axis. In order to increase the capability of the meter, the meter inform of solid state will be developed for accuracy in measurement without material fatigue in mechanism. [4]

2.2 Solid State Meter

2.2.1 Introduction

There is a new type of meter instead of the common electromechanical induction meter. It calls the solid state meter where the energy is displayed on LCD. This is means that the energy can be read automatically without the need of manual calculation from users. In addition to that, the meter can also records other
parameters such as reactive power used and power factor of the load. The values
can easily been view just by pressing the selection button.[4]

2.2.2 Technology

Solid state meters use current transformer to measure current. So, current
carrying conductor does not need to pass through the meter itself. Thus, the
meter can be located remotely from the main current carrying conductor.[4]

2.2.3 Communication Technology

Currently, high end electronic meters are design with quite a wide range of
communication technologies. Some of the technologies are Low Power Radio,
Bluetooth, apart from the now conventional RS-232 and RS-485 wired link.
Often, meters are design to be able to read serial interface bus so that the entire
usage profiles with time stamps are available at a click of a button.[4]

2.2.4 Advantages

There are a few advantages of this solid state meter. First of all, this type of
meter is user friendly. That is because users can read the value of consumed
energy automatically, while when using the electromehanical induction meter
users need to calculate the total energy using the formula \( P = 3600x\text{KWh/t} \).
Furthermore, the energy calculation is more accurate since it is done by
microcontroller and not done manually by human. In addition to that, solid state
meter not just provides the values of total energy but it also can be design to
provide other parameters of the supply and load which can be access only using a
selection button. Lastly, the solid state meters are built up without material
fatigue in mechanism like the electromechanical induction meter that depends on
the rotation of aluminum disc.[4]
Where $v(t)$ is the supply voltage and $i(t)$ is the load current. In actuality, a discrete version of Equation (1) is used, where the voltage and current signals, after proper conditioning, are sampled and converted to digital form by an 8 bits A/D converter, operating at a sampling frequency of 1,082 kHz. The voltage and current sampled values are transferred serially to the microcontroller. The microcontroller processes and stores the energy consumption. The energy is compared to a reference value ($E_{ref}$) set during the calibration process, where, for a 1kW load, the consumed energy is calculated and accumulated (integrated) for 100 periods of 924ps (a program cycle). [8]

2.6 Software structure description

The new meter comprises monitor/control programme, TIDA programme and EEC programme, Main programme is the main body of the software used for performing the functions of KWh meter, and comprise several subroutines.

TIDA and EEC programme deal with interruption due to a timer, i.e., sampling period. Operation will enter TIDA and EEC once after main programme has been put into service and initialized, at the end of an interruption, Operation will in turn return to main programme, as shown in Figure 2.1.[7]
Figure 2.1: Flow chart of the system
CHAPTER 3

METHODOLOGY

3.1 Hardware development

Referring to figure 3.1, the development of the hardware for this project is divided into three main parts. The first part is current and voltage sensing circuit. This circuit is used to sample the voltage and current that is consumed by load. The output voltage of this circuit is supposed to be 0.3V as the allowable voltage to be received by ADE7753 is about 0V to 0.5V. Next is energy measurement circuit to produce pulse that is proportional to the active power of the load. The most important part of the circuit is ADE7753. ADE7753 will generate the pulse represent the active power and others parameters also can be access from its serial bus. Finally, the last part is microcontroller circuit. There are two modules involved in the microcontroller circuit that are the display module and selection module. These two modules are developed for the users convenient. Selection module enable the users to select and view he desired values of current, voltage, active power and total energy of a particular load. The displays of the parameters are made possible by the display module.
3.1.1 Power Supply

The purpose of this circuit is to power some 5V logic from a 240VAC source. A stepped down (240V/9V) is connected from the 240V. This is how 240VAC is reduced to 9VAC. Next, the reduced voltage is sent to a bridge rectifier. Bridge rectifier is used to rectify AC to DC. The output voltage of this bridge rectifier is 9VDC. Then, to regulate the 9VDC to 5VDC, the bridge rectifier is connected to the LM7805 voltage regulator. LM7805 will reduce the 9VDC to 5VDC. Finally, the output from the regulator can be used to power up the PIC16F877A and ADE7753. Figure 3.2 shows the circuit of the power supply circuit.
3.1.2 Current and Voltage sensing circuit

Figure 3.3 illustrates the circuit connection of current and voltage circuit. The current sensing circuit is consisting of only one component, which is 20m\(\Omega\) and 5W single shunt resistor. The resistor is located at the neutral wire. The load side is connected to pin V1P of ADE7753, and the source side is connected to pin V1N of ADE7753. Maximum current that will be drawn through the line is 15A. So, voltage across the shunt resistor,

\[ V = IR \]
\[ = 15 \times 20m\]
\[ V = 0.3V \]

When the maximum current of 15A is being drawn, the Maximum power dissipation in the resistor,

\[ P = IR \]
\[ = 15^2 \times 20m\]
\[ = 4.5W \]
Since the 5W resistor is chosen, the power is still within the resistor rated value.

The voltage sensing circuit consists of high-impedance bridge between live and neutral wires. The bridge is actually resistors with values of 470kΩ and 680Ω that is connected in series between the live and neutral wires. Pin V1N and V2N will of ADE7753 are connected across 680Ω resistor. So, voltage across the 680Ω resistor,

\[
V_2 = \left(\frac{R_2}{(R_1+R_2)}\right) (V_i) \\
= \left[\frac{680}{(680+470k)}\right] \\
V_2 = 0.3V
\]

At 240VAC line voltage, the current leakage through the voltage sensing bridge is approximately 0.5mA, and therefore power dissipation in the voltage sense resistors is not a concern.

![Current and Voltage Sensing Circuit](image.png)

**Figure 3.3: Current and Voltage Sensing Circuit**