ENERGY MANAGEMENT SYSTEM

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the degree of Bachelor of Electrical Engineering (Electronics)"

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Date : 23 APRIL 2009

DEDICATION

Specially dedicated to
My beloved parents, lecturer,
and all of my best friends.

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I am greatly indebted to my supervisor, En Mohd Shawal bin Jadin for providing me with technical help and overall guidance with the design process. His dedication and motivation proved to be extremely encouraging throughout the project. I also would like to thank our FKEE staffs in selecting and ordering parts as well as their technical guidance throughout the project and helping me to complete my project with the implementation of the ADE board's. Suggestions and criticisms from my friends also have always been helpful in finding solutions to my problems for providing the concept for the project. I would like to extend mine appreciate to my parent member for giving me their loves and supports throughout my study in University Malaysia Pahang. Without the combined effort of the people those who involves directly or indirectly in completion of my project as mentioned above, this thesis project would not have been possible.

ABSTRACT

This project report describes the design and implementation of the computer system Home Energy Management System. The system provides a user the ability to differentiate between and limit the use of major power consuming appliances, allowing them to save energy and monitoring power usage at home. This system is developed to manage the power consumption in daily life. By creating this system the power usage will be consume wisely without any waste. This system control or limited the power consumption by turn off the electrical appliance when the amounts of power consumption exceed the limit. The user can set the desired amount of power usage in daily in order to save power consumption. It also allows the user to see the consumption rate for difference appliance in their house by monitor power consumption on LCD display. Buttons are used to select which parameter (voltage. current and power consumption) to be monitored. The system required three main parts include on hardware and software which is power source, controlling unit and monitoring system. The system used as PIC16F877A as a controller and ADE7753 where offer measured analog voltage and current input. The analog inputs are sample by ADC within the ADE7753, and their magnitude and phases are used to digitally calculate real, reactive and complex power in the line.

ABSTRAK

Laporan projek menerangkan berkenaan rekaan dan applikasi system berkomputer bagi Sistem Pengurusan Tenaga. Sistem ini menyediakan kemudahan utuk pengguna bagi membezakan diantara kawalan serta penggunaan kuasa eletrik dimana membantu pengguna menguruskan penggunaan elektrik dengan cermat.Dengan adanya system ini penggunaan elektrik akan lebih terkawal tanpa ada pembaziran berlaku.Sistem ini beroperasi dengan cara mengawal atau menghadkan penggunaan elektrik sekiranya penggunaan elektrik melebihi had yang ditetapkan.Kadar kawalan penggunaan elektrik ini boleh ditentukan oleh penguna itu sendiri.Pengguna juga boleh melihat atau memerhatikan kadar penggunaan elektrik bagi setiap perkakas elektrik di paparan skrin.Parameter seperti voltan, arus serta penggunaan kuasa boleh juga dipaparkan di skrin dengan menekan suis butang.Sistem ini terbahagi kepada tiga bahagian termasuk litar dan program elektrik seperti sumber kuasa, unit kawalan dan sistem paparan.Sistem ini menggunakan mikro cip PIC16F877A sebagai kawalan dan ADE7753 dimana menyediakan utuk pengukuran kemasukan analog voltan dan arus.Kemasukan analog dijadikan sebagai bahan utuk ADC (penukaran bentuk analog kepada system digital) didalam ADE7753 dan keluaran magnitude dan fasa daripada hasil tersebut digunakan utk pengiraan kuasa.

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LIST OF ABBREVIATIONS

CPU	Central Processing Unit
I/O	Input and Output
PC	Personal Computer
SSP	Synchronous Serial Port
SPI	Serial Peripheral Interface Protocol
CS	Chip Select
LCD	Liquid Crystal Display
SCK	Serial Clock
DC	Direct Current
USART	Universal Serial Asynchronous Receiver Transmitter
RS	Register Select
R/W	Read/Write
E	Enable
SDI	Serial Data In
SDO	Serial Data Out
ROM	Read Only Memory
RAM	Random Access Memory
PCB	Printed Circuit Board
GND	Ground
ADC	Analog to Digital Converter
AMR	Automatic Meter Reading
GUI	Graphic User Interface
VB	Visual Basic
LED	Light Emitted Diode
MSB	Most Significant Bit

LSB	Least Significant Bit
EMF	Electromagnetic Fields
PBP	PicBasic Pro compilers
IDE	Integrated Development Environment
ICD	In Circuit Debugging

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy Management System can also refer to a computer system which is designed specifically for the automated control and monitoring power usage at home. This system is developing to manage the power consumption in daily life. By creating this system the power usage will be consume wisely without any waste. This system control or limited the power consumption by turn off the electrical appliance when the amounts of power consumption exceed the limit. It also allows the user to see the consumption rate for difference appliance in their house by monitor power dissipation on LCD display and Personal Computer (PC).However the PC only receive the measured value of current and voltage, then user can interface with PC to determine the set point to be sent to the microcontroller. In doing this, user definitely can disable certain appliance when total power consumption is exceed the limit.

By using this system, the user can set the desired amount of power usage in daily in order to save power consumption. Besides that, user could find the suitable range of time to use the appliance which is consuming major power will cause the higher amount of power dissipation. The system also can manipulated the electrical appliance with automatically or manually turn on and off. This system will be expect to become an intelligent management where it such a good way to save the usage of power consumption in daily life.

The system required three main parts include on hardware and software which is power source, controlling unit and monitoring system. The system used a PIC16F877A as a controller. Basically, this project is designed to be interface with home electrical appliance based on development of Graphical User Interface (GUI) in Visual Basic 6.0.For advances features of this system the control unit will able to stand-alone running or work independently base on the program that been set in control unit to be automatically react to the data such in order to manipulate the energy consumption patterns without connected to the PC. This is important causes the usage of PC 24 hours will draw a lot of power that will affect on this system and bad effect to our self.

1.2 Research Problem

Rising electricity prices have made it worthwhile for consumers to be informed about the costs of operating their appliances. All types of consumers of electricity, from landlords to office managers to the simple home user, are seeking more and more information about the power consumption of their appliances and electronics in an effort to reduce power usage and save money. It can be difficult to obtain power consumption data for most appliances and electronics, and consumers often aren’t sure of the best ways in which to reduce power consumption. For years, large-scale industry has spent millions of dollars on equipment and services in an effort to reduce its power consumption, but there is little such practical and affordable help available to home and small office consumers.

1.3 Objective

The higher goals were to not only build a cheaper, more accurate and more functional device, but also provide some means by which the characterization of a load could help save power. To achieve this aim, the study is carried out for the following objectives.

i. To develop a system function to be as meter for current, voltage and power reading and also function as an automatic meter reading which is calculated the amount of power usage especially for management of various load at home.

ii. To develop system where control the appliance by turn on and off automatically through a PC where the system able to work independently base on program that has been set in control unit to manipulate the electrical appliance.

1.4 Scope of Project

i. To develop energy management system that view measurement of voltage (rms), current (rms) and power consumption on LCD display and using PIC16877A as a controller for this system.

ii. To integrate the hardware and software in order to develop an energy management system by interfacing of electrical appliance

iii. Develop Graphical User Interface (GUI) using Visual Basic for hardware and software interfacing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In various countries, there are presently attempts to replace electro-mechanical power meters with electronic ones. Although the module described in this article was not specifically designed for that purpose, it can be used as a low cost electronic power meter module for simple domestic electric power measurement applications. Some of its advantages over conventional systems are life expectancy and accuracy and the possibility of remote monitoring [1]

The circuit system is implemented with a power measurement IC (ADE7753) from Analog Devices. It is capable of measuring instantaneous voltage, current, and power, VRMSI,m s, and real. Reactive and apparent energy. The interface to the mains of a site is accomplished using a novel, non-intrusive flexible Rogowski coil developed as the current sensor. [2]

The ADE7753 is a highly accurate energy metering integrated circuit. It has the ability to calculate active, reactive and apparent energy. This chip can communicate via serial data transfer and has a pulse output frequency proportional to the active power measured. [7]

“LCD is used because it consumes less power than seven segment display. It is responsible for cycling through various modes as commanded by the user in order to display various power consumption data". [8]

The PIC16F877A was chosen for its SPI mode synchronous serial communication and large number of general I/O pins available. [7]

2.2 Component review

This section provides the necessary background information required for a proper understanding of the content discussed in this paper. This includes:

2.2.1 **ADE7753 Chip**

In this project, ADE7753 IC chip from Analog Devices are used for measuring electric appliance. This chip is based on an inexpensive shunt resistor.

2.2.2 Microchip PIC 16F877A

The Microcontroller primarily performs the function of converting the analog signal inputs into an 8 bit digital value. It performs basic measurements on the waveforms to obtain the average power and displays this on a 2 x 16, on green LCD display. To use a microcontroller in this project, all operation as states below are should be know.

2.2.2.1 Crystal operation

These circuits are used as a clock input for microcontroller to control the internal clock generator circuitry.

2.2.2.2 Reset circuit

This circuit is used as an input to initialize the PIC16F877A to a know start up state.

2.2.2.3 I/O circuit

In microcontroller, the input and output device are needed for develop system function. This section will describe in detail about the input and output circuit.

2.2.3 Liquid Crystal Display (LCD)

In this section described LCD as a monitoring system in develop this project.

2.2.4 Optocoupler

Describe the function of this device as an isolation using in Energy Management System.

2.2.5 Serial Peripheral Interface Protocol.

This topic will describe the way to communicate with one or more slave devices.

2.2.1 ADE7753 Chip

The ADE7753 is a highly accurate energy metering integrated circuit. It has the ability to calculate active, reactive, and apparent energy. This chip can communicate via serial data transfer and has a pulse output frequency proportional to the active power measured. This chip requires analog inputs of voltage and current applied to its input terminals. The maximum differential signal level is ± .5 volts with respect to AGND. The gain of both of these channels can be changed to account for error in the transformers. There is a selectable on-chip digital integrator which can provide an interface to a current sensor like a Rogowski coil. The analog to digital conversion in the ADE7753 is achieved by using two second-order Σ-Δ ADCs. The sampling rate is determined by the sampling clock which is equal to the input clock divided by four. There are many system calibration features in this chip including channel offset correction, phase calibration, and power calibration. This allows it to provide very accurate power information. The ADE7753 power measurement chip met all our operating specifications. This chip is capable of measuring single phase power with several built in calibration points for precise power measurement. The chip communicates via serial communication which can be easily integrated with a PIC microprocessor. The chip has 24 bit internal registers which are used to accumulate the power measured. This data can be read using a serial peripheral interface with the chip

2.2.2 Microchip PIC 16F877A

The Microchip PIC16F877A is an inexpensive 8-bit microcontroller. Its features include 256 bytes of EEPROM data memory, self programming, two Comparators, eight channels of 10-bit Analog-to-Digital (A/D) converter, a Synchronous Serial Port (SSP), a Universal Serial Asynchronous Receiver Transmitter (USART), and three separate timer modules. It contains 14.3KB worth of program memory and is capable of operating with up to a 20MHz clock (200ns instruction cycle). The primary functionality for the PIC in the EMS is to perform a serial read on the active energy register on the ADE chip. Secondary functions include turning the EMS on and off. The PIC16F877A was chosen for its SPI mode synchronous serial communication and large number of general I/O pins available.

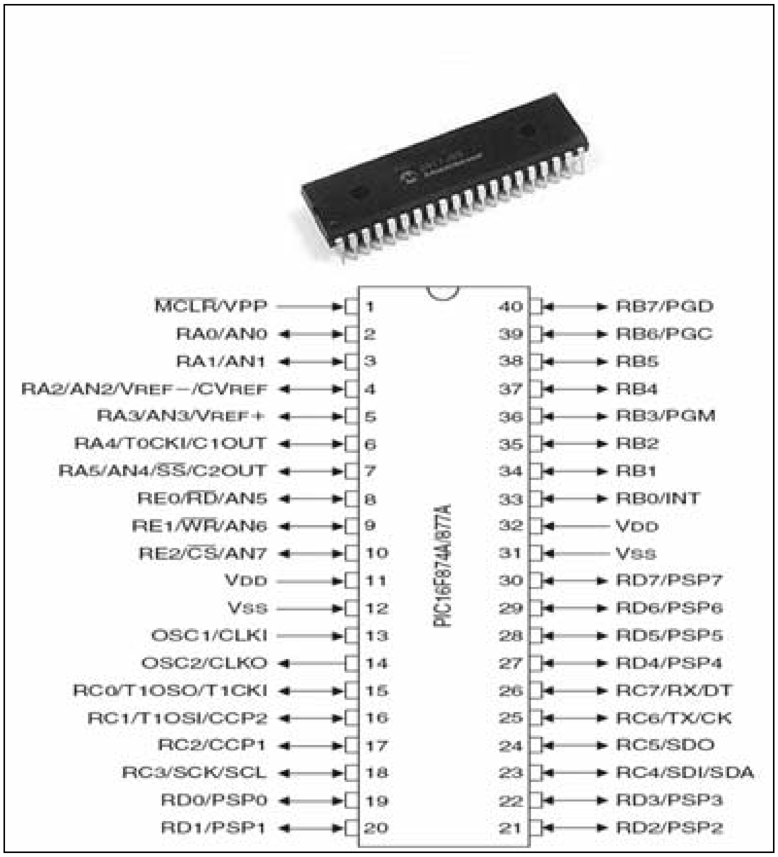

Figure 2.1: Pin out for the 40-pin PDPIP package of the PIC16F877A

2.2.2.1 Crystal operation

As shown in Figure 2.2, in this mode of operation an external crystal and two capacitors are connected to the OSC1 and OSC2 inputs of the microcontroller. The capacitors should be chosen as in Table 2.1. For example, with a crystal frequency of 4 MHz, two 22 pF capacitors can be used

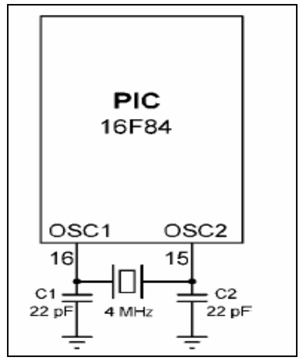

Figure 2.2 Crystal oscillator circuit

Table 2.1: Capacitor selection for crystal operation

Mode	Frequency	C1, C2
LP	32 kHz	68–100 pF
LP	200 kHz	15–33 pF
XT	100 kHz	100–150 pF
XT	2 MHz	15–33 pF
XT	4 MHz	15–33 pF
HS	4 MHz	15–33 pF
HS	10 MHz	15–33 pF

2.2.2.2 Reset circuit

Reset is used to put the microcontroller into a known state. Normally when a PIC microcontroller is reset execution starts from address 0 of the program memory. This is where the first executable user program resides. The reset action also initializes various SFR registers inside the microcontroller. PIC microcontrollers can be reset when one of the following conditions occur:

- Reset during power on (POR – Power On Reset)
- Reset by lowering MCLR input to logic 0
- Reset when the watchdog overflows.

As shown in Figure 2.3, a PIC microcontroller is normally reset when power is applied to the chip and when the MCLR input is tied to the supply voltage through a 4.7 K resistor.

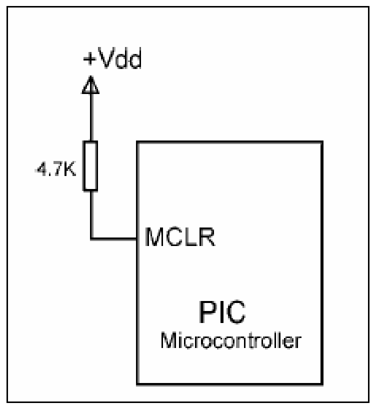

Figure 2.3 Using the power on reset

There are many applications where we want to reset the microcontroller, e.g. by pressing an external button. The simplest circuit to achieve an external reset is shown in Figure 2.4. In this circuit, the MCLR input is normally at logic 1 and the microcontroller is operating normally. When the reset button is pressed this pin goes to logic 0 and the microcontroller is reset. When the reset button is released the microcontroller starts executing from address 0 of the program memory

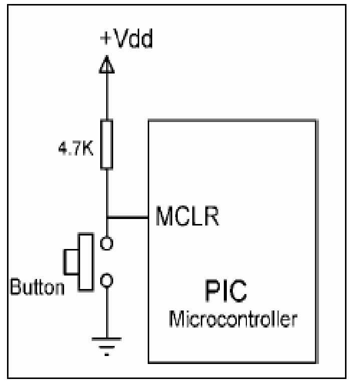

Figure 2.4: Using an external reset button

2.2.2.3 I/O circuit

A PIC microcontroller port can source and sink 25 mA of current. When sourcing current, the current is flowing out of the port pin, and when sinking current, the current is flowing into the pin. When the pin is sourcing current, one pin of the load is connected to the microcontroller port and the other pin to the ground (see Figure 2.5). The load is then energized when the port output is at logic 1. When the pin is sinking current, one pin of the load is connected to the supply voltage and the other pin to the output of the port (see Figure 2.6). The load is then energized when the port output is at logic 0.

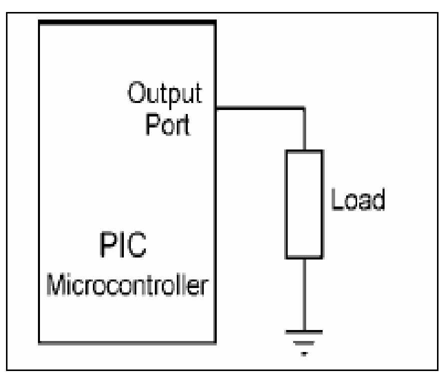

Figure 2.5: Current sourcing

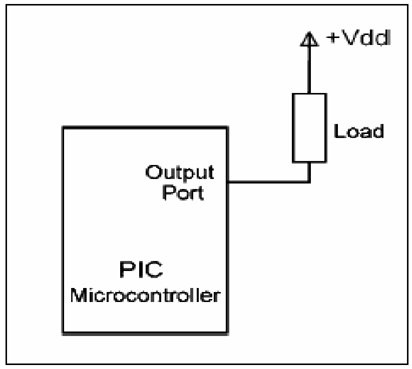

Figure 2.6: Current sinking

LED as an output interface

LEDs come in many different sizes, shapes, and colours. The brightness of an LED depends on the current through the device. Some small LEDs operate with only a few milliamperes of current, while standard size LEDs consume about 10 mA of current for normal brightness. Some very bright LEDs consume 15–20 mA of current. The voltage drop across an LED is about 2V, but the voltage at the output of a microcontroller port is about 5 V when the port is at logic 1 level. As a result of this it is not possible to connect an LED directly to a microcontroller output port. What is required is a resistor to limit the current in the circuit. The nearest physical resistor we can use is 330. Figure 2.8 shows how an LED can be connected to an output port pin in current source mode. In this circuit the LED will be ON when the port output is set to logic 1 Similarly, Figure 2.7 shows how an LED can be connected to an output port pin in current sink mode. In this circuit the LED will be ON when the port output is at logic 0.

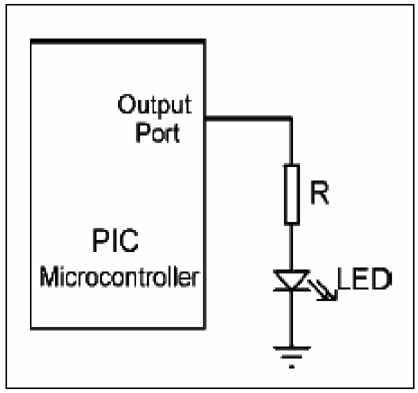

Figure 2.7 Connecting an LED in current sink mode

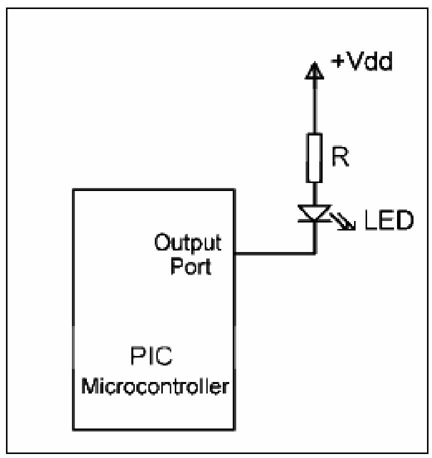

Figure 2.8 Connecting an LED in current source mode

2.2.3 Liquid Crystal Display (LCD)

In many microcontroller-based applications, it is required to display a message or the value of a variable. Basically, three types of displays can be used in practice. These are video displays, 7-segment LED displays, and LCD displays. For this project LCD are used for display purpose. LCDs are alphanumeric displays which are frequently used in microcontroller-based applications. Some of the advantages of LCDs are their low cost and low power consumption. LCDs are ideal in low-power, battery-operated portable applications. These displays come in different shapes and sizes. In this section, are looking at how interfacing for the standard LCDs to a PIC microcontroller and what commands are available to use the LCDs. Table 2.2 shows the pin configuration of the LCD. A description of the pin functions is given below.

Table 2.2: Pin configuration of LCD

Pin No	Name	Function
1	V_{SS}	Ground
2	V_{DD}	Positive supply
3	V_{EE}	Contrast
4	RS	Register select
5	R/W	Read/write
6	E	Enable
7	D0	Data bit 0
8	D1	Data bit 1
9	D2	Data bit 2
10	D3	Data bit 3
11	D4	Data bit 4
12	D5	Data bit 5
13	D6	Data bit 6
14	D7	Data bit 7

- **VSS** is the 0 V or ground. VDD pin should be connected to the positive supply. Although the manufacturers specify a 5 V supply, the module can be operated with as low as 3 V or as high as 6V.

- Pin 3 is named as **VEE** and this is the contrast control pin. This pin is used to adjust the contrast ofthe LCD and it should be connected to a variable voltage supply. A potentiometer is usually connected between the power supply lines with its wiper arm connected to this pin so that the contrast can be adjusted. This pin can be connected to ground if contrast adjustment is not needed.

- Pin 4 is the **Register Select (RS)** and when this pin is LOW, data transferred to the display is treated as commands. When RS is HIGH, character data can be transferred to and from the module.

- Pin 5 is the **read/write (R/W)** pin. This pin is pulled LOW in order to write commands or character data to the LCD module. When this pin is HIGH, character data or status information cannot be read from the module. This pin is usually connected to ground, i.e. the LCD is put into write mode.

- Pin 6 is the **Enable (E)** pin which is used to initiate the transfer of commands or data between the LCD module and the microcontroller. When writing to the display, data is transferred only on the HIGH to LOW transition of this pin. When reading from the display, data becomes available after the LOW to HIGH transition of the enable pin and this data remains valid as long as the enable pin is HIGH.

- Pins 7 to 14 are the eight **data bus lines (D0 to D7).** Data can be transferred between the microcontroller and the LCD module using either an 8-bit interface, or a 4-bit interface. In the latter case, only the upper four data lines (D4 to D7) are used and the data is transferred as two 4-bit nibbles.

When the connections are made between the microcontroller and the LCD, we can simply use the LCDOUT command to send data to the LCD module. Note that the connections between the microcontroller and the LCD can be changed using a set of **DEFINE** commands to assign the LCD pins to the PIC microcontroller. In the following example, PORTB pins 0 to 4 are used for LCD data (i.e. RB0 connected to D4,RB5 connected to D5, etc.), bit 4 of PORTB is connected to the RS pin of the LCD, bit 5 of PORTB is connected to the E pin of the LCD, the LCD is set for 4-bits of operation, and the LCD is assumed to have two rows.

DEFINE LCD_DREG PORTB ‘Set LCD data port to PORTB

DEFINE LCD_DBIT 0 ‘Set data starting bit to 0

DEFINE LCD_RSREG PORTB ‘Set RS register port to PORTB

DEFINE LCD_RSBIT 4 ‘Set RS register bit to 4

DEFINE LCD_EREG PORTB ‘Set E register port

DEFINE LCD_EBIT 5 ‘Set E register bit to 5

DEFINE LCD_BITS 4 ‘Set 4 bit operation

DEFINE LCD_LINES 2 ‘Set number of LCD rows

The character set of the LCD is given in Table 2.3

Table 2.3: LCD commands

Command	Operation
$FE, 1	Clear display
$FE, 2	Home cursor
$FE, $0C	Cursor off
$FE, $0E	Underline cursor on
$FE, $0F	Blinking cursor on
$FE, $10	Move cursor left by one position
$FE, $14	Move cursor right by one position
$FE, $80	Move cursor to the beginning of first row
$FE, $C0	Move cursor to the beginning of second row
$FE, $94	Move cursor to the beginning of third row
$FE, $D4	Move cursor to the beginning of fourth row

2.2.4 Optocoupler

This device is used because the source and destination are at very different voltage levels, like a microprocessor which is operating from 5V DC but being used to control an electrical appliance which is switching 240V AC. The link between the two must be an isolated one, to protect the microprocessor from overvoltage damage. Relays can of course provide this kind of isolation, but even small relays tend to be fairly bulky compared with ICs and many of today other miniature circuit components. Because they are electro-mechanical, relays are also not as reliable and only capable of relatively low speed operation. Where small size, higher speed and greater reliability are important, a much better alternative is to use an optocoupler. These use a beam of light to transmit the signals or data across an electrical barrier, and achieve excellent isolation. Optocouplers typically come in a small 6-pin or 8-pin IC package, but are essentially a combination of two distinct devices: an optical transmitter, typically a gallium arsenide LED (light-emitting diode) and an optical receiver such as a phototransistor or light-triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between the two, but does allow the passage of light. Usually the electrical connections to the LED section are brought out to the pins on one side of the package and those for the phototransistor or diac to the other side, to physically separate them as much as possible. This usually allows optocouplers to withstand voltages of anywhere between 500V and 7500V between input and output. Optocouplers are essentially digital or switching devices, so they are best for transferring either on-off control signals or digital data. Analog signals can be transferred by means of frequency or pulse-width modulation. Figure 2.9 show out pin of optocoupler.

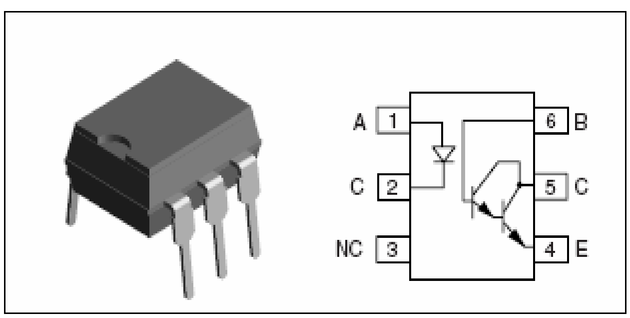

Figure 2.9: Pin out for the 6-pin of optocoupler

2.2.5 Serial Peripheral Interface Protocol

Serial Peripheral Interface Protocol (SPI) is a synchronous serial communications protocol developed by Motorola. It is designed to allow a single master device to control and communicate with one or more slave devices. Figure 2.10 shows a simple SPI connection structure

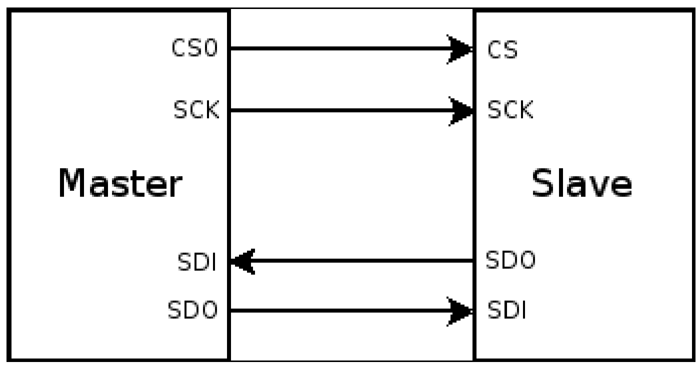

Figure 2.10: SPI Connection Structure

There are two control lines and two data lines that are used for SPI communications. Below show function of pin as in Table 2.4.

Table 2.4: describes each line and their function.

Signal	Function
CS	Chip Select – allows the master to select the slave or group of slaves with which it will communicate. Master provides output, slaves receive as input
SCK	Serial Clock – the synchronous clock signal. Master provides output, slaves receive as input.
SDI	Serial Data In – Serial data input line
SDO	Serial Data Out – Serial data output line

There are four different modes of operation for SPI communications. Each mode describes a clock idle polarity and edge select for when data is latched. These modes are shown in Table 2.5 below.

Table 2.5: Mode description

CKP	CKE	SPI Mode	Description
0	0	0,1	SCK idles low, data is latched on high-low clock transition
0	1	0,0	SCK idles low, data is latched on low-high clock transition
1	0	1,1	SCK idles high, data is latched on low-high clock transition
1	1	1,0	SCK idles high, data is latched on high-low clock transition

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the equipments used, the procedures and the method for the research is discussed. The main study of this chapter is to determine the overall circuit of the energy management system. The figure 1 has shown the overall system of energy management system. The system consists three main parts include on hardware and software which is power source, controlling unit and monitoring system. Controlling unit is a main of energy management system where control by PIC16F877A.This controller are choose because of instruction set are simple and seamless migration between product families make PIC16F877A microcontrollers the logical choice for designing requiring flexibility and performance. This controller used to execute the programs that has written or set that is stored in memory. This controller also functions to record and save the data in random access memory (RAM) and calculate the power average used of each appliance that connected to the system.

This system running in condition stand-alone running (without connected to the PC).. In overall this system is operated when the load (electrical appliance) is connected to the power source 240 Vrms, 50Hz. This system only operated in single phase source.

However this system can support more loads by using an extension socket. This system connected to source through switching technique which is used relay to be turn on and off. The current and voltage will be step-down first by interfacing circuit which is used to match with the internal device where the PIC16F877A controller operated in Direct Current (DC) and voltage level at 5V.To ensure the data sent to control unit is digital signal the data of electrical appliance that connected to this system is convert using Analog to Digital converter (ADC). The data from ADC port will be record for every millisecond and save it in random access memory (RAM). The data is power dissipation taken by recording the level of voltage and current. The controller unit will calculate the power average in that interval time and result will display either on LCD display

The signal conditioning circuit is the place conversion process happened, the device that perform signal conversion are often called as transducers or sensors. The conditioning circuit used to convert an AC current signal of 0 to 15 Amps (rms) into a dc voltage of 0 to 5V.For this system two type of sensor are used voltage and current sensor.

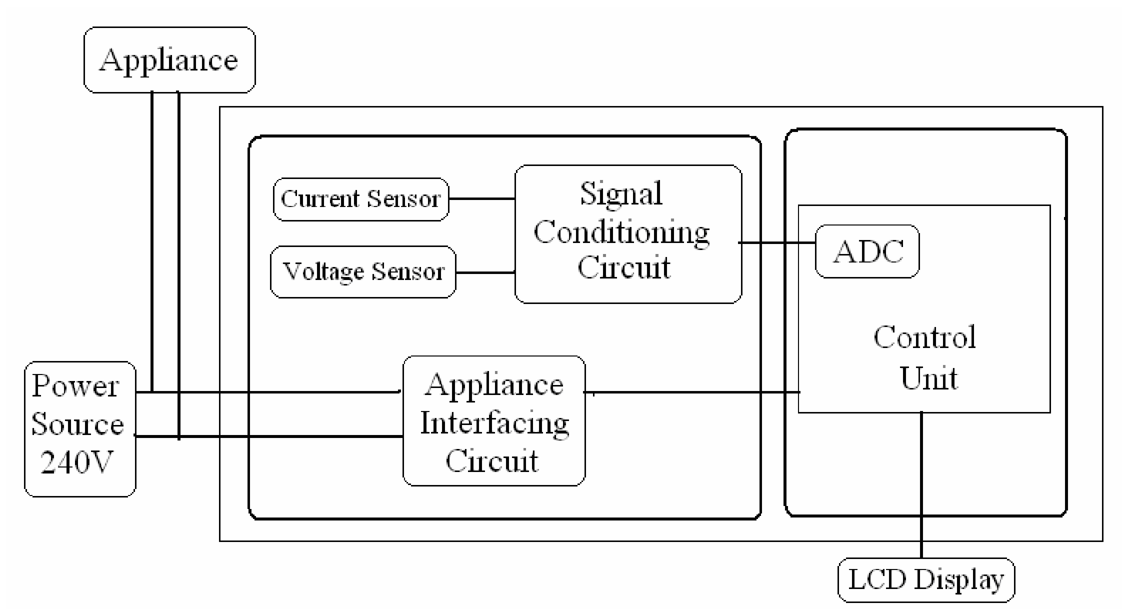

Figure 3.1: Overall view of energy management system

3.2 Hardware Design

The project involves the design, layout, and fabrication of a custom printed circuit board (PCB). The power consumption meter will be powered from the socket it is currently measuring and thus requires on-board power conversion hardware. The bulk of the hardware focuses on power consumption measurement and data storage. Finally, hardware to display the data and accept user input is also required.

3.3 Block Description

3.3.1 Load

These energy management systems use any house-hold consumer load. The system investigating various loads with rated power consumptions of around 9 KW such as water heater, lamp and etc.

3.3.2 Power Supply Circuit

For this circuit utilize an appropriate power supply that converts the 240 V, 50 Hz AC voltage to appropriate DC values (mainly 5 volt, and additionally 12 volts if required) to power the ADE, PIC, Relay, and LCD circuit. Batteries and adapter also are looking for providing power for this circuit. The main purpose of power supply module is to be as power source to the system.

3.3.3 Energy Measurement Circuit

The Energy Measurement circuit is responsible for direct current, voltage, and power angle measurements, and from them, determining real and reactive power consumption. The Energy Measurement circuit must be capable of relaying these measured and calculated values to the microcontroller via a serial bus. The heart of the Energy Measurement subsystem is Analog Devices Energy Meter p/n ADE7753. The ADE7753 offers analog voltage and current inputs, and an SPI serial interface. Both voltage and current inputs require a 0 to 0.5V analog input. The analog inputs are sampled by ADCs within the ADE7753, and their magnitudes and phases are used to digitally calculate real, reactive, and complex power in the line. The current sensing circuit consists of a single shunt resistor rated at 0.02 Ohms and 5W.The resistor is located in the Neutral wire, and is tapped at both sides. The load side is connected to pin V1P, and the source side is connected to pin V1N. Maximum current to be drawn through the line is 15A, and so voltage across the current sense resistor will range from zero to 0.3VAC. Maximum sustained power dissipation in the resistor when 15A is being drawn will be approximately 4.5W, which is within the resistor s rated operation. The voltage sensing circuit consists of a high-impedance bridge between the Hot and Neutral wires. Two high-precision resistors rated at 470k Ohms and 680 Ohms are connected in series between the Hot and Neutral lines as shown in figure 4.1 Pins V2P and V2N are connected across the 680 Ohm resistor. Note that 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. In Appendix B shows the circuits diagram of the Energy Measurement system and Table 3.1 below outlines in detail each pin connection of the device

Table 3.1: Energy Measurement Circuit Pin Assignment

Pin	Connection	Description
RESET	Microcontroller RA4	Reset pin
DIN	Microcontroller SDO	Serial interface data input
DOUT	Microcontroller SDI	Serial interface data output
SCLK	Microcontroller SCK	Serial interface clock
CS'	Microcontroller RC6	Serial interface chip select
CLKOUT	Clock Gen	Chip clock. Parallel AT crystal @ 3.579545MHz provide clock source
CLKIN	Clock Gen	
IRQ'	NC	
SAG'	NC	
2X	NC	
CF	NC	
DGND	Dig. Ground	Digital Ground Reference. Provides ground reference for the digital circuitry
REF	Ana. Gnd w/ 10uF decoupling	On-chip voltage reference
AGND	Ana. Ground	Analog Ground Reference. Provides ground reference for analog circuitry
V2P	Neutral Wire	Analog inputs for channel 2, used with the voltage transducer
V2N	Voltage Sense	
V1P	Neutral Wire (load side)	Analog inputs for channel 1, used with the current transducer
V1N	Neutral Wire (source side)	
AVDD	+5V Power	Analog voltage supply. Provides supply voltage for analog circuitry
DVDD	+5V Power	Digital voltage supply. Provides supply voltage for digital circuitry

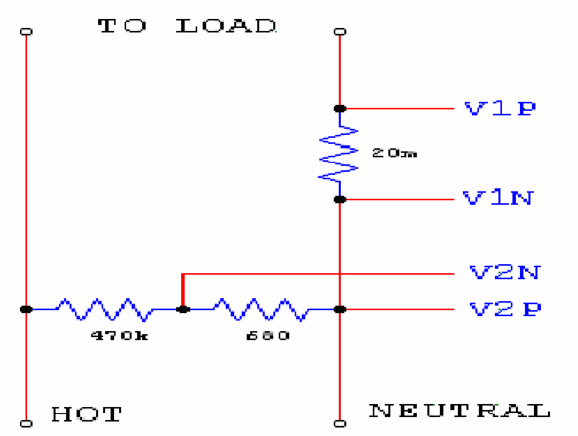

Figure 3.2: Connection of shunt resistor and voltage divider

In operation, the chip directly interfaces with a shunt resistor (current sensor) and ac voltage sensing input. Pins V1P and V1N accept the current sensing input obtained from the current sense resistor. Pins V2P and V2N obtain inputs via a resistor divider that provides a signal proportional to the ac line voltage. The small, full-scale analog input range allows the chip to interface to low-value shunt resistances without sacrificing dynamic range. Low-frequency pulse outputs supply average real power information and can directly interface to a stepper motor counter display. In addition, synchronized high-frequency pulse outputs are available for calibration and test purposes. The high-frequency pulse outputs can also be used with a microcontroller or an automatic meter reading (AMR) module. The shunt size 0.02 Ohms and 5W is selected to maximize the use of the dynamic range on Channel V1 (current channel). However, there are some important considerations when selecting a shunt for an energy metering application as state below.

- Minimize the power dissipation in the shunt.
- The higher power dissipation may make it difficult to manage the thermal issues
- Ability of the meter to resist attempts to tamper, by shorting the phase circuit.
- with a very low value of shunt resistance

3.3.4 Microcontroller

The purpose of the Microprocessor is to log, manipulate, and display data reported by the Energy Measurement subsystem. The Microcontroller must connect to the ADE7753 Energy Meter via an SPI serial interface, must share a clock with the ADE7753, must accept inputs from buttons, and must generate outputs to drive an LCD display. The chosen controller is the Microchip PIC16F877A.The PIC16F877A has multiple digital I/O pins available, and these pins are used for user input and output. Pins RD0 to RD3 are used as digital inputs, and are connected to simple normally open switch buttons used for user input. The controller-side of the switches is connected through a pull-up resistor to VDD. The pins are pulled to GND when the switches are closed (button is pressed). Pins RB0 to RB5 are used as digital outputs to drive the LCD display. The first four pins are data pins, while pin RB4 is used to specify read/write operation to the LCD, and pin RB5 is used to specify 4- or 8-bit usage. The LCD chosen in this case accept both 4- and 8-bit data packets, however only three additional digital outputs are available from the PIC16F877A, so the LCD interface is therefore implemented with 4 bits. A 4-pin interface is more desirable anyway, as it improves expandability and risk management, in addition to reducing cost and complexity. The PIC16F877A will communicate with the ADE7753 energy via an SPI serial interconnect, and provides clock, chip select, and I/O pins for that purpose. Brightness control of the LCD display is accomplished with potentiometer. The user selects brightness control from the appropriate software menu, and when changes are commanded, the microcontroller drives a digital output to change the resistance of the potentiometer. Pin RC1 is a digital output used to specify the forward/backward operation of the potentiometer. Pin RC2 is output from the microcontroller used to command the variable resistance increase or decrease. In Appendix B show simple circuit diagrams for Microcontroller and LCD circuit and Table 3.2 below show list in detail pin connection.

Table 3.2: Microcontroller pin assignment

Pin	Connection	Description
MCLR'	+5V	Master clear, always high.
RA0	Button 1	Digital input from Button 1.
RA1	Button 2	Digital input from Button 2.
RA2	Button 3	Digital input from Button 3.
RA3	Button 4	Digital input from Button 4.
RA4	ADE7753 RESET	Digital output, used to reset ADE7753.
RA5	NC	
RA6	NC	
RA7	NC	
VSS	Ground	0V Ground.
RC0	LCD E	
RC1	Potentiometer CS	Digital output to Potentiometer chip select (LCD brightness control).
RC2	Potentiometer U/D	Digital output to Potentiometer Up/Down (LCD brightness control).
SCK	ADE7753 SCLK	Serial interface clock.
RC6	ADE7753 CS	Serial interface chip select.
RC7	240/120V Select	Sense for 120/240V transformer jumper.
SDO	ADE7753 DIN	Serial interface data output.
SDI	ADE7753 DOUT	Serial interface data input.
VDD	+5V	+5V supply voltage.
PGC	ICD PGC	In-circuit debugger interface.
PGD	ICD PGD	
RB0	LCD DB7	LCD Data Pins.
RB1	LCD DB6	
RB2	LCD DB5	
RB3	LCD DB4	
RB4	LCD RW	LCD read/write command.
RB5	LCD RS	LCD bus select.

3.3.5 Data Display

The system is created to obtain the following data using the voltage and current wave forms obtained:

- Instantaneous values of voltage and current, displayed to the user at a slow rate of around 1 data point per second.
- RMS voltage and current readings.
- Average real power consumed

3.3.6 Interfacing Circuit for Energy Management System

This topic describe in detail, the whole system in developing of Energy Management System.

3.3.6.1 PIC-ADE Serial Interface

For product like ADE7753 single-phase, calibration is done using the registers through the SPI interface .Refer to product data sheets and application in Appandix A.

3.3.6.2 ADE7753 Serial Communication

The ADE7753 is fully accessible by a built in serial communications module. To initiate any read or write operation to or from the ADE, there must first be a write to the ADE’s communication register. The communication register is 8-bits wide. The MSB indicates whether the desired operation will be a read or a write. The 6 LSBs contain the address that will be written to or read from. Figure 3.3 shows the addressing system via the communications register on the ADE.

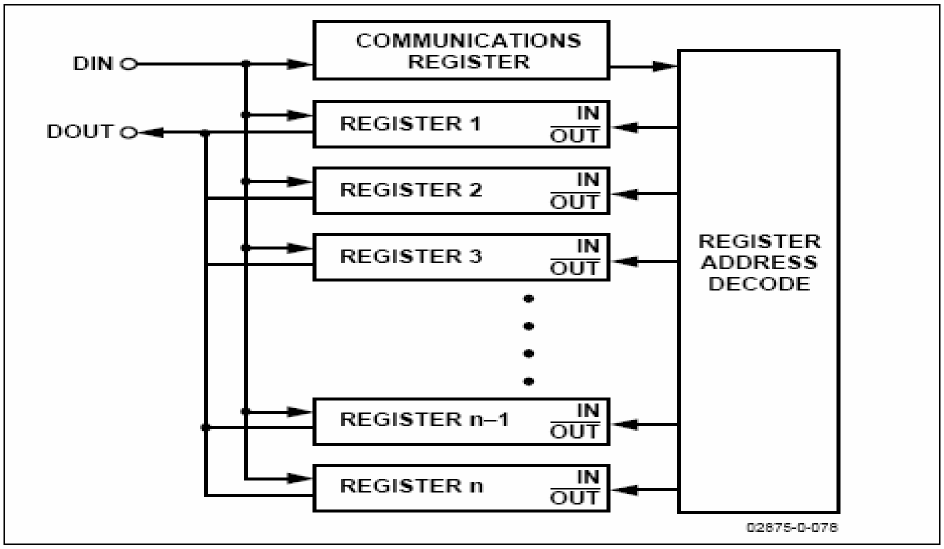

Figure 3.3: Addressing the ADE7753 Registers via the Communications Register.

The communications protocol itself is compatible with SPI protocol with some specific timing requirements on the serial clock. The format for serial communication with the ADE7753 is detailed in Figure 3.4.

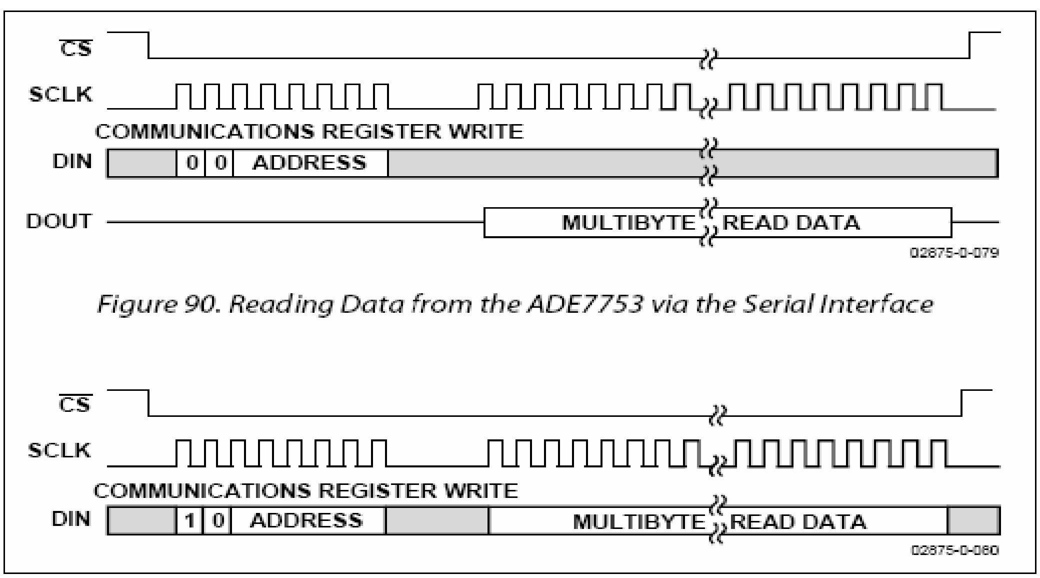

Figure 3.4: General Format for Serial Communications

3.3.6.3 PIC Microprocessor

The PIC Microprocessor serves as an interface between the ADE7753 and LCD display. The primary functionality for the PIC is to perform a serial read on the active energy register on the ADE chip. Secondary functions include turning the Smart-Plug on and off and controlling whether the UPS is charging or supplying. The PIC16F877A was chosen for its SPI mode synchronous serial communication, USART and large number of general I/O pins available.

3.3.7 Relay

The relay provided was rated at 20A, model (ACCU400). Using an optocoupler H11B1 the relay was triggered to switch the phase on and off using a 12V signal. The relay was connected to the circuit as follows in Appandix B. To switch inductive loads such as relays, a diode has to use in the circuit to prevent the transistor from being damaged. An inductive load can generate a back EMF which could easily damage an optocoupler H11B1. By connecting a diode in reverse bias mode this back EMF is dissipated without damaging the optocoupler H11B1.

3.3.8 Optocoupler

Since stray currents from external switch control circuitries may cause damages to the microcontroller of PIC16F877A, the output pins of external circuitries need to be isolated. In this project design, H11B1 phototransistor optocouplers are used to provide physical isolation. Each optocoupler consists of a gallium arsenide infrared emitting diode and a silicon phototransistor.For more detail datasheet of optocoupler H11B1 are included at Appandix A.

3.3.9 Implementation

3.3.9.1 Serial Communication Implementation

The ADE7753's serial connections were wired to the PIC16F877A microcontroller through the parallel port connector located on the ADE7753's evaluation board. The block diagram in Figure 3.5 shows how each signal line was connected. Several output lines from the ADE7753 were not connected to the PIC because they were providing information only necessary for the ADE's calibration. The PIC acts as the SPI master device and the ADE as the slave. /RESET is a signal required for the proper operation of the ADE and was supplied at a constant +5V. /CS is the chip select line as was provided by the PIC to go low when a read operation was to be performed. SCLK is the serial clock provided by the PIC to the ADE. DIN was the ADE's data in line connected to the PIC's SDO serial data out. DOUT was the ADE's data out line connected to the PIC's SDI serial data in.

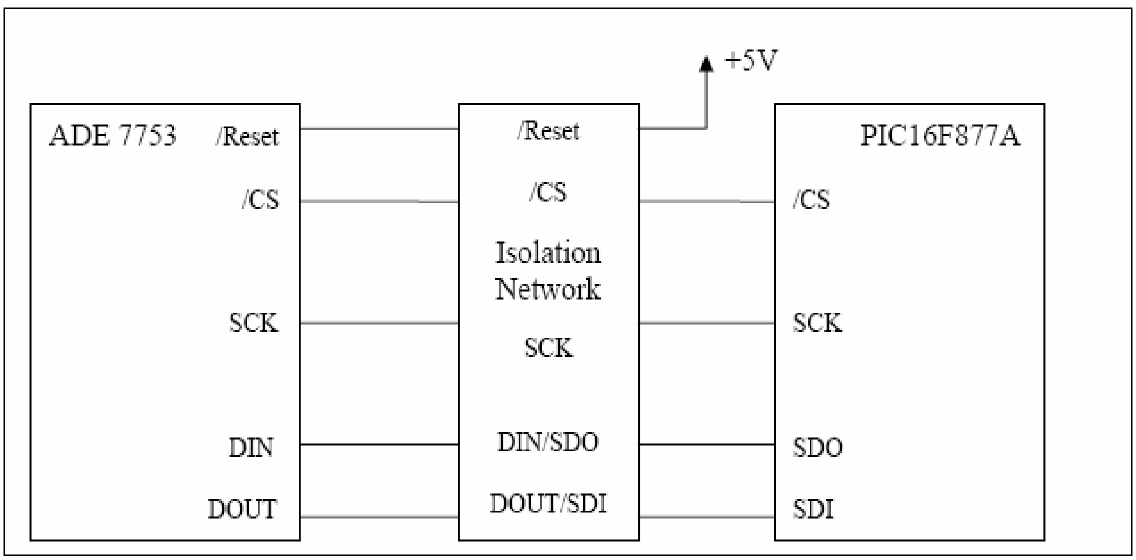

Figure 3.5: Block Diagram of ADE7753 to PIC16F877A Interface

3.3.9.2 PIC Programming

The primary focus of the PIC's programming was to activate the ADE7553 to PIC16F887A serial communications. Implementation of the Smart-Plug on/off was considered trivial and was not yet completed in code.

Figure 3.6 details a flow chart of how the serial communications was implemented in code. The 4us wait is part of the specific timing requirements of the ADE773's serial communications, detailed in the ADE's datasheet.

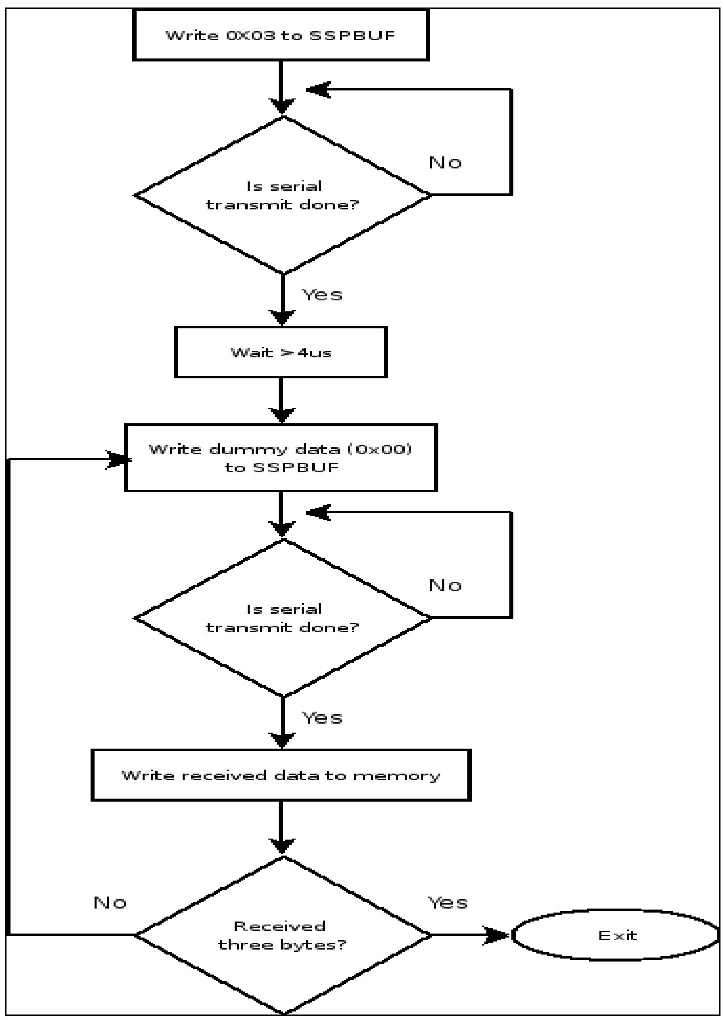

Figure 3.6: Flow Chart for Serial Communication with the ADE7753

To generate the serial clock, the PIC's Timer2 module was selected to give the ability to easily adjust the baud rate. The minimum allowable clock period was 100ns which was faster than the PIC could generate it. A much slower clock speed of 256 instruction cycles per serial clock cycle, or 51.2us, was selected for testing and debugging the serial communications. Since the ADE expected data to be latched on the falling edge of the clock, and for the idle clock state to be digital low, SPI mode (0, 1) was set and the appropriate CKE and CKP values were set in software.

On a read request from the PC, the PIC would write the read command to the ADE's communication register, wait for 4us or longer, then read all 3 bytes of data from the ADE's active energy register. Each byte was stored in a separate location in the PIC's data memory. After the serial read operation was complete the PIC would transmit the 3 bytes of energy data to the PC via the wireless network.

3.3.9.3 Testing

Testing and full implementation of the PIC-ADE serial communications was not completed. A recurring problem of the signal from the PIC not being propagated properly through the parallel port to the ADE was encountered. Several different test configurations were attempted, with no success. The PIC consistently would generate correct data output on its output pins, but the signal received at the ADE would be incorrect.

A test program to generate a simple SCK signal to pulse eight times was created. When measured at the PIC's output pin, the signal showed eight individual clock pulses. The cause of this phenomenon remains undiagnosed and has resulted in this portion of the project remaining incomplete.

3.3.9.4 Improvements

Successful communication between the PIC and ADE would be the primary goal of future work done on this project. Determining the cause of and solution to the PIC-generated signals' behaviors is a necessity for any further progress to be made. Once serial communication has been successfully established, other useful statistics can be read from the ADE's registers, including temperature, reactive power, and power waveforms.

3.4.0 Interface LCD (LCD-JHD162A) with PIC16F877A

This project utilize a 2-line LCD display as in Figure 3.7 that will receive data input from the PIC and provide on the fly information of data collected that includes average current, voltage, power values, and information about the overall status of devices including possibly a warning when any of the inputs exceed safe limits .To use the LCD display, user have to solder 16 pin header pin to the LCD display. LCD-JHD162A is a 2X16 character LCD. LCD connection pin and function of each pin is shown in Table 3.3 below:

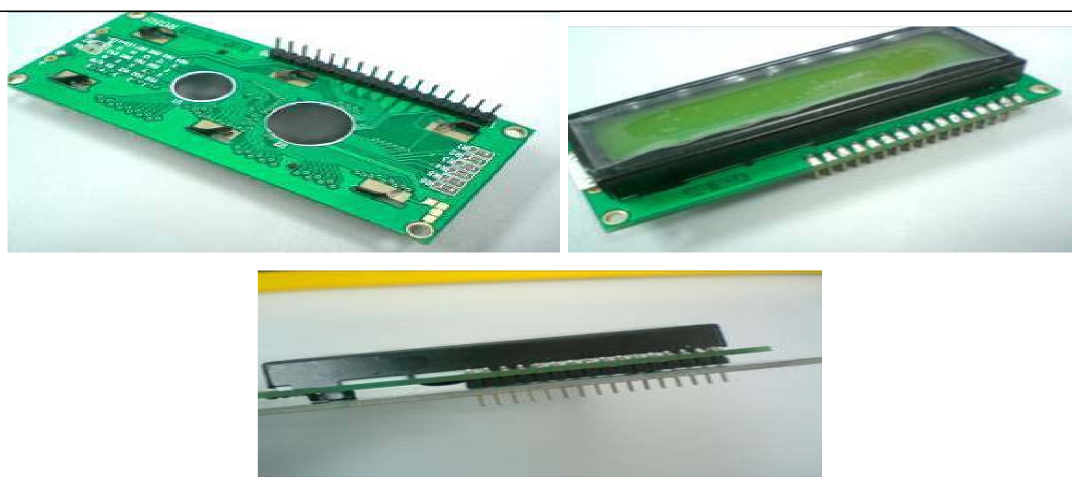

Figure 3.7: LCD-JHD162A

Table 3.3: LCD connection pin configuration and function of each pin

Pin	Name	Pin function	Connection
1	VSS	Ground	GND
2	VCC	Positive supply for LCD	5V
3	VEE	Brightness adjust	Connected to a preset to adjust brightness
4	RS	Select register, select instruction or data register	RB7
5	R/W	Select read or write	GND
6	E	Start data read or write	RB6
7	DB0	Data bus pin	RD0
8	DB1	Data bus pin	RD1
9	DB2	Data bus pin	RD2
10	DB3	Data bus pin	RD3
11	DB4	Data bus pin	RD4
12	DB5	Data bus pin	RD5
13	DB6	Data bus pin	RD6
14	DB7	Data bus pin	RD7
15	LED+	Backlight positive input	5V
16	LED-	Backlight negative input	RA2 control Transistor

3.4.1 Simulation with ISIS

ISIS provides the development environment for PROTEUS VSM, revolutionary interactive system level simulator. This product combines mixed mode circuit simulation, micro-processor models and interactive component models to allow the simulation of complete micro-controller based designs. ISIS provides the means to enter the design in the first place, the architecture for real time interactive simulation and a system for managing the source and object code associated with each project. In addition, a number of graph objects can be placed on the schematic to enable conventional time, frequency and swept variable simulation to be performed.

3.4.1.1 Using ISIS

Blue rectangular is the working area. This area can be changed by using *System / Set Sheet Sizes Menu*.Devices are need to load which can be used in project into *Devices* area seen in Figure 3.8.and Figure 3.9 To select devices, you should use *P* button or *Library/Pick Device/Symbol Menu.*

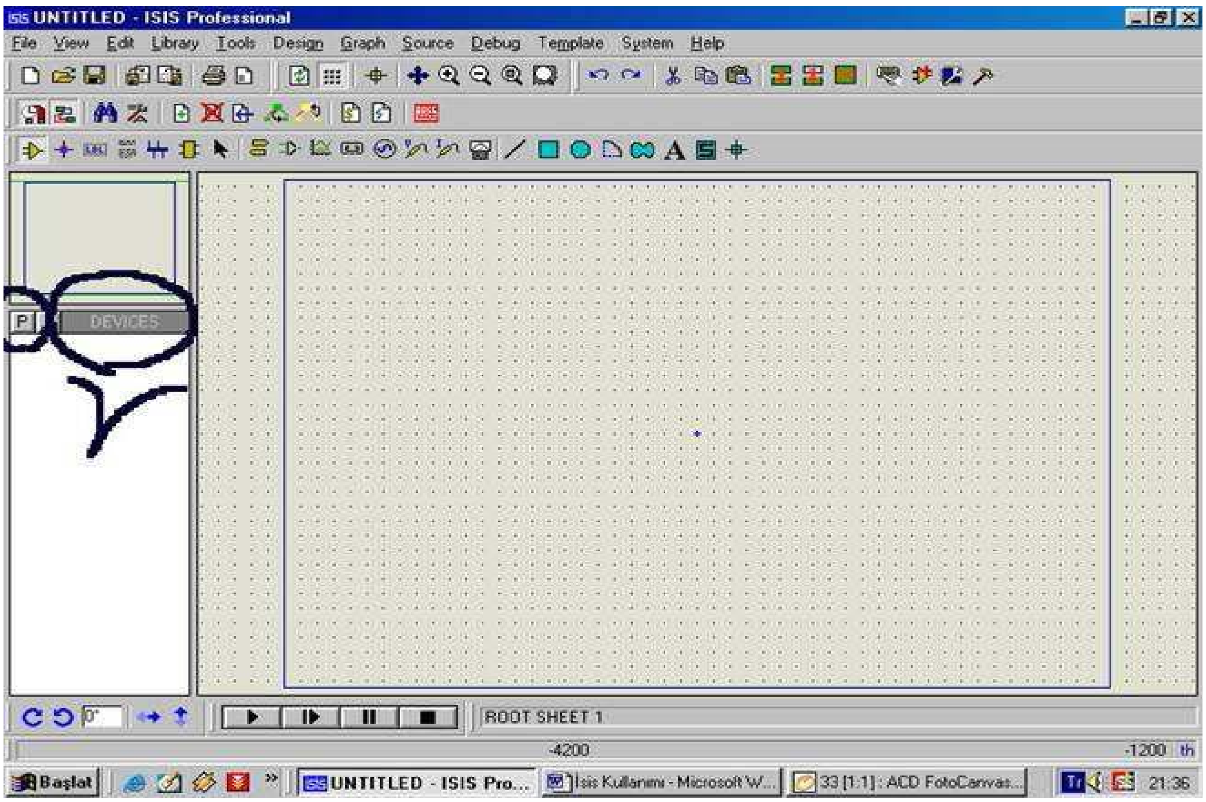

Figure 3.8: ISIS Main Menu

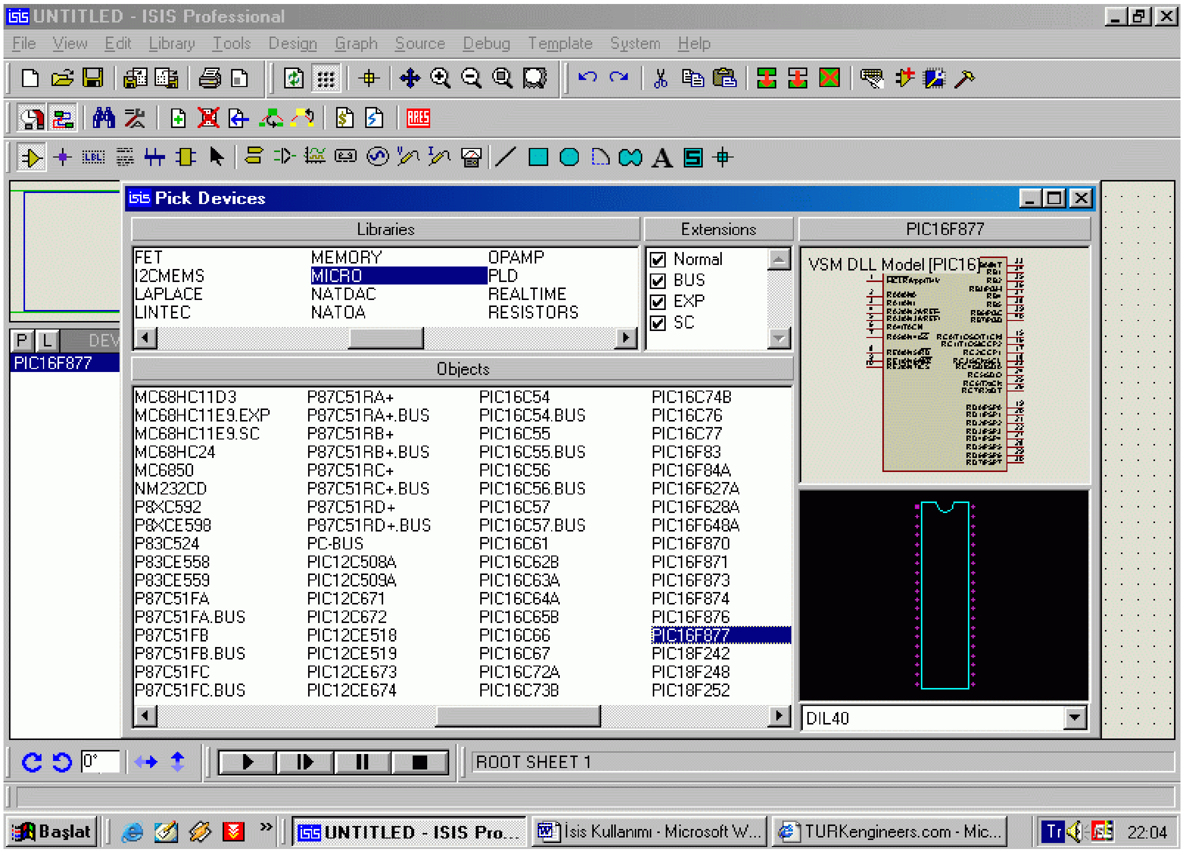

Figure 3.9: Pick Devices

Also, for this simulation also have to use Ground, Supply, and Label etc. These are found by clicking *Inter Sheet Terminal Button* seen in Figure 3.10.

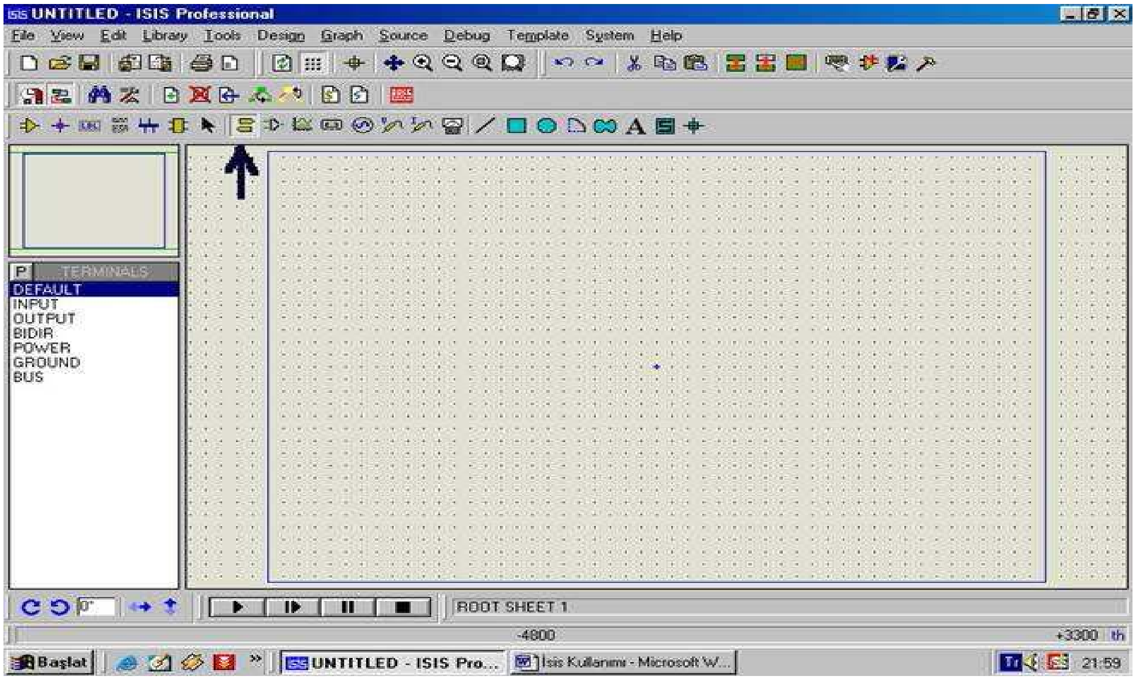

Figure 3.10: Terminals

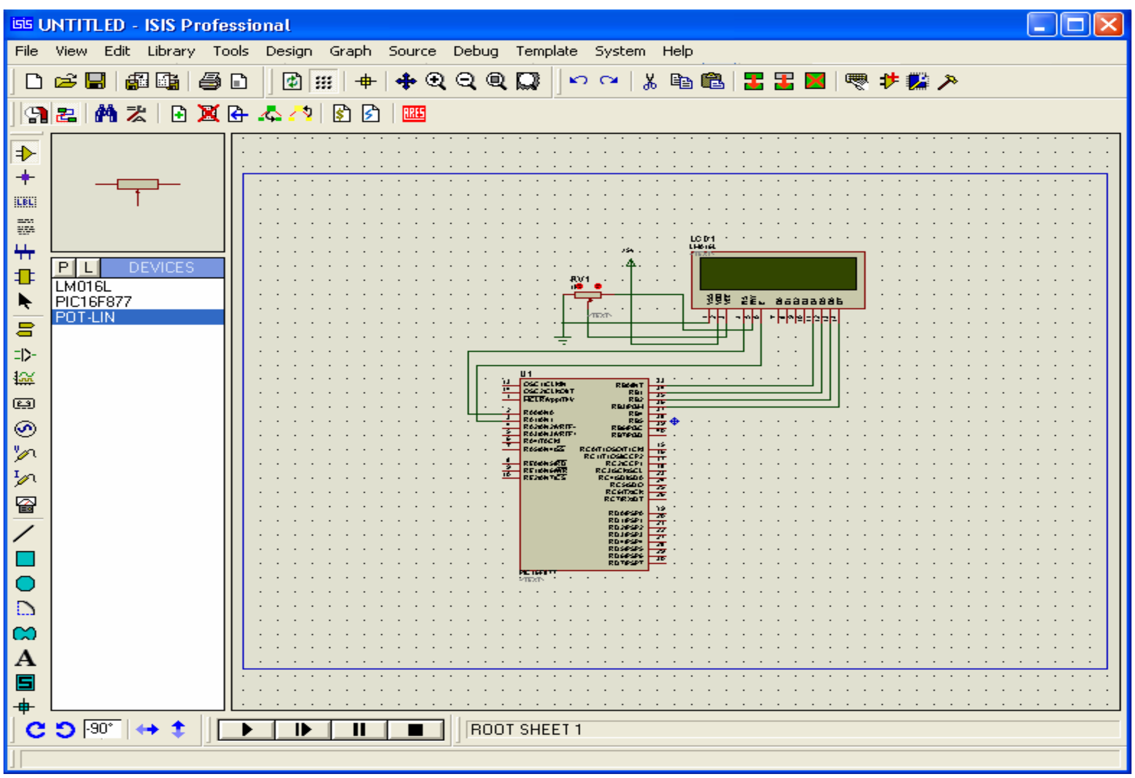

Figure 3.11: Example Circuit

There is no need to connect XTAL and MCLR pins. ISIS works regularly without these connections. Then, load hex file to PIC. For this, right click on the PIC then we will see that PIC becomes red color. Then left click on the PIC again. At this point, we see *Edit Component* window seen in Figure 3.11.At this window, we define Microprocessor's Clock Frequency and hex file destination. Then click okay button to exit the window. Finally, click the *play* button which is located in the left-bottom place to work your simulation. Working system is seen in Figure 3.12.

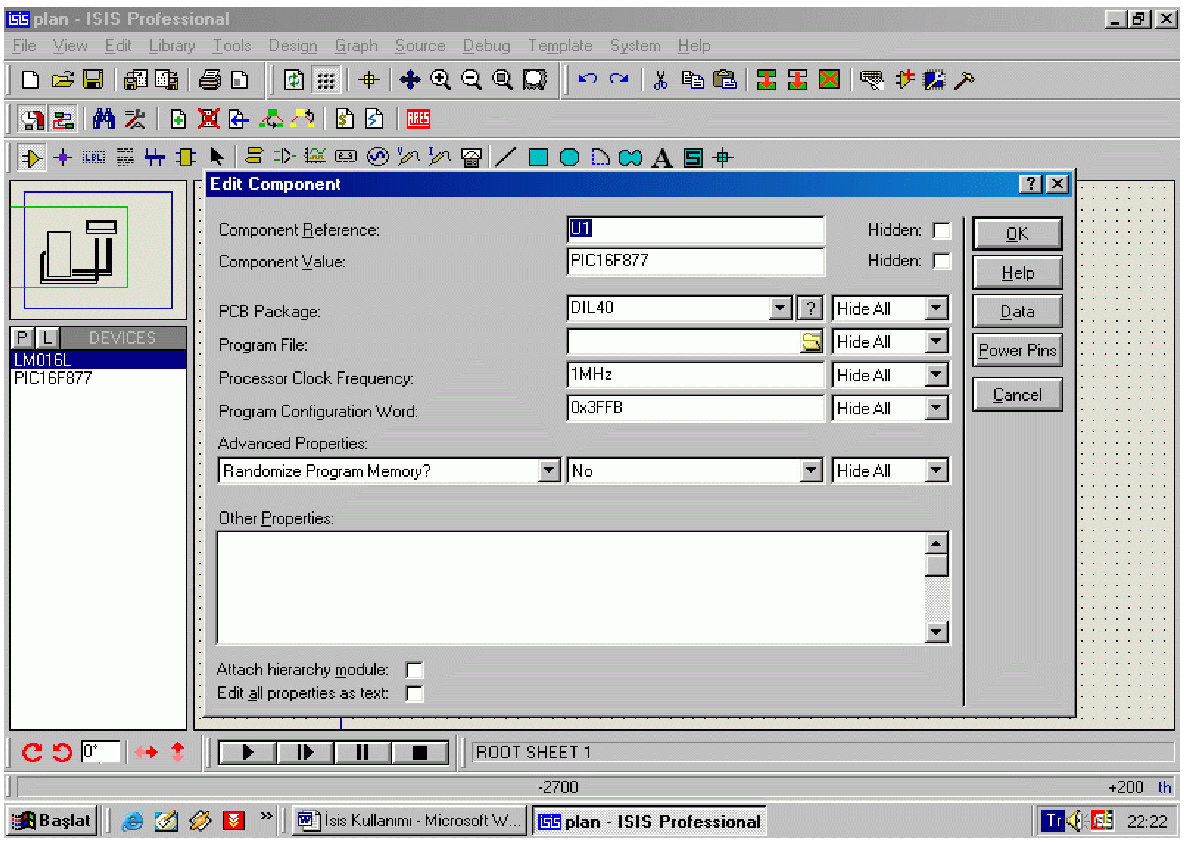

Figure 3.12: Edit Component

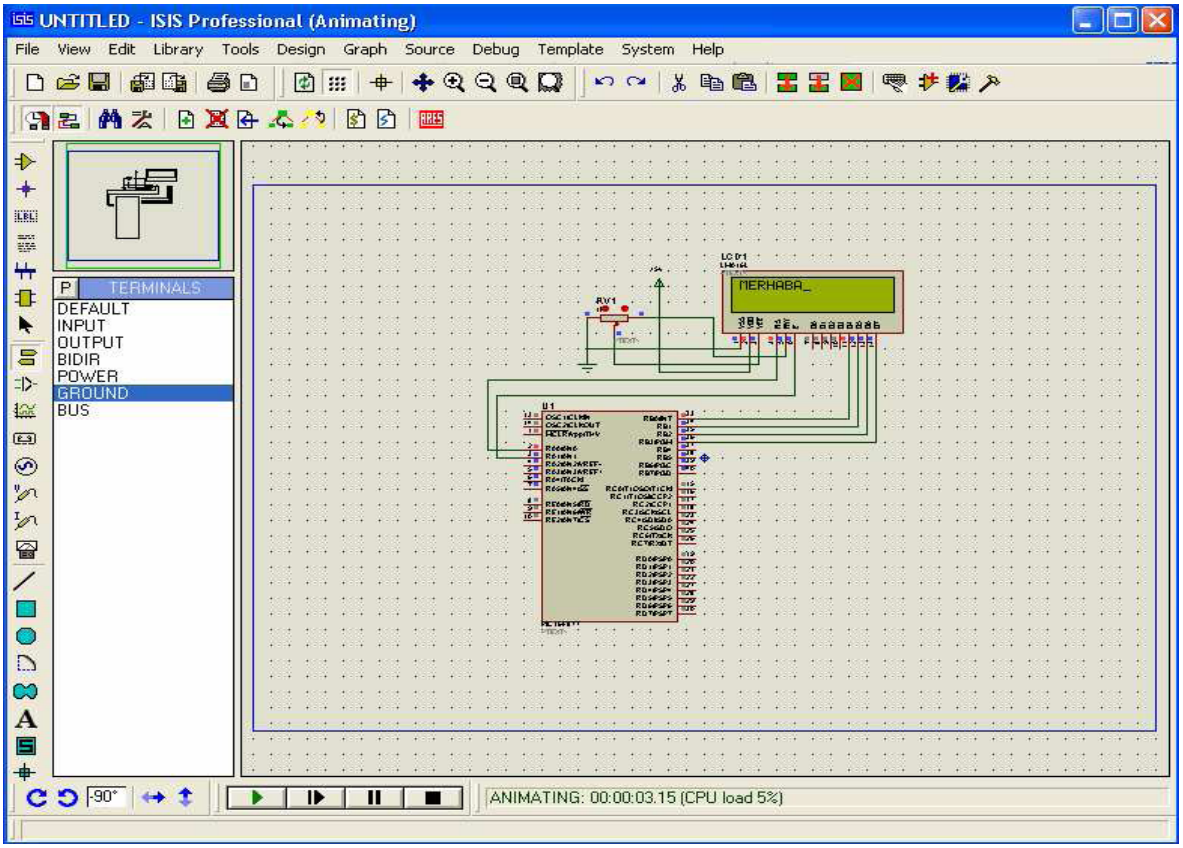

Figure 3.13: Working Simulation

3.4.2 PIC Microcontroller Tools Development

All microcontrollers require a program or software for their operation. This program is developed and tested by the programmer. The following software tools are normally required in a PIC microcontroller-based project development cycle.

- PicBasic Pro compilers (pbp)
- Window interface software
- Programming Adapters and melabs U2 pic programmer

We shall look at each of these tools in detail now.

3.4.2.1 Picbasic pro compiler (pbp)

PICBASIC PRO™ Compiler is the easiest way to program the fast and powerful Microchip Technology PICmicro microcontrollers (PIC16F877A). PICBASIC PRO converts BASIC programs into files that can be programmed directly into a PICmicro MCU. The BASIC language is much easier to read and write than the quirky Microchip assembly language. PBP compiler produces code that may be programmed into a wide variety of PICmicro microcontroller having from 8 up to 84 pins and various on-chip features including A/D converters hardware timers and serial ports. The PIC16F877A use Harvard technology to allow rapid erasing and reprogramming for program debugging. The PIC16F877A devices also contain between 64 and 1024 bytes of non-volatile data memory that can be used to store program and data and other parameters even when the power is turned off.

3.4.2.2 Window interface software

MicroCode Studio is actually Integrated Development Environment (IDE) with In Circuit Debugging (ICD) capability designed specifically for PICBASIC PRO compiler. This software is easy to set up and capable to identify, correct the compilation and assembler an error. The controller algorithm programming writes in MicroCode Studio. See Figure 3.14.

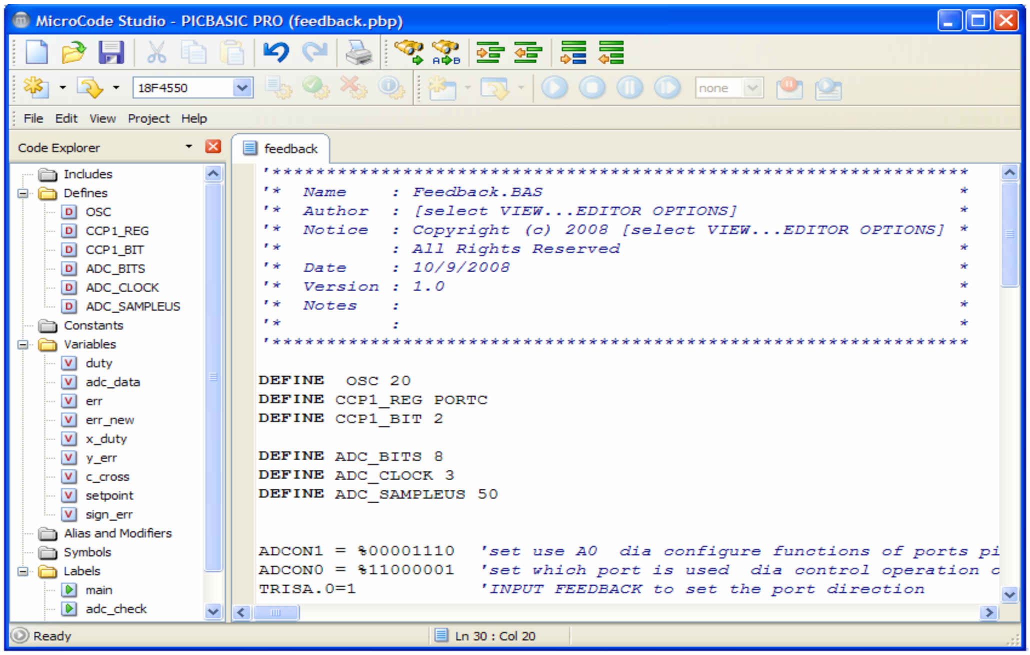

Figure 3.14: MicroCode Studio screenshots

3.4.2.3 Programming Adapters and melabs U2 pic programmer

The melabs U2 PIC Programmer is driven and powered from a single USB port on computer. Then adapters connect to the programmer's 40-pin expansion header to allow programming of PIC microcontrollers in DIP, PLCC or surface mount packages. See Figure 3.14 for programming adapters.

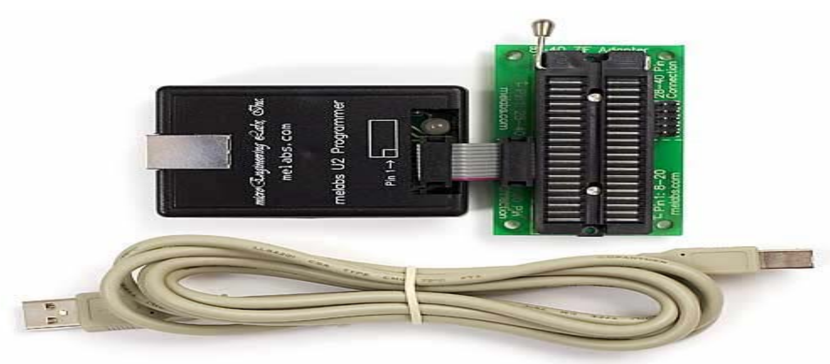

Figure 3.15: Melabs U2 PIC programmer (black chasing) and programming adapter.

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CHAPTER 4

4.1 Conclusion

This report described the design and implementation of the computer system Energy Management System. A plug was devised to measure and control the power consumed by single phase appliances. The LCD provides one or more users to monitor and control their household power consumption.
Accomplishments of the project include

• Design and implementation of the Power Source and Limiting Circuits

• Design and implementation of the Plug

• Design of the Monitor circuit using LCD.

• Design and partial implementation of the ADE – PIC Serial Interface

The power measuring circuit works as intended and allows the ADE 7753 to calculate active energy readings from the plug. The limiting circuit successfully limits power consumption by using the value of potentiometer that sample from ADC. These appliance are integrated into the Plug, which is fully functional. The ADE – PIC serial interface is fully designed. Implementation proved problematic due to unforeseen difficulties sending the signal from the PIC to the ADE. However, the code on the PIC executes properly and the outstanding issue is a hardware problem.

Although the project does not completely meet the proposed requirements, it was a good introduction into project management and the design process. The design work that was done could be used as a basis for future achievements in power conservation.

4.2 Recommendation

- The system can be improved by interfacing personal computer (PC) with internet, short message system (sms) using handphone and etc.
- Function of switching by using wireless control system
- The system can develop for commercialize by using Printed Circuit Board (PCB) to replace the wrapping technique.

4.3 Cost and Commercialization

The total coast in developing this project could be referred in the appendix D. The estimate coast for overall components in this project was due to analysis in Energy Management System project where about RM285.50. This system develops in constrained by a loose price requirement. The most difficult component to be found is analog devices,ADE7753 since it was not widely used and this IC available in type of surface mounted device (SMD).In develop this circuit, PCB are used and a soldering tool for this type IC is needed.

The potential of this project to be commercial is quite high since homeowner may find the solution in order to reduce the energy usage of each appliance that used in daily life. This could be verified when certain industries already develop this system in more advantages to attract the homeowner to buy that product. This system also not limited used for home usage but also can applied in industry.

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APPENDIX A

Datasheet of PIC16F877A

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

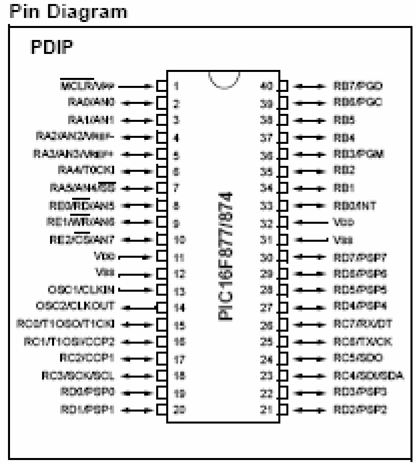
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram

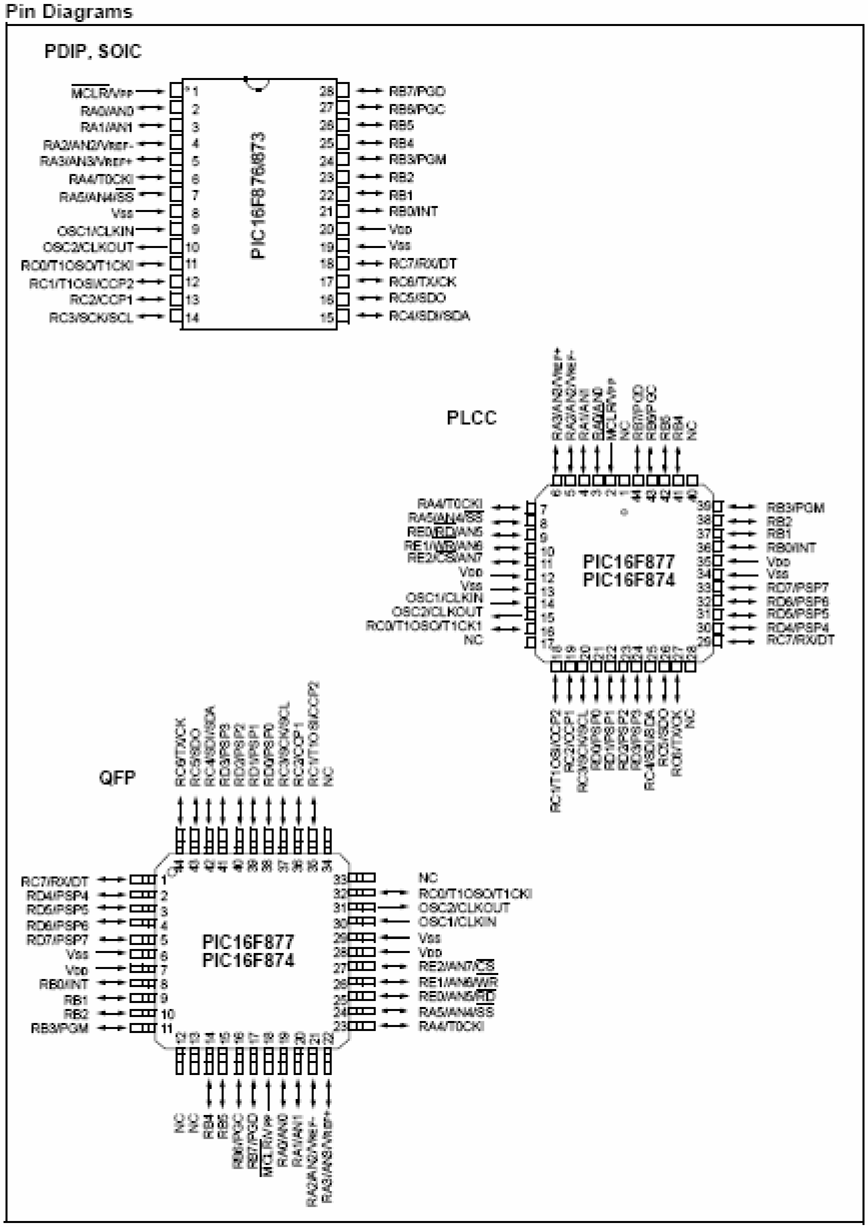


Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

PIC16F87X

Pin Diagrams



APPENDIX A

Datasheet of ADE7753

ANALOG DEVICES

Single-Phase Multifunction Metering IC with di/dt Sensor Interface

ADE7753

FEATURES

- High accuracy; supports IEC 60687/61036/61268 and IEC 62053-21/62053-22/62053-23
- On-chip digital integrator enables direct interface to current sensors with di/dt output
- Active, reactive, and apparent energy; sampled waveform; current and voltage rms
- Less than 0.1% error in active energy measurement over a dynamic range of 1000 to 1 at 25°C
- Positive-only energy accumulation mode available
- On-chip user programmable threshold for line voltage surge and SAG and PSU supervisory
- Digital calibration for power, phase, and input offset
- On-chip temperature sensor (±3°C typical)
- SPI* compatible serial interface
- Pulse output with programmable frequency
- Interrupt request pin (IRQ) and status register
- Reference 2.4 V with external overdrive capability
- Single 5 V supply, low power (25 mW typical)

GENERAL DESCRIPTION

The ADE7753 features proprietary ADCs and DSP for high accuracy over large variations in environmental conditions and time. The ADE7753 incorporates two second-order 16-bit Σ-Δ ADCs, a digital integrator (on CH1), reference circuitry, temperature sensor, and all the signal processing required to perform active, reactive, and apparent energy measurements, line-voltage period measurement, and rms calculation on the voltage and current. The selectable on-chip digital integrator provides direct interface to di/dt current sensors such as Rogowski coils, eliminating the need for an external analog integrator and resulting in excellent long-term stability and precise phase matching between the current and voltage channels.

The ADE7753 provides a serial interface to read data, and a pulse output frequency (CF), which is proportional to the active power. Various system calibration features, i.e., channel offset correction, phase calibration, and power calibration, ensure high accuracy. The part also detects short duration low or high voltage variations.

The positive-only accumulation mode gives the option to accumulate energy only when positive power is detected. An internal no-load threshold ensures that the part does not exhibit any creep when there is no load. The zero-crossing output (ZX) produces a pulse that is synchronized to the zero-crossing point of the line voltage. This signal is used internally in the line cycle active and apparent energy accumulation modes, which enables faster calibration.

The interrupt status register indicates the nature of the interrupt, and the interrupt enable register controls which event produces an output on the IRQ pin, an open-drain, active low logic output.

The ADE7753 is available in a 20-lead SSOP package.

FUNCTIONAL BLOCK DIAGRAM

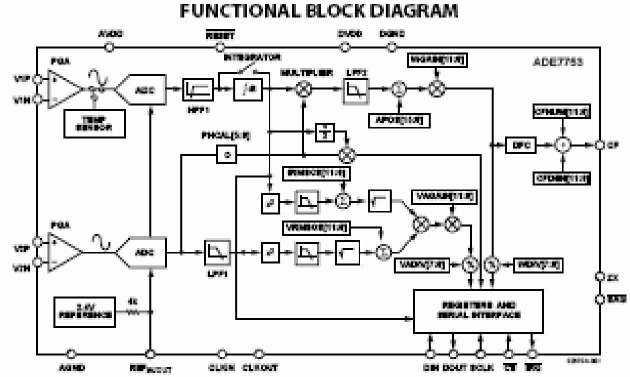


Figure 1.

*U.S. Patents 5,745,323; 5,760,617; 5,862,069; 5,872,469; others pending.

Rev. A

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SPECIFICATIONS

$AV_{DD} = DV_{DD} = 5\ V \pm 5\%$, AGND = DGND = 0 V, on-chip reference, CLKIN = 3.579545 MHz XTAL, T_{MIN} to T_{MAX} = −40°C to +85°C.

Table 1.

Parameter[1]	Spec	Unit	Test Conditions/Comments
ENERGY MEASUREMENT ACCURACY			
Active Power Measurement Error			CLKIN = 3.579545 MHz
Channel 1 Range = 0.5 V Full Scale			Channel 2 = 300 mV rms/60 Hz, gain = 2
Gain = 1	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 2	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 4	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 8	0.1	% typ	Over a dynamic range 1000 to 1
Channel 1 Range = 0.25 V Full Scale			
Gain = 1	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 2	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 4	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 8	0.2	% typ	Over a dynamic range 1000 to 1
Channel 1 Range = 0.125 V Full Scale			
Gain = 1	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 2	0.1	% typ	Over a dynamic range 1000 to 1
Gain = 4	0.2	% typ	Over a dynamic range 1000 to 1
Gain = 8	0.2	% typ	Over a dynamic range 1000 to 1
Active Power Measurement Bandwidth	14	kHz	
Phase Error 1 between Channels[2]	±0.05	max	Line Frequency = 45 Hz to 65 Hz, HPF on
AC Power Supply Rejection[2]			$AV_{DD} = DV_{DD}$ = 5 V + 175 mV rms/120 Hz
Output Frequency Variation (CF)	0.2	% typ	Channel 1 = 20 mV rms, gain = 16, range = 0.5 V
			Channel 2 = 300 mV rms/60 Hz, gain = 1
DC Power Supply Rejection[2]			$AV_{DD} = DV_{DD}$ = 5 V ± 250 mV dc
Output Frequency Variation (CF)	±0.3	% typ	Channel 1 = 20 mV rms/60 Hz, gain = 16, range = 0.5 V
			Channel 2 = 300 mV rms/60 Hz, gain = 1
IRMS Measurement Error	0.5	% typ	Over a dynamic range 100 to 1
IRMS Measurement Bandwidth	14	kHz	
VRMS Measurement Error	0.5	% typ	Over a dynamic range 20 to 1
VRMS Measurement Bandwidth	140	Hz	
ANALOG INPUTS[3]			See the Analog Inputs section
Maximum Signal Levels	±0.5	V max	V1P, V1N, V2N, and V2P to AGND
Input Impedance (dc)	390	k min	
Bandwidth	14	kHz	CLKIN/256, CLKIN = 3.579545 MHz
Gain Error[2,3]			External 2.5 V reference, gain = 1 on Channels 1 and 2
Channel 1			
Range = 0.5 V Full Scale	±4	% typ	V1 = 0.5 V dc
Range = 0.25 V Full Scale	±4	% typ	V1 = 0.25 V dc
Range = 0.125 V Full Scale	±4	% typ	V1 = 0.125 V dc
Channel 2	±4	% typ	V2 = 0.5 V dc
Offset Error[2]	±32	mV max	Gain 1
Channel 1	±13	mV max	Gain 16
	±32	mV max	Gain 1
Channel 2	±13	mV max	Gain 16
WAVEFORM SAMPLING			Sampling CLKIN/128, 3.579545 MHz/128 = 27.9 kSPS
Channel 1			See the Channel 1 Sampling section
Signal-to-Noise Plus Distortion	62	dB typ	150 mV rms/60 Hz, range = 0.5 V, gain = 2
Bandwidth (−3 dB)	14	kHz	CLKIN = 3.579545 MHz

Footnotes on next page.

Parameter	Spec	Unit	Test Conditions/Comments
Channel 2			See the Channel 2 Sampling section
Signal-to-Noise Plus Distortion	60	dB typ	150 mV rms/60 Hz, gain = 2
Bandwidth (–3 dB)	140	Hz	CLKIN = 3.579545 MHz
REFERENCE INPUT			
$REF_{IN/OUT}$ Input Voltage Range	2.6	V max	2.4 V + 8%
	2.2	V min	2.4 V – 8%
Input Capacitance	10	pF max	
ON-CHIP REFERENCE			Nominal 2.4 V at $REF_{IN/OUT}$ pin
Reference Error	±200	mV max	
Current Source	10	μA max	
Output Impedance	3.4	kΩ min	
Temperature Coefficient	30	ppm/°C typ	
CLKIN			All specifications CLKIN of 3.579545 MHz
Input Clock Frequency	4	MHz max	
	1	MHz min	
LOGIC INPUTS			
$\overline{RESET}$, DIN, SCLK, CLKIN, and $\overline{CS}$			
Input High Voltage, V_{INH}	2.4	V min	DV_{DD} = 5 V ± 10%
Input Low Voltage, V_{INL}	0.8	V max	DV_{DD} = 5 V ± 10%
Input Current, I_{IN}	±3	μA max	Typically 10 nA, V_{IN} = 0 V to DV_{DD}
Input Capacitance, C_{IN}	10	pF max	
LOGIC OUTPUTS			
$\overline{SAG}$ and $\overline{IRQ}$			Open-drain outputs, 10 kΩ pull-up resistor
Output High Voltage, V_{OH}	4	V min	I_{SOURCE} = 5 mA
Output Low Voltage, V_{OL}	0.4	V max	I_{SINK} = 0.8 mA
ZX and DOUT			
Output High Voltage, V_{OH}	4	V min	I_{SOURCE} = 5 mA
Output Low Voltage, V_{OL}	0.4	V max	I_{SINK} = 0.8 mA
CF			
Output High Voltage, V_{OH}	4	V min	I_{SOURCE} = 5 mA
Output Low Voltage, V_{OL}	1	V max	I_{SINK} = 7 mA
POWER SUPPLY			For specified performance
AVDD	4.75	V min	5 V – 5%
	5.25	V max	5 V + 5%
DVDD	4.75	V min	5 V – 5%
	5.25	V max	5 V + 5%
AI_{DD}	3	mA max	Typically 2.0 mA
DI_{DD}	4	mA max	Typically 3.0 mA

[1] See the plots in the Typical Performance Characteristics section.
[2] See the Terminology section for explanation of specifications.
[3] See the Analog Inputs section.

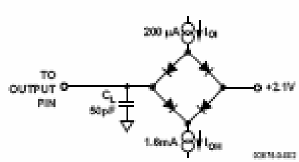


Figure 2. Load Circuit for Timing Specifications

TIMING CHARACTERISTICS

$AV_{DD} = DV_{DD} = 5$ V ± 5%, AGND = DGND = 0 V, on-chip reference, CLKIN = 3.579545 MHz XTAL, T_{MIN} to $T_{MAX} = -40°C$ to +85°C.

Table 2.

Parameter[1, 2]	Spec	Unit	Test Conditions/Comments
Write Timing			
t_1	50	ns (min)	$\overline{CS}$ falling edge to first SCLK falling edge.
t_2	50	ns (min)	SCLK logic high pulse width.
t_3	50	ns (min)	SCLK logic low pulse width.
t_4	10	ns (min)	Valid data setup time before falling edge of SCLK.
t_5	5	ns (min)	Data hold time after SCLK falling edge.
t_6	400	ns (min)	Minimum time between the end of data byte transfers.
t_7	50	ns (min)	Minimum time between byte transfers during a serial write.
t_8	100	ns (min)	$\overline{CS}$ hold time after SCLK falling edge.
Read Timing			
t_9[3]	4	μs (min)	Minimum time between read command (i.e., a write to communication register) and data read.
t_{10}	50	ns (min)	Minimum time between data byte transfers during a multibyte read.
t_{11}	30	ns (min)	Data access time after SCLK rising edge following a write to the communications register.
t_{12}[4]	100	ns (max)	Bus relinquish time after falling edge of SCLK.
	10	ns (min)	
t_{12}[5]	100	ns (max)	Bus relinquish time after rising edge of $\overline{CS}$.
	10	ns (min)	

[1] Sample tested during initial release and after any redesign or process change that could affect this parameter. All input signals are specified with tr = tf = 5 ns (10% to 90%) and timed from a voltage level of 1.6 V.
[2] See Figure 3, Figure 4, and the ADE7753 Serial Interface section.
[3] Minimum time between read command and data read for all registers except waveform register, which is t_9 = 500 ns min.
[4] Measured with the load circuit in Figure 2 and defined as the time required for the output to cross 0.8 V or 2.4 V.
[5] Derived from the measured time taken by the data outputs to change 0.5 V when loaded with the circuit in Figure 2. The measured number is then extrapolated back to remove the effects of charging or discharging the 50 pF capacitor. This means that the time quoted in the timing characteristics is the true bus relinquish time of the part and is independent of the bus loading.

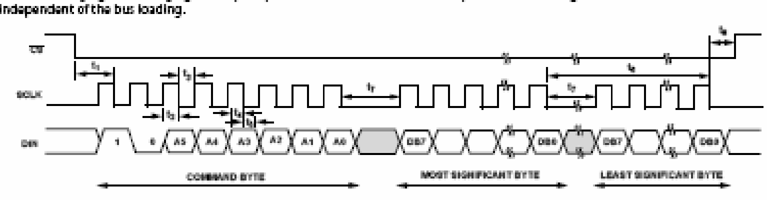


Figure 3. Serial Write Timing

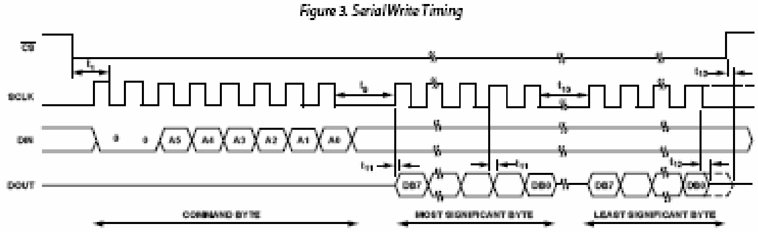


Figure 4. Serial Read Timing

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C, unless otherwise noted.

Table 3.

Parameter	Rating
AVDD to AGND	−0.3 V to +7 V
DVDD to DGND	−0.3 V to +7 V
DVDD to AVDD	−0.3 V to +0.3 V
Analog Input Voltage to AGND V1P, V1N, V2P, and V2N	−6 V to +6 V
Reference Input Voltage to AGND	−0.3 V to AVDD + 0.3 V
Digital Input Voltage to DGND	−0.3 V to DVDD + 0.3 V
Digital Output Voltage to DGND	−0.3 V to DVDD + 0.3 V
Operating Temperature Range	
Industrial	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Junction Temperature	150°C
20-Lead SSOP, Power Dissipation	450 mW
θ_{JA} Thermal Impedance	112°C/W
Lead Temperature, Soldering	
Vapor Phase (60 sec)	215°C
Infrared (15 sec)	220°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

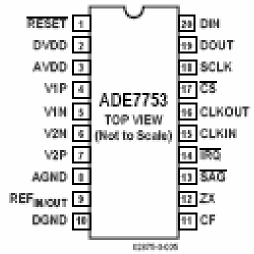


Figure 5. Pin Configuration (SSOP Package)

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	RESET	Reset Pin for the ADE7753. A logic low on this pin holds the ADCs and digital circuitry (including the serial interface) in a reset condition.
2	DVDD	Digital Power Supply. This pin provides the supply voltage for the digital circuitry in the ADE7753. The supply voltage should be maintained at 5 V ± 5% for specified operation. This pin should be decoupled to DGND with a 10 µF capacitor in parallel with a ceramic 100 nF capacitor.
3	AVDD	Analog Power Supply. This pin provides the supply voltage for the analog circuitry in the ADE7753. The supply should be maintained at 5 V ± 5% for specified operation. Every effort should be made to minimize power supply ripple and noise at this pin by the use of proper decoupling. The typical performance graphs show the power supply rejection performance. This pin should be decoupled to AGND with a 10 µF capacitor in parallel with a ceramic 100 nF capacitor.
4, 5	V1P, V1N	Analog Inputs for Channel 1. This channel is intended for use with a di/dt current transducer such as a Rogowski coil or another current sensor such as a shunt or current transformer (CT). These inputs are fully differential voltage inputs with maximum differential input signal levels of ±0.5 V, ±0.25 V, and ±0.125 V, depending on the full-scale selection—see the Analog Inputs section. Channel 1 also has a PGA with gain selections of 1, 2, 4, 8, or 16. The maximum signal level at these pins with respect to AGND is ±0.5 V. Both inputs have internal ESD protection circuitry, and, in addition, an overvoltage of ±6 V can be sustained on these inputs without risk of permanent damage.
6, 7	V2N, V2P	Analog Inputs for Channel 2. This channel is intended for use with the voltage transducer. These inputs are fully differential voltage inputs with a maximum differential signal level of ±0.5 V. Channel 2 also has a PGA with gain selections of 1, 2, 4, 8, or 16. The maximum signal level at these pins with respect to AGND is ±0.5 V. Both inputs have internal ESD protection circuitry, and an overvoltage of ±6 V can be sustained on these inputs without risk of permanent damage.
8	AGND	Analog Ground Reference. This pin provides the ground reference for the analog circuitry in the ADE7753, i.e., ADCs and reference. This pin should be tied to the analog ground plane or the quietest ground reference in the system. This quiet ground reference should be used for all analog circuitry, for example, anti-aliasing filters, current and voltage transducers, etc. To keep ground noise around the ADE7753 to a minimum, the quiet ground plane should connected to the digital ground plane at only one point. It is acceptable to place the entire device on the analog ground plane.
9	$REF_{IN/OUT}$	Access to the On-Chip Voltage Reference. The on-chip reference has a nominal value of 2.4 V ± 8% and a typical temperature coefficient of 30 ppm/°C. An external reference source can also be connected at this pin. In either case, this pin should be decoupled to AGND with a 1 µF ceramic capacitor.
10	DGND	Digital Ground Reference. This pin provides the ground reference for the digital circuitry in the ADE7753, i.e., multiplier, filters, and digital-to-frequency converter. Because the digital return currents in the ADE7753 are small, it is acceptable to connect this pin to the analog ground plane of the system. However, high bus capacitance on the DOUT pin could result in noisy digital current, which could affect performance.
11	CF	Calibration Frequency Logic Output. The CF logic output gives active power information. This output is intended to be used for operational and calibration purposes. The full-scale output frequency can be adjusted by writing to the CFDEN and CFNUM registers—see the Energy-to-Frequency Conversion section.

Pin No.	Mnemonic	Description
12	ZX	Voltage Waveform (Channel 2) Zero-Crossing Output. This output toggles logic high and logic low at the zero crossing of the differential signal on Channel 2—see the Zero-Crossing Detection section.
13	$\overline{SAG}$	This open-drain logic output goes active low when either no zero crossings are detected or a low voltage threshold (Channel 2) is crossed for a specified duration—see the Line Voltage Sag Detection section.
14	$\overline{IRQ}$	Interrupt Request Output. This is an active low open-drain logic output. Maskable interrupts include active energy register rollover, active energy register at half level, and arrivals of new waveform samples—see the ADE7753 Interrupts section.
15	CLKIN	Master Clock for ADCs and Digital Signal Processing. An external clock can be provided at this logic input. Alternatively, a parallel resonant AT crystal can be connected across CLKIN and CLKOUT to provide a clock source for the ADE7753. The clock frequency for specified operation is 3.579545 MHz. Ceramic load capacitors of between 22 pF and 33 pF should be used with the gate oscillator circuit. Refer to the crystal manufacturer's data sheet for load capacitance requirements.
16	CLKOUT	A crystal can be connected across this pin and CLKIN as described for Pin 15 to provide a clock source for the ADE7753. The CLKOUT pin can drive one CMOS load when either an external clock is supplied at CLKIN or a crystal is being used.
17	$\overline{CS}$	Chip Select. Part of the 4-wire SPI serial interface. This active low logic input allows the ADE7753 to share the serial bus with several other devices—see the ADE7753 Serial Interface section.
18	SCLK	Serial Clock Input for the Synchronous Serial Interface. All serial data transfers are synchronized to this clock—see the ADE7753 Serial Interface section. The SCLK has a Schmitt-trigger input for use with a clock source that has a slow edge transition time, for example, opto-isolator output.
19	DOUT	Data Output for the Serial Interface. Data is shifted out at this pin on the rising edge of SCLK. This logic output is normally in a high impedance state unless it is driving data onto the serial data bus—see the ADE7753 Serial Interface section.
20	DIN	Data Input for the Serial Interface. Data is shifted in at this pin on the falling edge of SCLK—see the ADE7753 Serial Interface section.

ADE7753 SERIAL INTERFACE

All ADE7753 functionality is accessible via several on-chip registers—see Figure 89. The contents of these registers can be updated or read using the on-chip serial interface. After power-on or toggling the $\overline{\text{RESET}}$ pin low or a falling edge on $\overline{\text{CS}}$, the ADE7753 is placed in communications mode. In communications mode, the ADE7753 expects a write to its communications register. The data written to the communications register determines whether the next data transfer operation is a read or a write and also which register is accessed. Therefore all data transfer operations with the ADE7753, whether a read or a write, must begin with a write to the communications register.

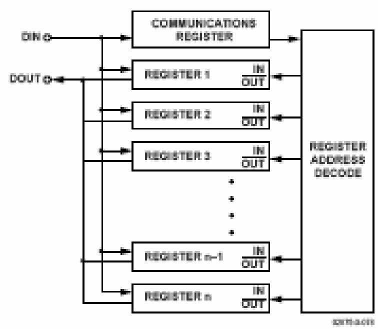


Figure 89. Addressing ADE7753 Registers via the Communications Register

The communications register is an 8-bit wide register. The MSB determines whether the next data transfer operation is a read or a write. The six LSBs contain the address of the register to be accessed—see the Communications Register section for a more detailed description.

Figure 90 and Figure 91 show the data transfer sequences for a read and write operation, respectively. On completion of a data transfer (read or write), the ADE7753 once again enters communications mode. A data transfer is complete when the LSB of the ADE7753 register being addressed (for a write or a read) is transferred to or from the ADE7753.

Figure 90. Reading Data from the ADE7753 via the Serial Interface

Figure 91. Writing Data to the ADE7753 via the Serial Interface

The serial interface of the ADE7753 is made up of four signals: SCLK, DIN, DOUT, and $\overline{\text{CS}}$. The serial clock for a data transfer is applied at the SCLK logic input. This logic input has a Schmitt-trigger input structure that allows slow rising (and falling) clock edges to be used. All data transfer operations are synchronized to the serial clock. Data is shifted into the ADE7753 at the DIN logic input on the falling edge of SCLK. Data is shifted out of the ADE7753 at the DOUT logic output on a rising edge of SCLK. The $\overline{\text{CS}}$ logic input is the chip-select input. This input is used when multiple devices share the serial bus. A falling edge on $\overline{\text{CS}}$ also resets the serial interface and places the ADE7753 into communications mode. The $\overline{\text{CS}}$ input should be driven low for the entire data transfer operation. Bringing $\overline{\text{CS}}$ high during a data transfer operation aborts the transfer and places the serial bus in a high impedance state. The $\overline{\text{CS}}$ logic input can be tied low if the ADE7753 is the only device on the serial bus. However, with $\overline{\text{CS}}$ tied low, all initiated data transfer operations must be fully completed, i.e., the LSB of each register must be transferred because there is no other way of bringing the ADE7753 back into communications mode without resetting the entire device by using $\overline{\text{RESET}}$.

ADE7753 Serial Write Operation

The serial write sequence takes place as follows. With the ADE7753 in communications mode (i.e., the $\overline{CS}$ input logic low), a write to the communications register first takes place. The MSB of this byte transfer is a 1, indicating that the data transfer operation is a write. The LSBs of this byte contain the address of the register to be written to. The ADE7753 starts shifting in the register data on the next falling edge of SCLK. All remaining bits of register data are shifted in on the falling edge of subsequent SCLK pulses—see Figure 92. As explained earlier, the data write is initiated by a write to the communications register followed by the data. During a data write operation to the ADE7753, data is transferred to all on-chip registers one byte at a time. After a byte is transferred into the serial port, there is a finite time before it is transferred to one of the ADE7753 on-chip registers. Although another byte transfer to the serial port can start while the previous byte is being transferred to an on-chip register, this second byte transfer should not finish until at least 4 μs after the end of the previous byte transfer. This functionality is expressed in the timing specification t_6—see Figure 92. If a write operation is aborted during a byte transfer ($\overline{CS}$ brought high), then that byte cannot be written to the destination register.

Destination registers can be up to 3 bytes wide—see the ADE7753 Register Description tables. Therefore the first byte shifted into the serial port at DIN is transferred to the MSB (most significant byte) of the destination register. If, for example, the addressed register is 12 bits wide, a 2-byte data transfer must take place. The data is always assumed to be right justified, therefore in this case, the four MSBs of the first byte would be ignored and the four LSBs of the first byte written to the ADE7753 would be the four MSBs of the 12-bit word. Figure 93 illustrates this example.

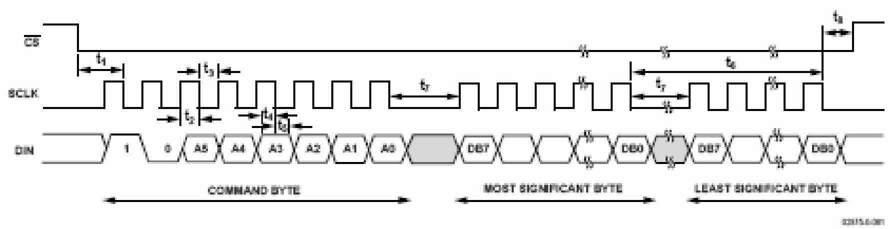


Figure 92. Serial Interface Write Timing

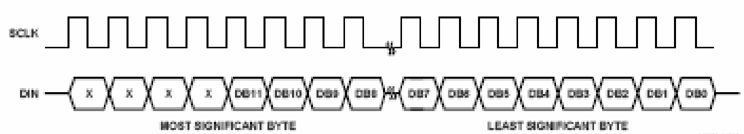


Figure 93. 12-Bit Serial Write Operation

ADE7753 Serial Read Operation

During a data read operation from the ADE7753, data is shifted out at the DOUT logic output on the rising edge of SCLK. As is the case with the data write operation, a data read must be preceded with a write to the communications register.

With the ADE7753 in communications mode (i.e., $\overline{CS}$ logic low), an 8-bit write to the communications register first takes place. The MSB of this byte transfer is a 0, indicating that the next data transfer operation is a read. The LSBs of this byte contain the address of the register that is to be read. The ADE7753 starts shifting out of the register data on the next rising edge of SCLK—see Figure 94. At this point, the DOUT logic output leaves its high impedance state and starts driving the data bus. All remaining bits of register data are shifted out on subsequent SCLK rising edges. The serial interface also enters communications mode again as soon as the read has been completed. At this point, the DOUT logic output enters a high impedance state on the falling edge of the last SCLK pulse. The read operation can be aborted by bringing the $\overline{CS}$ logic input high before the data transfer is complete. The DOUT output enters a high impedance state on the rising edge of $\overline{CS}$.

When an ADE7753 register is addressed for a read operation, the entire contents of that register are transferred to the serial port. This allows the ADE7753 to modify its on-chip registers without the risk of corrupting data during a multibyte transfer.

Note that when a read operation follows a write operation, the read command (i.e., write to communications register) should not happen for at least 4 µs after the end of the write operation. If the read command is sent within 4 µs of the write operation, the last byte of the write operation could be lost. This timing constraint is given as timing specification t_9.

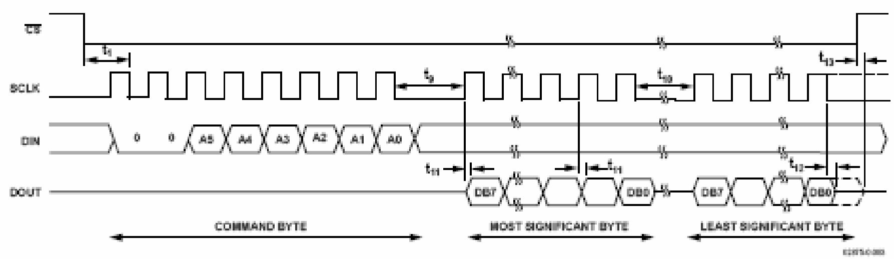


Figure 94. Serial Interface Read Timing

ADE7753 REGISTERS

Table 10. Summary of Registers by Address

Address	Name	R/W	No. Bits	Default	Type[1]	Description
0x01	WAVEFORM	R	24	0x0	S	Waveform Register. This read-only register contains the sampled waveform data from either Channel 1, Channel 2, or the active power signal. The data source and the length of the waveform registers are selected by data Bits 14 and 13 in the mode register—see the Channel 1 Sampling and Channel 2 Sampling sections.
0x02	AENERGY	R	24	0x0	S	Active Energy Register. Active power is accumulated (integrated) over time in this 24-bit, read-only register—see the Energy Calculation section.
0x03	RAENERGY	R	24	0x0	S	Same as the active energy register except that the register is reset to 0 following a read operation.
0x04	LAENERGY	R	24	0x0	S	Line Accumulation Active Energy Register. The instantaneous active power is accumulated in this read-only register over the LINCYC number of half line cycles.
0x05	VAENERGY	R	24	0x0	U	Apparent Energy Register. Apparent power is accumulated over time in this read-only register.
0x06	RVAENERGY	R	24	0x0	U	Same as the VAENERGY register except that the register is reset to 0 following a read operation.
0x07	LVAENERGY	R	24	0x0	U	Line Accumulation Apparent Energy Register. The instantaneous real power is accumulated in this read-only register over the LINECYC number of half line cycles.
0x08	LVARENERGY	R	24	0x0	S	Line Accumulation Reactive Energy Register. The instantaneous reactive power is accumulated in this read-only register over the LINECYC number of half line cycles.
0x09	MODE	R/W	16	0x000C	U	Mode Register. This is a 16-bit register through which most of the ADE7753 functionality is accessed. Signal sample rates, filter enabling, and calibration modes are selected by writing to this register. The contents can be read at any time—see the Mode Register (0x9) section.
0x0A	IRQEN	R/W	16	0x40	U	Interrupt Enable Register. ADE7753 interrupts can be deactivated at any time by setting the corresponding bit in this 16- bit enable register to Logic 0. The status register continues to register an interrupt event even if disabled. However, the $\overline{IRQ}$ output is not activated—see the ADE7753 Interrupts section.
0x0B	STATUS	R	16	0x0	U	Interrupt Status Register. This is an 16-bit read-only register. The status register contains information regarding the source of ADE7753 interrupts—the see ADE7753 Interrupts section.
0x0C	RSTSTATUS	R	16	0x0	U	Same as the interrupt status register except that the register contents are reset to 0 (all flags cleared) after a read operation.
0x0D	CH1OS	R/W	8	0x00	S*	Channel 1 Offset Adjust. Bit 6 is not used. Writing to Bits 0 to 5 allows offsets on Channel 1 to be removed—see the Analog Inputs and CH1OS Register (0x0D) sections. Writing a Logic 1 to the MSB of this register enables the digital integrator on Channel 1, a Logic 0 disables the integrator. The default value of this bit is 0.
0x0E	CH2OS	R/W	8	0x0	S*	Channel 2 Offset Adjust. Bits 6 and 7 are not used. Writing to Bits 0 to 5 of this register allows any offsets on Channel 2 to be removed—see the Analog Inputs section. Note that the CH2OS register is inverted. To apply a positive offset, a negative number is written to this register.
0x0F	GAIN	R/W	8	0x0	U	PGA Gain Adjust. This 8-bit register is used to adjust the gain selection for the PGA in Channels 1 and 2—see the Analog Inputs section.
0x10	PHCAL	R/W	6	0x0D	S	Phase Calibration Register. The phase relationship between Channel 1 and 2 can be adjusted by writing to this 6-bit register. The valid content of this twos compliment register is between 0x1D to 0x21. At a line frequency of 60 Hz, this is a range from –2.06° to +0.7°—see the Phase Compensation section.
0x11	APOS	R/W	16	0x0	S	Active Power Offset Correction. This 16-bit register allows small offsets in the active power calculation to be removed—see the Active Power Calculation section.

Address	Name	R/W	No. Bits	Default	Type[1]	Description
0x12	WGAIN	R/W	12	0x0	S	Power Gain Adjust. This is a 12-bit register. The active power calculation can be calibrated by writing to this register. The calibration range is ±50% of the nominal full-scale active power. The resolution of the gain adjust is 0.0244%/LSB —see the Calibrating an Energy Meter Based on the ADE7753 section.
0x13	WDIV	R/W	8	0x0	U	Active Energy Divider Register. The internal active energy register is divided by the value of this register before being stored in the AENERGY register.
0x14	CFNUM	R/W	12	0x3F	U	CF Frequency Divider Numerator Register. The output frequency on the CF pin is adjusted by writing to this 12-bit read/write register—see the Energy-to-Frequency Conversion section.
0x15	CFDEN	R/W	12	0x3F	U	CF Frequency Divider Denominator Register. The output frequency on the CF pin is adjusted by writing to this 12-bit read/write register—see the Energy-to-Frequency Conversion section.
0x16	IRMS	R	24	0x0	U	Channel 1 RMS Value (Current Channel).
0x17	VRMS	R	24	0x0	U	Channel 2 RMS Value (Voltage Channel).
0x18	IRMSOS	R/W	12	0x0	S	Channel 1 RMS Offset Correction Register.
0x19	VRMSOS	R/W	12	0x0	S	Channel 2 RMS Offset Correction Register.
0x1A	VAGAIN	R/W	12	0x0	S	Apparent Gain Register. Apparent power calculation can be calibrated by writing to this register. The calibration range is 50% of the nominal full-scale real power. The resolution of the gain adjust is 0.02444%/LSB.
0x1B	VADIV	R/W	8	0x0	U	Apparent Energy Divider Register. The internal apparent energy register is divided by the value of this register before being stored in the VAENERGY register.
0x1C	LINECYC	R/W	16	0xFFFF	U	Line Cycle Energy Accumulation Mode Line-Cycle Register. This 16-bit register is used during line cycle energy accumulation mode to set the number of half line cycles for energy accumulation—see the Line Cycle Energy Accumulation Mode section.
0x1D	ZXTOUT	R/W	12	0xFFF	U	Zero-Crossing Timeout. If no zero crossings are detected on Channel 2 within a time period specified by this 12-bit register, the interrupt request line ($\overline{IRQ}$) is activated—see the Zero-Crossing Detection section.
0x1E	SAGCYC	R/W	8	0xFF	U	Sag Line Cycle Register. This 8-bit register specifies the number of consecutive line cycles the signal on Channel 2 must be below SAGLVL before the SAG output is activated—see the Line Voltage Sag Detection section.
0x1F	SAGLVL	R/W	8	0x0	U	Sag Voltage Level. An 8-bit write to this register determines at what peak signal level on Channel 2 the $\overline{SAG}$ pin becomes active. The signal must remain low for the number of cycles specified in the SAGCYC register before the $\overline{SAG}$ pin is activated—see the Line Voltage Sag Detection section.
0x20	IPKLVL	R/W	8	0xFF	U	Channel 1 Peak Level Threshold (Current Channel). This register sets the level of the current peak detection. If the Channel 1 input exceeds this level, the PKI flag in the status register is set.
0x21	VPKLVL	R/W	8	0xFF	U	Channel 2 Peak Level Threshold (Voltage Channel). This register sets the level of the voltage peak detection. If the Channel 2 input exceeds this level, the PKV flag in the status register is set.
0x22	IPEAK	R	24	0x0	U	Channel 1 Peak Register. The maximum input value of the current channel since the last read of the register is stored in this register.
0x23	RSTIPEAK	R	24	0x0	U	Same as Channel 1 Peak Register except that the register contents are reset to 0 after read.
0x24	VPEAK	R	24	0x0	U	Channel 2 Peak Register. The maximum input value of the voltage channel since the last read of the register is stored in this register.
0x25	RSTVPEAK	R	24	0x0	U	Same as Channel 2 Peak Register except that the register contents are reset to 0 after a read.
0x26	TEMP	R	8	0x0	S	Temperature Register. This is an 8-bit register which contains the result of the latest temperature conversion—see the Temperature Measurement section.

Address	Name	R/W	No. Bits	Default	Type[1]	Description
0x27	PERIOD	R	16	0x0	U	Period of the Channel 2 (Voltage Channel) Input Estimated by Zero-Crossing Processing. The MSB of this register is always zero.
0x28–0x3C						Reserved.
0x3D	TMODE	R/W	8	–	U	Test Mode Register.
0x3E	CHKSUM	R	6	0x0	U	Checksum Register. This 6-bit read-only register is equal to the sum of all the ones in the previous read—see the ADE7753 Serial Read Operation section.
0x3F	DIEREV	R	8	–	U	Die Revision Register. This 8-bit read-only register contains the revision number of the silicon.

[1] Type decoder: U = unsigned, S = signed by twos complement method, and S* = signed by sign magnitude method.

ADE7753 REGISTER DESCRIPTIONS

All ADE7753 functionality is accessed via the on-chip registers. Each register is accessed by first writing to the communications register and then transferring the register data. A full description of the serial interface protocol is given in the ADE7753 Serial Interface section.

COMMUNICATIONS REGISTER

The communications register is an 8-bit, write-only register which controls the serial data transfer between the ADE7753 and the host processor. All data transfer operations must begin with a write to the communications register. The data written to the communications register determines whether the next operation is a read or a write and which register is being accessed. Table 11 outlines the bit designations for the communications register.

DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
W/R	0	A5	A4	A3	A2	A1	A0

Table 11. Communications Register

Bit Location	Bit Mnemonic	Description
0 to 5	A0 to A5	The six LSBs of the communications register specify the register for the data transfer operation. Table 10 lists the address of each ADE7753 on-chip register.
6	RESERVED	This bit is unused and should be set to 0.
7	W/R	When this bit is a Logic 1, the data transfer operation immediately following the write to the communications register is interpreted as a write to the ADE7753. When this bit is a Logic 0, the data transfer operation immediately following the write to the communications register is interpreted as a read operation.

MODE REGISTER (0x09)

The ADE7753 functionality is configured by writing to the mode register. Table 12 describes the functionality of each bit in the register.

Table 12. Mode Register

Bit Location	Bit Mnemonic	Default Value	Description
0	DISHPF	0	HPF (high-pass filter) in Channel 1 is disabled when this bit is set.
1	DISLPF2	0	LPF (low-pass filter) after the multiplier (LPF2) is disabled when this bit is set.
2	DISCF	1	Frequency output CF is disabled when this bit is set.
3	DISSAG	1	Line voltage sag detection is disabled when this bit is set.
4	ASUSPEND	0	By setting this bit to Logic 1, both ADE7753 A/D converters can be turned off. In normal operation, this bit should be left at Logic 0. All digital functionality can be stopped by suspending the clock signal at CLKIN pin.
5	TEMPSEL	0	Temperature conversion starts when this bit is set to 1. This bit is automatically reset to 0 when the temperature conversion is finished.
6	SWRST	0	Software Chip Reset. A data transfer should not take place to the ADE7753 for at least 18 µs after a software reset.
7	CYCMODE	0	Setting this bit to Logic 1 places the chip into line cycle energy accumulation mode.
8	DISCH1	0	ADC 1 (Channel 1) inputs are internally shorted together.
9	DISCH2	0	ADC 2 (Channel 2) inputs are internally shorted together.
10	SWAP	0	By setting this bit to Logic 1 the analog inputs V2P and V2N are connected to ADC 1 and the analog inputs V1P and V1N are connected to ADC 2.
12, 11	DTRT1, 0	00	These bits are used to select the waveform register update rate. DTRT 1 — DTRT0 — Update Rate 0 — 0 — 27.9 kSPS (CLKIN/128) 0 — 1 — 14 kSPS (CLKIN/256) 1 — 0 — 7 kSPS (CLKIN/512) 1 — 1 — 3.5 kSPS (CLKIN/1024)

Bit Location	Bit Mnemonic	Default Value	Description		
14, 13	WAVSEL1, 0	00	These bits are used to select the source of the sampled data for the waveform register.		
			WAVSEL1, 0	Length	Source
			0	0	24 bits active power signal (output of LPF2)
			0	1	Reserved
			1	0	24 bits Channel 1
			1	1	24 bits Channel 2
15	POAM	0	Writing Logic 1 to this bit allows only positive power to be accumulated in the ADE7753.		

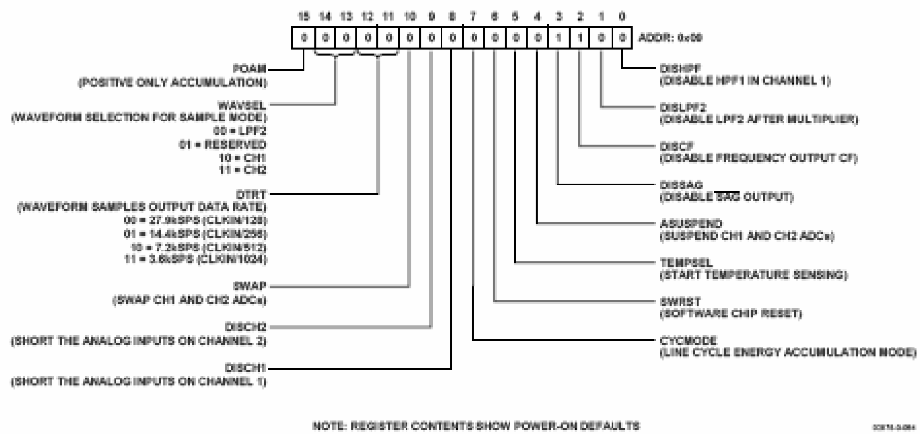


Figure 95. Mode Register

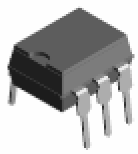
APPENDIX A

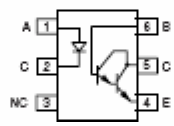
Datasheet of Optocoupler H11B1

H11B1, H11B2, H11B3

Vishay Semiconductors

Optocoupler, Photodarlington Output, High Gain, with Base Connection





FEATURES

- Isolation test voltage: 5300 V_{RMS}
- Coupling capacitance, 0.5 pF
- Lead (Pb)-free component
- Component in accordance to RoHS 2002/95/EC and WEEE 2002/96/EC

AGENCY APPROVALS

- UL1577, file no. E52744 system code J
- DIN EN 60747-5-5 (VDE 0884) available with option 1

DESCRIPTION

The H11B1, H11B2, H11B3 are industry standard optocouplers, consisting of a gallium arsenide infrared LED and a silicon photodarlington.

ORDER INFORMATION	
PART	REMARKS
H11B1	CTR > 500 %, DIP-6
H11B2	CTR > 200 %, DIP-6
H11B3	CTR > 100 %, DIP-6
H11B1-X007	CTR > 500 %, SMD-6 (option 7)
H11B1-X009	CTR > 500 %, SMD-6 (option 9)
H11B2-X009	CTR > 200 %, SMD-6 (option 9)

Note
For additional information on the available options refer to option information.

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
INPUT				
Reverse voltage		V_R	3	V
Forward continuous current		I_F	60	mA
Power dissipation		P_{diss}	100	mW
Derate linearly from 25 °C			1.33	mW/°C
OUTPUT				
Collector emitter breakdown voltage		BV_{CEO}	25	V
Emitter collector breakdown voltage		BV_{ECO}	7	V
Collector base breakdown voltage		BV_{CBO}	30	V
Collector current (continuous)		I_C	100	mA
Power dissipation		P_{diss}	150	mW
Derate linearly from 25 °C			2	mW/°C

Optocoupler, Photodarlington Output, High Gain, with Base Connection

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
COUPLER				
Isolation test voltage between emitter and detector		V_{ISO}	5300	V_{RMS}
Creepage distance			≥ 7	mm
Clearance distance			≥ 7	mm
Comparative tracking index per DIN IEC 112/VDE 0303, part 1		CTI	175	
Isolation resistance	V_{IO} = 500 V, T_{amb} = 25 °C	R_{IO}	≥ 10^{12}	Ω
	V_{IO} = 500 V, T_{amb} = 100 °C	R_{IO}	≥ 10^{11}	Ω
Total package dissipation (LED plus detector)		P_{tot}	260	mW
Derate linearly from 25 °C			3.5	mW/°C
Storage temperature		T_{stg}	- 55 to + 150	°C
Operating temperature		T_{amb}	- 55 to + 100	°C
Lead soldering time at 260 °C			10	s

Note
T_{amb} = 25 °C, unless otherwise specified.
Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operational sections of this document. Exposure to absolute maximum ratings for extended periods of the time can adversely affect reliability.

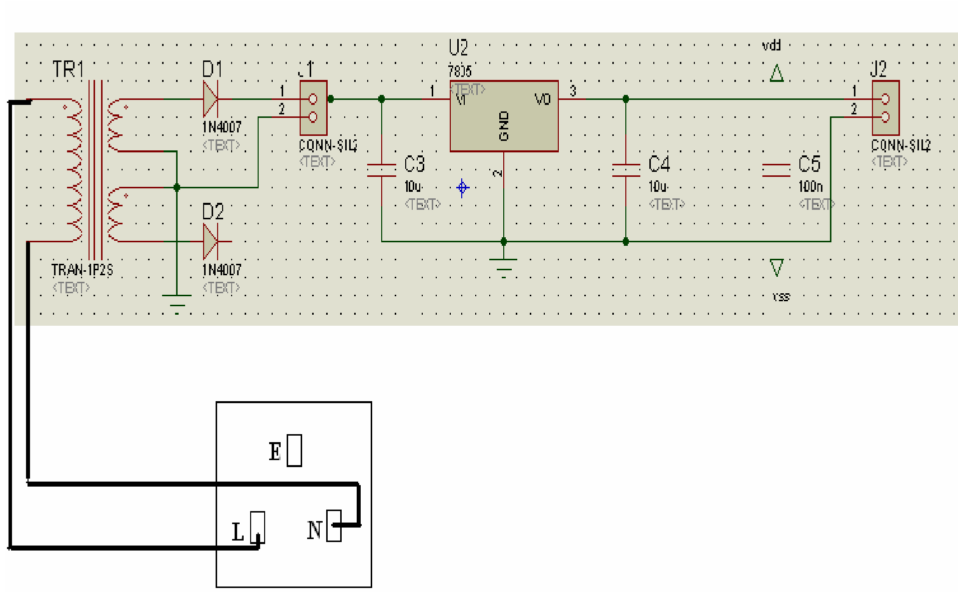
ELECTRICAL CHARACTERISTCS							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
INPUT							
Forward voltage	I_F = 50 mA	H11B1	V_F		1.1	1.5	V
		H11B2	V_F		1.1	1.5	V
	I_F = 10 mA	H11B3	V_F		1.1	1.5	V
Reverse current	V_R = 3 V		I_R			10	µA
Junction capacitance	V_F = 0 V, f = 1 MHz		C_j		50		pF
OUTPUT							
Collector emitter breakdown voltage	I_C = 1 mA, I_F = 0 mA		BV_{CEO}	30			V
Emitter collector breakdown voltage	I_E = 100µA, I_F = 0 mA		BV_{ECO}	7			V
Collector base breakdown voltage	I_C = 100 µA , I_F = 0 mA		BV_{CBO}	30			V
Collector emitter leakage current	V_{CE} = 10 V, I_F = 0 mA		I_{CEO}			100	nA
COUPLER							
Saturation voltage collector-emitter	I_C = 1 mA, I_C = 1 mA		V_{CEsat}			1	V
Capacitance (input to output)			C_{IO}		0.5		pF

Note
T_{amb} = 25 °C, unless otherwise specified.
Minimum and maximum values were tested requierements. Typical values are characteristics of the device and are the result of engineering evaluations. Typical values are for information only and are not part of the testing requirements.

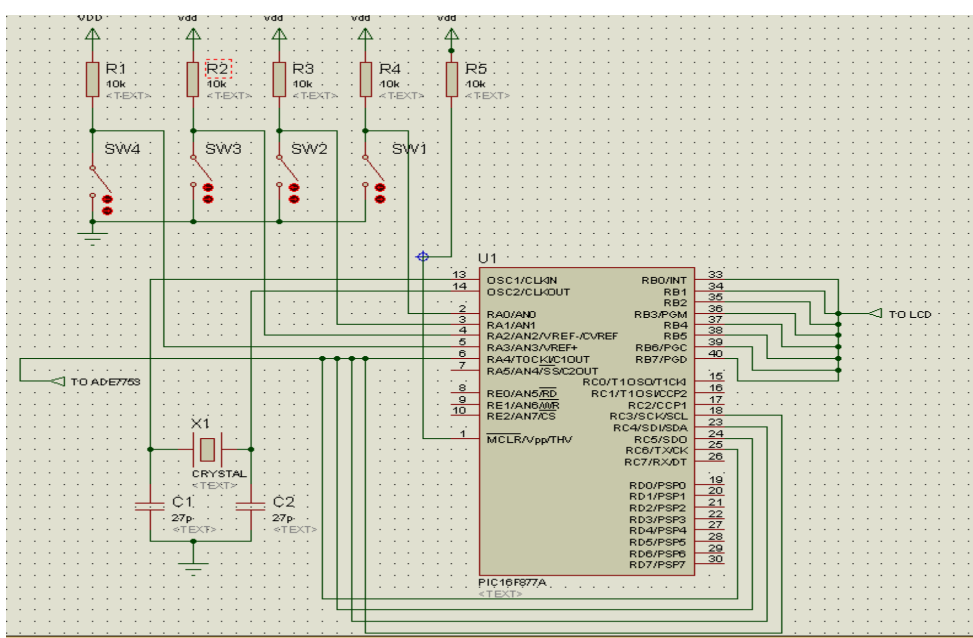
CURRENT TRANSFER RATIO							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
DC current transfer ratio	V_{CE} = 5 V, I_F = 1 mA	H11B1	CTR_{DC}	500			%
		H11B2	CTR_{DC}	200			%
		H11B3	CTR_{DC}	100			%

APPENDIX B

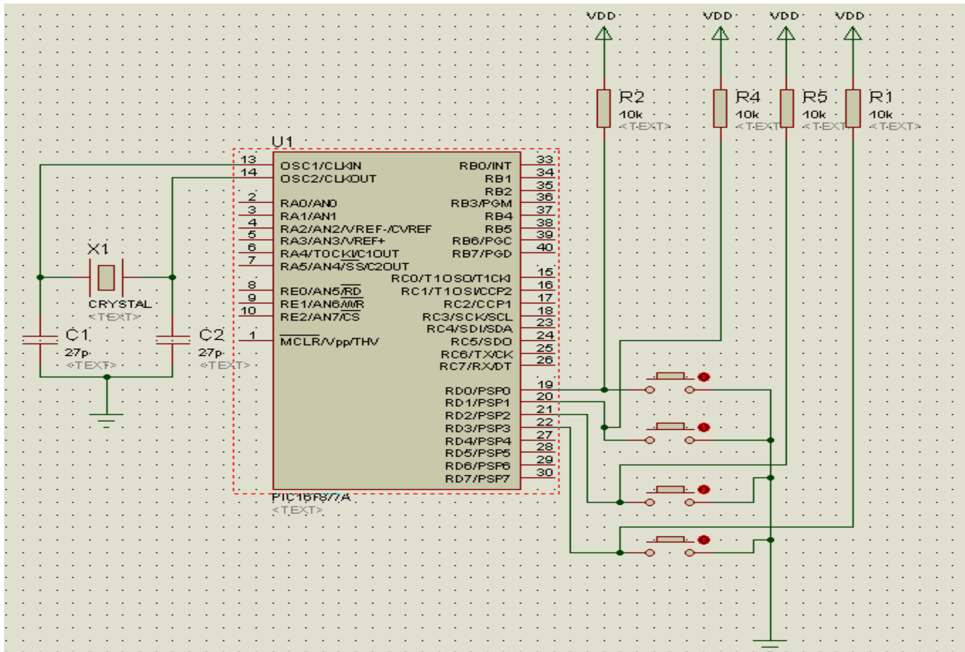
Schematic of Energy Management System



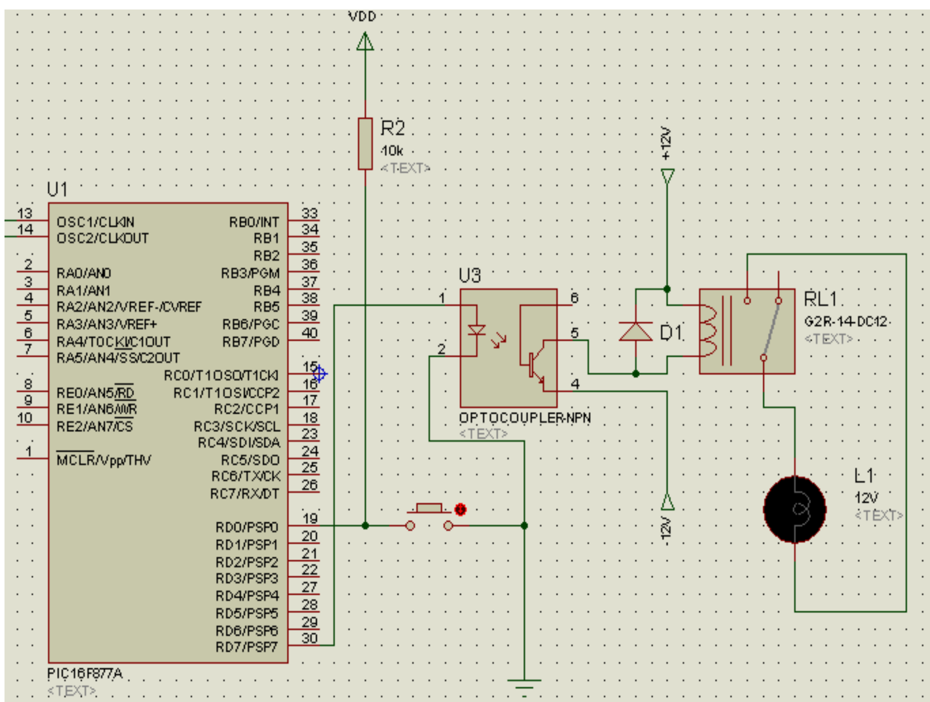
Power Supply circuit



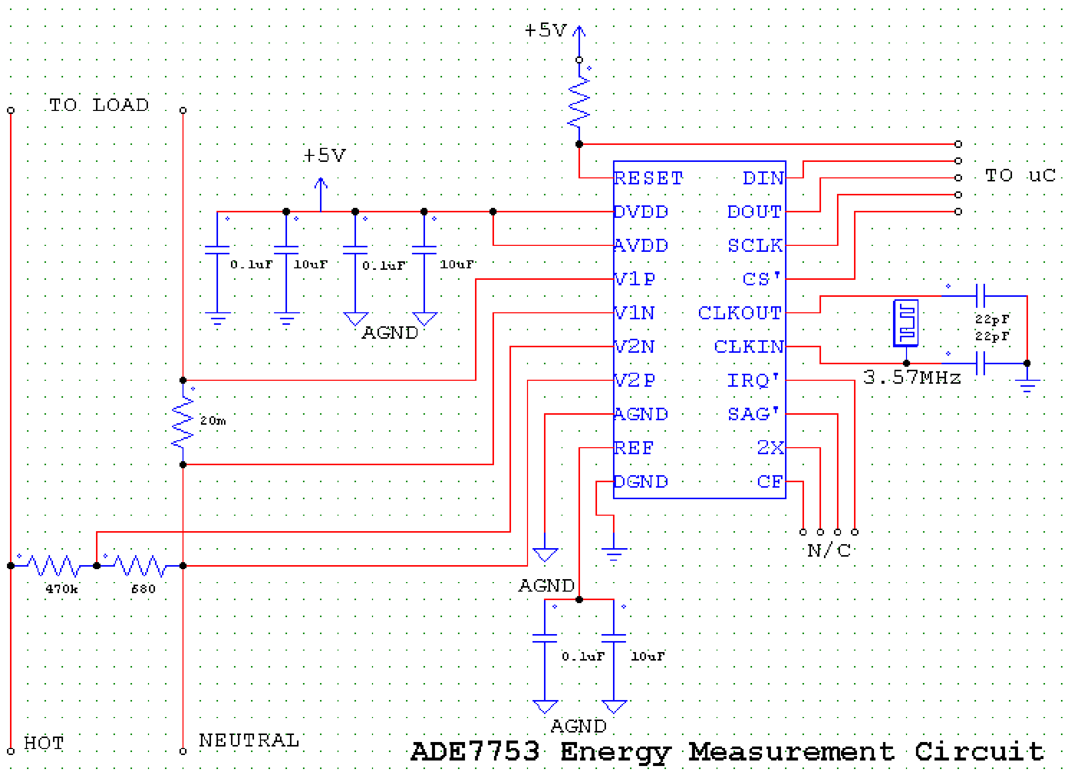
Microcontroller circuit



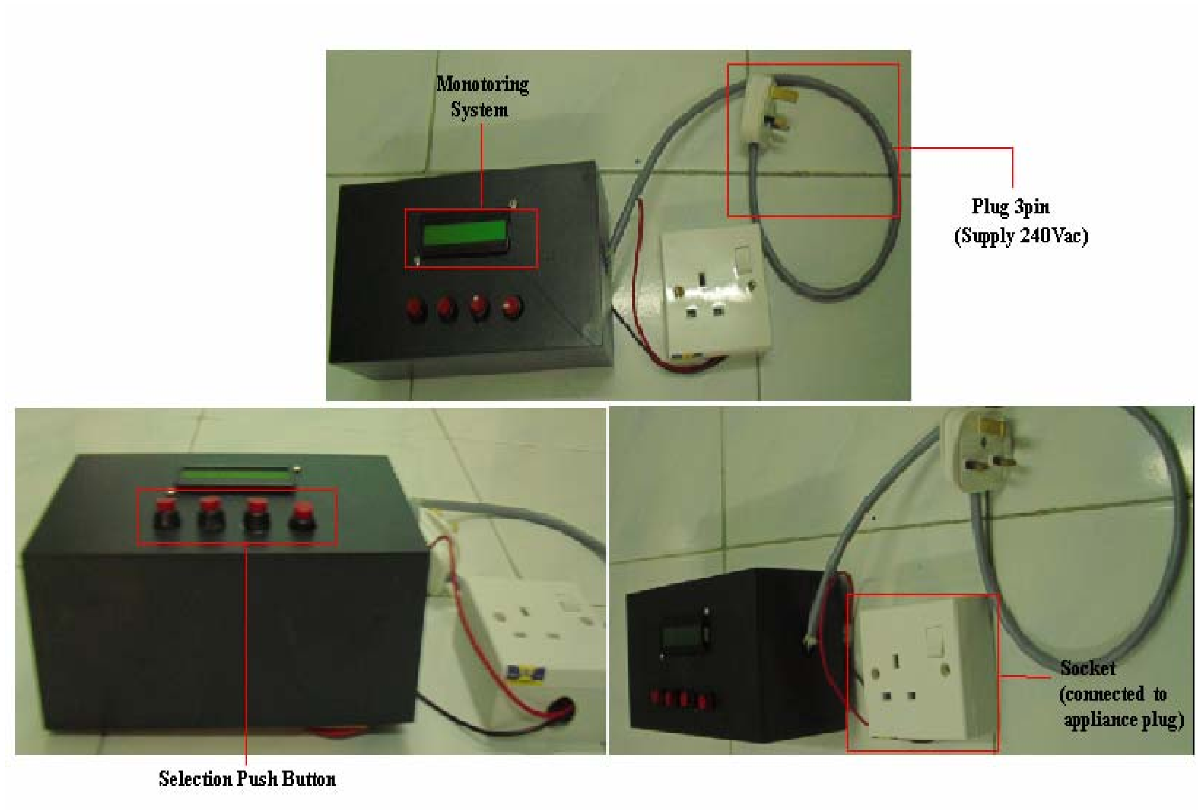
Push Button Circuit



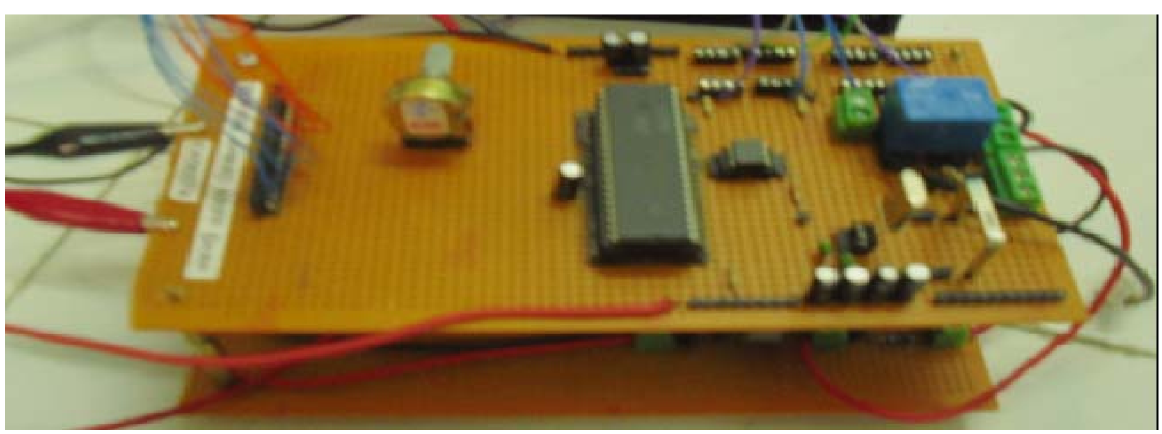
Relay Circuit



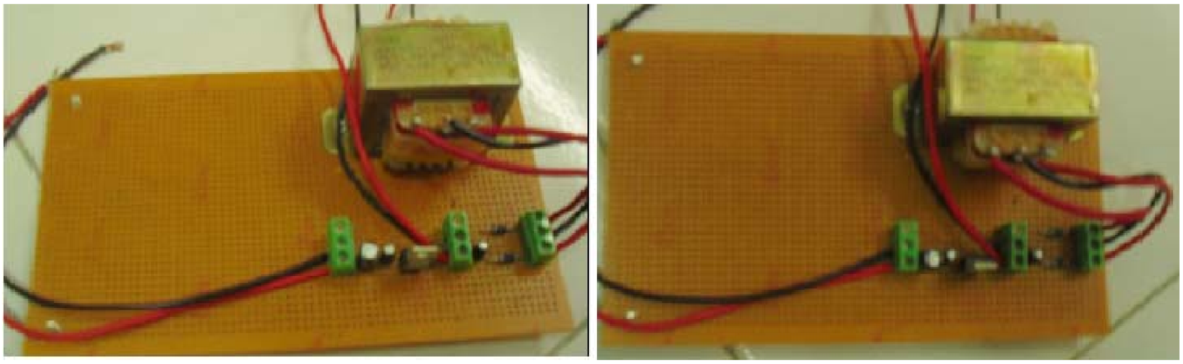
Energy Management Circuit



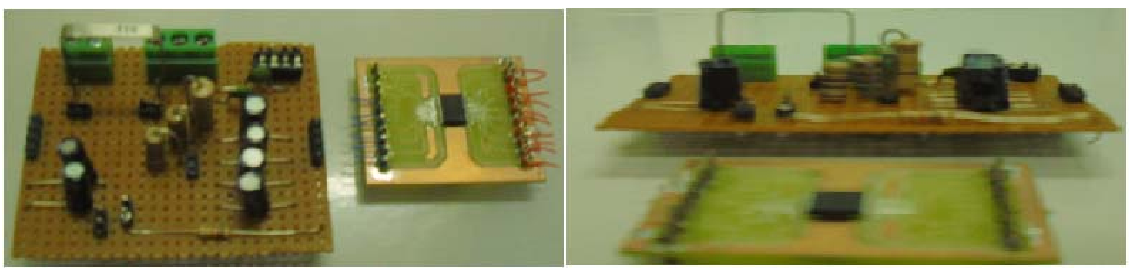
Full view of Energy Management System (EMS)



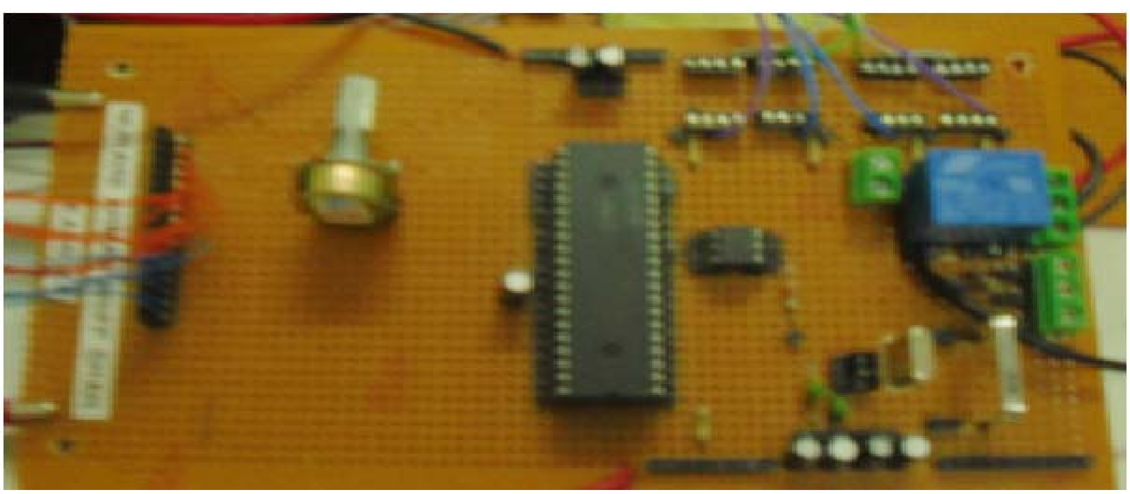
Developing an Energy Management System.



Power Supply and Voltage Regulator (5Vdc and 12Vdc)



Energy Management Circuit (ADE7753)



Microcontroller circuit (PIC16F877A)

APPENDIX C

Programming Language

```
 *****************************************************************
'*  Name    : ENERGY MANAGEMENT SYSTEM.BAS                          *
'*  Author  : [NURAINI BINTI AHMAD ARIFF SHAH]                      *
'*  Notice  : Copyright (c) 2009 [select VIEW...EDITOR OPTIONS]     *
'*          : All Rights Reserved                                   *
'*  Date    : 4/6/2009                                              *
'*  Version : 1.0                                                   *
'*  Notes   :                                                       *
'*          :                                                       *
'*****************************************************************
DEFINE OSC 4
' Set LCD Data port
DEFINE LCD_DREG PORTB
' Set starting Data bit (0 or 4) if 4-bit bus
DEFINE LCD_DBIT 4
' Set LCD Register Select port
DEFINE LCD_RSREG PORTC
' Set LCD Register Select bit
DEFINE LCD_RSBIT 1
' Set LCD Enable port
DEFINE LCD_EREG PORTC
' Set LCD Enable bit
DEFINE LCD_EBIT 0
' Set LCD bus size (4 or 8 bits)
DEFINE LCD_BITS 4
' Set number of lines on LCD
DEFINE LCD_LINES 2
' Set command delay time in us
DEFINE LCD_COMMANDUS 2000
' Set data delay time in us
DEFINE LCD_DATAUS 50

DEFINE ADC_BITS 10
DEFINE ADC_CLOCK    3
DEFINE ADC_SAMPLEUS  50

ABC VAR BYTE
ADCON1=2 'PORTA is analog

symbol bton = PORTD.0
symbol bton1 = PORTD.1
symbol bton2 = PORTD.2
symbol light = PORTD.7
delay var byte
disp var byte
B0 var byte
B1 VAR BYTE
i VAR BYTE
cnt var byte
TRISD = %00001111
```

```
on interrupt goto isr
intcon=$a0
Lcdout $fe, 1  ' Clear LCD
int:
if bton=1 then
      LCDOUT $FE,1
      LCDOUT $FE,2
      LCDOUT "ENERGY MANAGEMNT"
      LCDOUT 254,192
      LCDOUT $FE,$C5
      LCDOUT "SYSTEM"

      For B0= 0 to 40
      LCDOUT 254, 24
      Pause 200
      Next B0

      For B0= 0 to 40
      LCDOUT 254, 28
      Pause 200
      Next B0
      endif
Main:

if bton=0&&bton1!=0&&bton2!=0 THEN
        LCDOUT $FE,1
        LCDOUT $FE,$80
        LCDOUT "LAMP TURN ON"
        high light
        pause 1000
        for i=0 to 10000
            pause 100
        next i
        LCDOUT $FE,1
        LCDOUT $FE,$80
        LCDOUT "LAMP TURN OFF"
        LOW LIGHT
        pause 100
        while bton=0
        wend
        gosub debounce
        if bton=1 then goto int

        gosub debounce
endif
if bton1=0&&bton!=0&&bton2!=0 THEN
         ADCIN PORTA.0,ABC
         LCDOUT $FE,1
         LCDOUT $FE,2
         LCDOUT "VOLTAGE:"
         LCDOUT $FE,$C0
         LCDOUT DEC3 ABC
         pause 3000
         if bton1=1 then goto int
          while bton1=0&&bton!=0&&bton2!=0
        wend
         gosub debounce
```

```
endif
if bton2=0&&bton1!=0&&bton!=0 THEN
         ADCIN PORTA.0,ABC
         LCDOUT $FE,1
         LCDOUT $FE,$2
         LCDOUT "CURRENT:",DEC ABC
         LCDOUT $FE,$C0
         LCDOUT DEC3 ABC
         pause 3000
         if bton2=1 then goto int
         while bton2=0&&bton1!=0&&bton!=0
        wend
         gosub debounce



endif
if bton=0&&bton1=0||bton=0&&bton2=0||bton1=0&&bton2=0||bton=0&&bton1=0&&bton2=0  THEN
         LCDOUT $FE,1
         LCDOUT $FE,2
         LCDOUT "PLEASE SELECT"
         LCDOUT 254,192
         LCDOUT "ONE BUTTON ONLY"
         pause 3000
         'if bton=0&&bton1=0||bton=0&&bton2=0||bton1=0&&bton2=0||bton=0&&bton1=0&&bton2=0 then
         goto int
         gosub debounce


ENDIF

goto main

DEBOUNCE:
'FOR Delay = 1 To 100
'Pause 1 ' Delay 1ms inside a loop. This way,
'NEXT Delay ' timer interrupts are not stopped
'DISP = 1 ' Set display flag to 1
return

disable
isr:
```

```
    if bton=1 then
      LCDOUT $FE,1
      LCDOUT $FE,2
      LCDOUT "ENERGY MANAGEMNT"
      LCDOUT 254,192
      LCDOUT $FE,$C5
      LCDOUT "SYSTEM"

      For B0= 0 to 40
      LCDOUT 254, 24
      Pause 200
      Next B0

      For B0= 0 to 40
      LCDOUT 254, 28
      Pause 200
      Next B0
      endif

 noupdate:
 intcon.2=0
 resume
 enable
 goto main
 end

end
```

APPENDIX D
List of components

Bil	Components	Specification	Quantity	Price (each)	Amount: (price x quantity)
1.	Analog Devices	ADE7753	1	RM 32.70	RM 32.70
2.	Resistor, open air current sense,	5W,R020	1	RM 6.94	RM 34.70
3.	Microcontroller	PIC16F877A	1	RM 22.00	RM 22.00
4.	Optocoupler	H11B1	1	RM 3.50	RM 3.50
5.	LCD	JHD162A	1	RM 35.00	RM 35.00
6.	Relay	Rated at 20A, 12Vdc	1	RM 2.50	RM 2.50
7.	Push Button		4	RM 4.00	RM 16.00
8.	Transformer	240: 12 (0.1A)	1	RM 15.00	RM 15.00
9.	Crystal	4MHz	1	RM 1.20	RM 1.20
		3.57MHz	1	RM 1.50	RM 1.50
10.	Capacitor	0.1uF	3	RM 0.30	RM 0.90
		10uF	3	RM 0.30	RM 0.90
		22pF	2	RM 0.30	RM 0.60
		330uF	1	RM 0.30	RM 0.30
		4.7uF	1	RM 0.30	RM 0.30
		100uF	1	RM 0.50	RM 0.50
11.	Resistor	470kΩ,1W	1	RM 1.00	RM 1.00
12.		680Ω,1W	1	RM 1.00	RM 1.00
13.		10kΩ	6	RM 0.30	RM 0.30
14.		330Ω	1	RM 0.30	RM 0.30
15.	Potentiometer	10K Ω	1	RM 0.50	RM 0.50
16.	Regulator	7812	1	RM 1.00	RM 1.00
17.		7805	1	RM 1.00	RM 1.00
18.	Diode	IN4007	2	RM 0.80	RM 1.60
19.	I.C Base	Overall	7		RM 7.00
20.	Plug	3pin,13A	1	RM 3.00	RM 3.00
21	Socket		1	RM 4.90	RM 4.90
22.	Header		10	RM 0.80	RM 8.00
23.	Strip Board	10”x4” (independent)	2	RM 4.50	RM 9.00
24.	Connecter	3pin,3A	6	RM 1.00	RM 6.00
25.	Wrapping wire		1	RM 18.00	RM 18.00
26.	Riben cabble	2meter	1	RM 4.50	RM 4.50
27.	Stand	Medium size	12	RM 1.00	RM 12.00
28.	Casing		1	RM 15.00	RM 15.00
29.	Adapter	AC adapter + DC socket	1	RM 24.00	RM 24.00
				TOTAL ESTIMATION PRICE	**RM 285.50**