

# **MICROCONTROLLER BASED POWER FACTOR CORRECTOR**

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## ABSTRACT

Now day, power factor is very important in electrical system. Power factor means defined as the ratio of the real power over apparent power. It is a measure of how efficiently electrical power is converted into useful work output. Low power factor is expensive, inefficient and waste power. It is because reduces an electrical system's distribution capacity by increasing current flow and causing voltage drops. Normally in industry, they have system capacitor bank to improve power factor. But in house we don't have the system capacitor bank. The project is power factor corrector. This project focuses to need improve power factor for application in home. The objective the project is reducing usage current. In this project, a Microcontroller PIC 16F877A will be used as a brain of the system that will control the system through a PIC Basis programming. The PIC Basic Programming will be developed to control when capacitor can turn on. Input of the Microcontroller is a current transducer. Function of the current transducer to read the current from line. The current transducer can convert 5A to 5 mA. The maximum value can read of current transducer is 5A. We use current transducer because Microcontroller very sensitive device. It only can read voltage from 0V to 5V. When give value greater than 5V to Microcontroller, it can make Microcontroller burnt. When the Microcontroller senses certain current, it will give signal to output to turn on the capacitor. Function of the capacitor to improve level power factor. The benefit improve power factor is reduce of electricity bills, increased electrical system capacity and voltage drop at the point of use will be reduced

## **CHAPTER 1**

### **INTRODUCTION**

The power factor of an AC electric power system is defined as the ratio of the real power to the apparent power, and is a number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power can be greater than the real power. Low-power-factor loads increase losses in a power distribution system and result in increased energy costs

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads result in a time difference between the current and voltage waveforms. This stored energy returns to the source and is not available to do work at the load. A circuit with a low power factor will have thus higher currents to transfer a given quantity of real power than a circuit with a high power factor.

Circuits containing purely resistive heating elements (filament lamps, strip heaters, cooking stoves, etc.) have a power factor of 1.0. Circuits containing inductive or

capacitive elements (lamp ballasts, motors, etc.) often have a power factor below 1.0. For example, in electric lighting circuits, normal power factor ballasts (NPF) typically have a value of 0.4 - 0.6. Ballasts with a power factor greater than 0.9 are considered high power factor ballasts (HPF).

The significance of power factor lies in the fact that utility companies supply customers with volt-amperes, but bill them for watts. Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current.

## **1.1 Objective**

These projects have 2 objectives to achieve:

- To maximizes the usage of power
- To develop a prototype of power factor corrector

## **1.2 Project Scope**

The scopes of this project are to:

- To improve power factor using capacitor bank and reduce current draw by the load
- Use microcontroller to turn on capacitor automatically

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

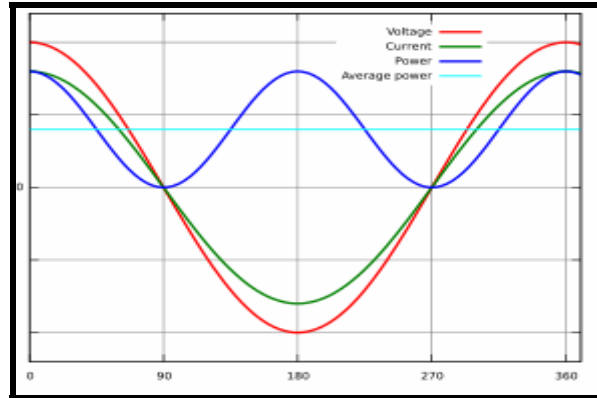
This chapter will review about the definition power factor. in this chapter also explain power factor correction. Then after that will review about components of hardware and software that will be use to make this project.

#### **2.2 Power Factor**

The power factor of an AC electric power system is defined as the ratio of the real power to the apparent power, and is a number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power can be greater than the real power. Low-power-factor loads increase losses in a power distribution system and result in increased energy costs [1].

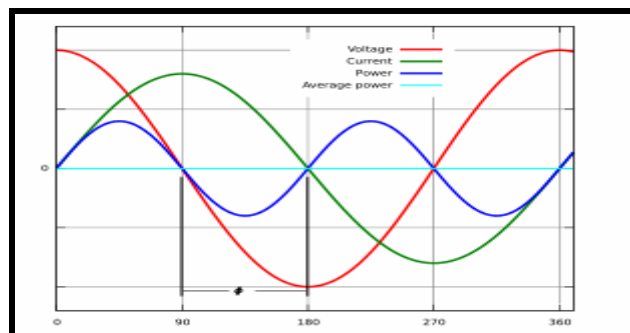
### 2.3 Power Factor In Linear Circuits

Figure 2.1 show the ac voltage, current and power when zero power factor.



**Figure 2.1:** Instantaneous and average power calculated from AC voltage and current with a zero power factor ( $\phi=90$ ,  $\cos\phi=0$ )

Figure 2.2 show lagging power factor.



**Figure 2.2:** Instantaneous and average power calculated from AC voltage and current with a lagging power factor ( $\phi=45$ ,  $\cos\phi=0.71$ ).

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads result in a time difference between the current and voltage waveforms. This stored energy

returns to the source and is not available to do work at the load. A circuit with a low power factor will have thus higher currents to transfer a given quantity of real power than a circuit with a high power factor.

The current required by motor, light, and computer is made up the the real and reactive power[6]. Load such as heater required component of real power. The real current is that component that is converted by the equipment into useful works such as the production of heat through the heater.

Circuits containing purely resistive heating elements (filament lamps, strip heaters, cooking stoves, etc.) have a power factor of 1.0. Circuits containing inductive or capacitive elements (lamp ballasts, motors, etc.) often have a power factor below 1.0. For example, in electric lighting circuits, normal power factor ballasts (NPF) typically have a value of 0.4 - 0.6 . Ballasts with a power factor greater than 0.9 are considered high power factor ballasts (HPF).

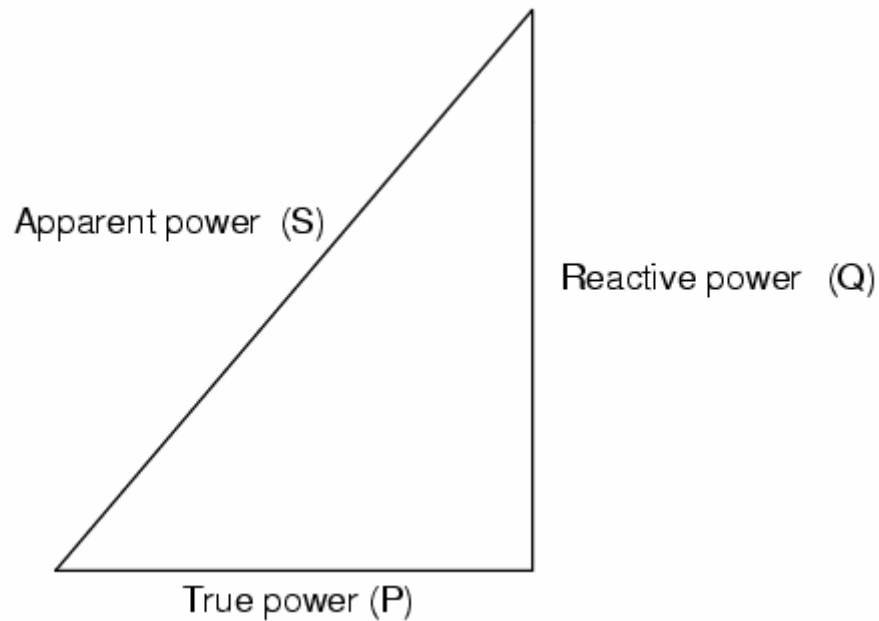
The significance of power factor lies in the fact that utility companies supply customers with volt-amperes, but bill them for watts. Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts)[1]. This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current.

Good power factor is considered to be greater than 90 to 95%. Utilities typically charge additional costs to customers who have a power factor below some limit, which is typically 90 to 95%. Engineers are often interested in the power factor of a load as one of the factors that affect the efficiency of power transmission.



## 2.4 Definition And Calculation

AC power flow has the three components: real power (P), measured in watts (W); apparent power (S), measured in volt-amperes (VA); and reactive power (Q), measured in reactive volt-amperes (VAr)[6].



The power factor is defined as

$$\frac{P}{S}. \quad (1)$$

In the case of a perfectly sinusoidal waveform, P, Q and S can be expressed as vectors that form a vector triangle such that

$$S^2 = P^2 + Q^2 \quad (2)$$

If  $\theta$  is the phase angle between the current and voltage, then the power factor is equal to  $\cos \theta$ , and

$$P = S |\cos \phi| \quad (3)$$

Since the units are consistent, the power factor is by definition a dimensionless number between 0 and 1. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle, where leading indicates a negative sign.

If a purely resistive load is connected to a power supply, current and voltage will change polarity in step, the power factor will be unity (1), and the electrical energy flows in a single direction across the network in each cycle. Inductive loads such as transformers and motors (any type of wound coil) consume reactive power with current waveform lagging the voltage. Capacitive loads such as capacitor banks or buried cable generate reactive power with current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle [1].

For example, to get 1 kW of real power if the power factor is unity, 1 kVA of apparent power needs to be transferred ( $1 \text{ kW} \div 1 = 1 \text{ kVA}$ ). At low values of power factor, more apparent power needs to be transferred to get the same real power. To get 1 kW of real power at 0.2 power factor 5 kVA of apparent power needs to be transferred ( $1 \text{ kW} \div 0.2 = 5 \text{ kVA}$ ).

It is often possible to adjust the power factor of a system to very near unity. This practice is known as *power factor correction* and is achieved by switching in or out banks of inductors or capacitors. For example the inductive effect of motor loads may be offset by locally connected capacitors.

## **2.5 Power Factor Correction.**

Power factor correction (PFC) is a technique of counteracting the undesirable effects of electric loads that create a power factor that is less than 1. Power factor correction may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network; or, correction may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier.

An electrical load that operates on alternating current requires apparent power, which consists of real power plus reactive power. Real power is the power actually consumed by the load. Reactive power is repeatedly demanded by the load and returned to the power source, and it is the cyclical effect that occurs when alternating current passes through a load that contains a reactive component. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1 [9].

The reactive power increases the current flowing between the power source and the load, which increases the power losses through transmission and distribution lines. This results in operational and financial losses for power companies. Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified amount (usually 0.90 or higher) or be subject to additional charges. Electrical engineers involved with the generation, transmission, distribution and consumption of electrical power have an interest in the power factor of loads because power factors affect efficiencies and costs for both the electrical power industry and the consumers. In addition to the increased operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current capacities.

Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.00) through various methods. Simple methods include switching in or out banks of capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively. For example, the inductive effect of motor loads may be offset by locally connected capacitors. It is also possible to effect power factor correction with an unloaded synchronous motor

connected across the supply. The power factor of the motor is varied by adjusting the field excitation and can be made to behave like a capacitor when over excited.

Non-linear loads create harmonic currents in addition to the original AC current. The simple correction techniques described above do not cancel out the reactive power at harmonic frequencies, so more sophisticated techniques must be used to correct for non-linear loads.

## **2.6 Electricity Industry Aspects**

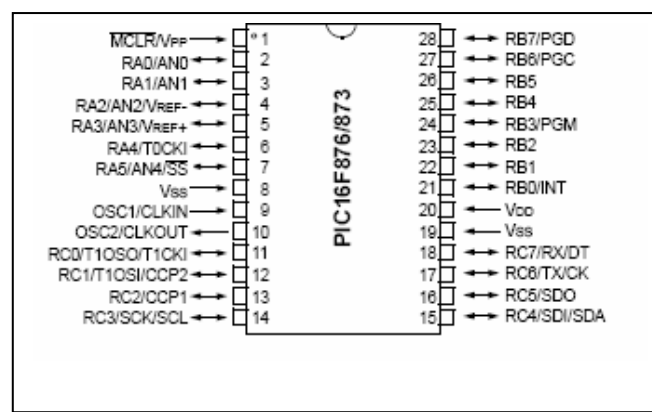
PFC is desirable because the source of electrical energy must be capable of supplying real power as well as any reactive power demanded by the load. This can require larger, more expensive power plant equipment, transmission lines, transformers, switches, etc. than would be necessary for only real power delivered. Also, resistive losses in the transmission lines mean that some of the generated power is wasted because the extra current needed to supply reactive power only serves to heat up the power lines [2].

The electric utilities therefore put a limit on the power factor of the loads that they will supply. The ideal figure for load power factor is 1, (that is, a purely resistive load), because it requires the smallest current to transmit a given amount of real power. Real loads deviate from this ideal. Electric motor loads are phase lagging (inductive), therefore requiring capacitor banks to counter this inductance. Sometimes, when the power factor is leading due to capacitive loading, inductors (also known as *reactors* in this context) are used to correct the power factor. In the electricity industry, inductors are said to consume reactive power and capacitors are said to supply it, even though the reactive power is actually just moving back and forth between each AC cycle.

Electricity utilities measure reactive power used by high demand customers and charge higher rates accordingly. Some consumers install power factor correction schemes at their factories to cut down on these higher costs.

## 2.7 MICROCONTROLLER (PIC 16F873)

**PIC** is a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC was originally an acronym for "Programmable Intelligent Computer". Figure 2.3 show the PIC16F873.



**Figure 2.3:** Show the PIC16F873

In this project, a microcontroller; PIC16F873 (Figure ) is use to control the output. The reason for use microcontroller is the PIC architecture is distinctively minimalist. It is characterized by the following features:

- separate code and data spaces
- a small number of fixed length instructions
- most instructions are single cycle execution (4 clock cycles), with single delay cycles upon branches and skips
- a single accumulator (W), the use of which (as source operand) is implied
- All RAM locations function as registers as both source and/or destination of math and other functions.
- data space mapped CPU, port, and peripheral registers
- the program counter is also mapped into the data space and writable (this is used to synthesize indirect jumps)

- 10-bit multi-channel Analog-to-Digital converter

Unlike most other CPUs, there is no distinction between "memory" and "register" space because the ram serves the job of both memory and registers, and the ram is usually just referred to as the register file or simply as the registers.

PIC microcontroller have a very small set of instructions (only 35 instruction), leading some to consider them as RISC devices, however many salient features of RISC CPU's are not reflected in the PIC architecture. For example:

- it does not have load-store architecture, as memory is directly referenced in arithmetic and logic operations
- it has a singleton working register, whereas most modern architectures have significantly more

PIC have a set of register files that function as general purpose RAM, special purpose control registers for on-chip hardware resources are also mapped into the data space. The addressability of memory varies depending on device series, and all PIC devices have some banking mechanism to extend the addressing to additional memory. Later series of devices feature move instructions which can cover the whole addressable space, independent of the selected bank. In earlier devices (ie. the baseline and mid-range cores), any register move had to be through the accumulator.

To synthesize indirect addressing, a "file select register" (FSR) and "indirect register" (INDF) are used: A read or write to INDF will be to the memory pointed to by FSR. Later devices extended this concept with post and pre increment/decrement for greater efficiency in accessing sequentially stored data. This also allows FSR to be treated like a stack pointer.

All PICs feature Harvard architecture, so the code space and the data space are separate. PIC code space is generally implemented as EPROM, ROM, or FLASH ROM. In general, external code memory is not directly addressable due to the lack of an external memory interface.

The PIC architecture has no (or very meager) hardware support for saving processor state when servicing interrupts. The 18 series improved this situation by

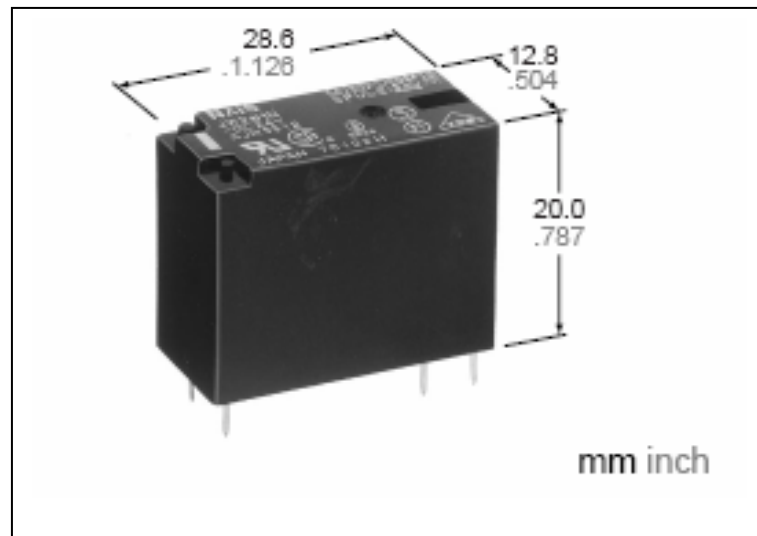
implementing shadow registers which save several important registers during an interrupt.

The PIC architecture may be criticized on a few important points.

- The few instructions, limited addressing modes, code obfuscations due to the "skip" instruction and accumulator register passing makes it difficult to program in assembly language, and resulting code difficult to comprehend. This drawback has been alleviated by the increasing availability of high level language compilers.
- Data stored in program memory is space inefficient and/or time consuming to access, as it is not directly addressable.

## **2.8 Relay**

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of an electrical amplifier. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts [3]. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, it is used to reduce noise. In a high voltage or high current application, it is used to reduce arcing. The relay is shown in Figure.2.4



**Figure 2.4:** Relay

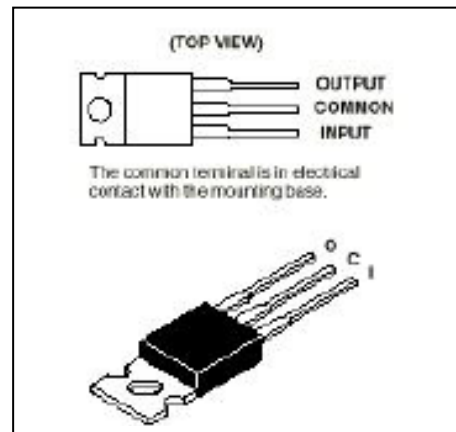
**Features:**

- Miniature package with universal terminal footprint
- High dielectric withstanding for transient protection: 10000V surge in us between coil and contact
- Sealed construction
- Class B coil types available
- TV rated (TV-5) types available

## **2.9 Voltage Regulator**

When the 12V through voltage regulator, the supply will be fixing to 5V and divide it to switch ON the PIC 16F877a and relays. The type of the voltage regulator is LM 7805(see Figure 2.5). The features of LM 7805 are shown in data sheet at appendix.





**Figure 2.5:** Show about voltage regulator

## 2.10 Current Transducer

There are several types of current detector such as current transducer, transtronics current detector and current transformer which are use for detected current by sensing the AC current[4]. Below is an example figure 2.6 for current detector:



**Figure 2.6:** Current transducer

The application of current transducer normally use in sensing overload current, ground fault detection, metering and analog to digital circuit.

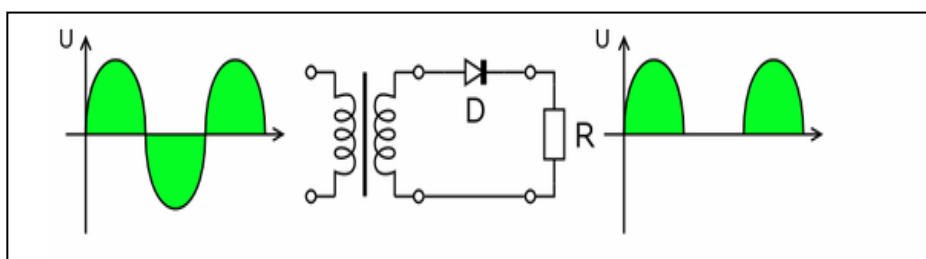
## 2.11 Rectifier

A rectifier is an electrical device, which converts alternating current to direct current, a process known as rectification. Rectifiers are used as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other technologies.

Two type of rectifier. Half wave and full wave.

### 1. Half wave

A half wave rectifier is a special case of a clipper. In half wave rectification, either the positive or negative half of the AC wave is passed easily while the other half is blocked, depending on the polarity of the rectifier. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half wave rectification can be achieved with a single diode in a one phase supply

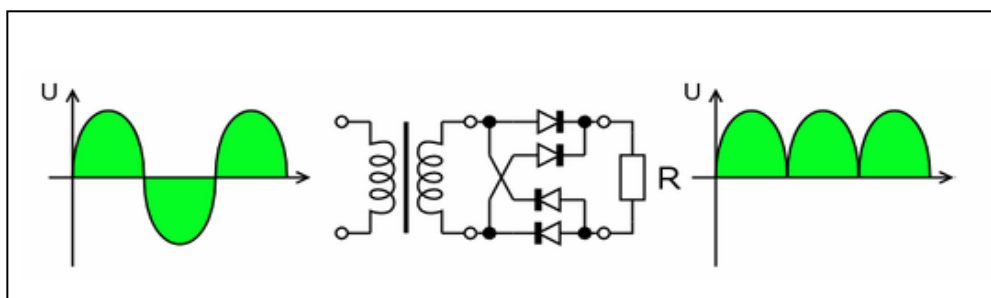


**Figure2.7:** Show the halfwave rectifier

### 2. Fullwave rectifier

Full wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative

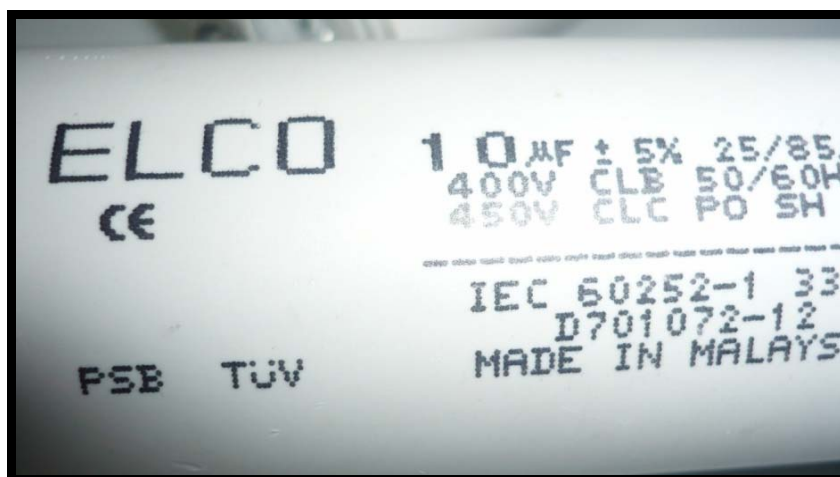
(or positive) portions of the alternating current waveform. The positive (negative) portions thus combine with the reversed negative (positive) portions to produce an entirely positive (negative) voltage/current waveform. For single phase AC, if the transformer is center-tapped, then two diodes back-to-back (i.e. anodes-to-anode or cathode-to-cathode) form a full wave rectifier. [5]



**Figure 2.8:** Show the fullwave rectifier.

## 2.12 Capacitor

This capacitor we use to correct level power factor. this part is very import in the circuit. With capacitor, we cannot the power factor [8]. A capacitor is an electrical/electronic device that can store energy in the electric field between a pair of conductors (called "plates"). The process of storing energy in the capacitor is known as "charging", and involves electric charges of equal magnitude, but opposite polarity, building up on each plate. Figure 2.9 show the capacitor.



**Figure 2.9:** Capacitor

## 2.13 Software Part

Software part will discuss about the software that would be used for designing and simulating circuit of the project and this part is the very important part where it decide how to start the project. After the designing and simulating the project circuit success, then the real circuit would be made based on it. Actually there are 3 softwares assist to make this project:

- PIC BASIC PRO COMPLIER
- ISIS PROFESSIONAL (designing simulating circuit).
- MELABS PROGRAMMER (PIC program's burner)

### 2.13.1 Pic Bacis Pro Complier

PicBasic Pro Compiler (or PBP) is our next-generation programming language that makes it even quicker and easier for you to program Microchip Technology's powerful PICmicro microcontrollers (MCUs). The English-like BASIC language is much easier to read and write than the quirky Microchip assembly language [10].

The PicBasic Pro Compiler is "BASIC Stamp II like" and has most of the libraries and functions of both the BASIC Stamp I and II. Being a true compiler, programs execute much faster and may be longer than their Stamp equivalents.

PBP is not quite as compatible with the BASIC Stamps as our original PicBasic Compiler is with the BS1. Decisions were made that we hope improve the language overall. One of these was to add a real **IF..THEN..ELSE..ENDIF** instead of the **IF..THEN(GOTO)** of the Stamps. These differences are spelled out later in this manual. PBP defaults to create files that run on a PIC16F84-04/P clocked at 4MHz. Only a minimum of other parts are necessary: 2 22pf capacitors for the 4MHz crystal, a 4.7K pull-up resistor tied to the /MCLR pin and a suitable 5- volt power supply. Many PICmicro MCUs other than the 16F84, as well as oscillators of frequencies other than 4MHz, may be used with the PicBasic Pro Compiler.

### 2.13.2 Isis Professional Software

Many CAD users dismiss schematic capture as a necessary evil in the process of creating PCB layout. With PCB layout now offering automation of both component placement and track routing, getting the design into the computer can often be the most time consuming element of the exercise.

ISIS has been created with this in mind. It has evolved over twelve year's research and development and has been proven by thousands of users worldwide. The strength of its architecture has allowed us to integrate first conventional graph based simulation and now - with PROTEUS VSM - interactive circuit simulation into the design environment. For the first time ever it is possible to draw a complete circuit for a micro-controller based system and then test it interactively, all from within the same piece of software. Meanwhile, ISIS retains a host of features aimed at the PCB designer, so that the same design can be exported for production with ARES or other PCB layout software.

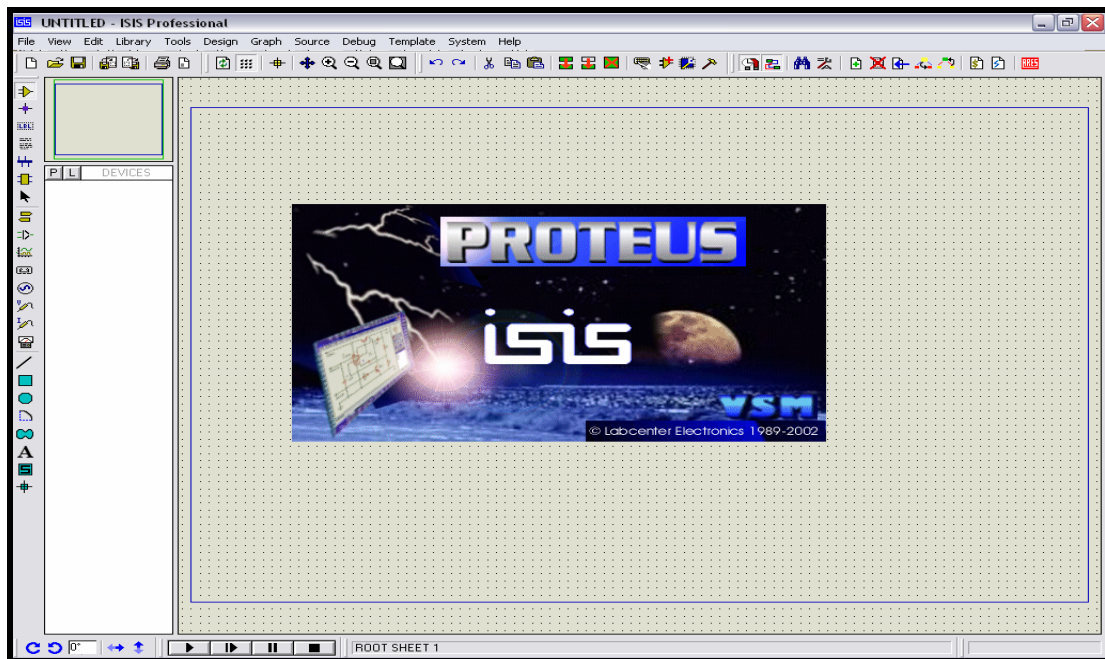
For the educational user and engineering author, ISIS also excels at producing attractive schematics like you see in the magazines. It provides total control of drawing appearance in terms of line widths, fill styles, colors and fonts. In addition, a system of templates allows you to define a 'house style' and to copy the appearance of one drawing to another.

Other general features include:

- Runs on Windows 98/Me/2k/XP and later.
- Automatic wire routing and dot placement/removal.
- Powerful tools for selecting objects and assigning their properties.
- Total support for buses including component pins, inter-sheet terminals, module ports and wires.
- Bill of Materials and Electrical Rules Check reports.
- Netlist outputs to suit all popular PCB layout tools.

For the 'power user', ISIS incorporates a number of features which aid in the management of large designs. Indeed, a number of our customers have used it to produce designs containing many thousands of components.

- Hierarchical design with support for parameterized component values on sub-circuits.
  - Design Global Annotation allowing multiple instances of a sub-circuit to have different component references.
  - Automatic Annotation - the ability to number the components automatically.
- ASCII Data Import - .this facility provides the means to automatically bring component stock codes and costs into ISIS design or library files where they can then be incorporated or even totaled up in the Bill of Materials report.



**Figure 2.10:** Window Of Isis Professional Software

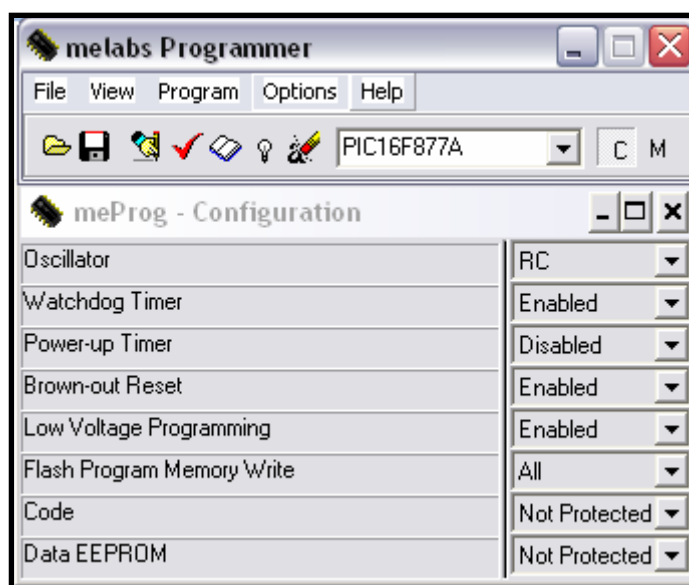
### 2.13.3 Melabs Programmer

The melabs Programmer can program most PIC<sup>®</sup> microcontrollers (MCUs) either in-circuit or in an optional ZIF, surface-mount or PLCC adapter. It will not program the base-line PIC16C5x parts or the high-end PIC17C4x parts. The melabs EPIC<sup>™</sup> Programmer and melabs Serial Programmer are powered from an AC adapter, available separately. A 16VDC, 500ma, center pin positive AC adapter is recommended. A suitable AC adapter is available from us. The melabs USB Programmer and melabs U2 Programmer are powered from the USB port. The melabs EPIC<sup>™</sup> Programmer connects to a PC compatible parallel printer port. The melabs Serial Programmer connects to a PC compatible serial port. The melabs USB Programmer and melabs U2 Programmer connect to a PC USB port or powered USB hub. Each programmer may be controlled by the melabs Programmer software.

HEX files may be programmed into a PIC<sup>®</sup> MCU using the melabs Programmer software. The software runs under Windows 98/ME/NT/2000/XP.Start

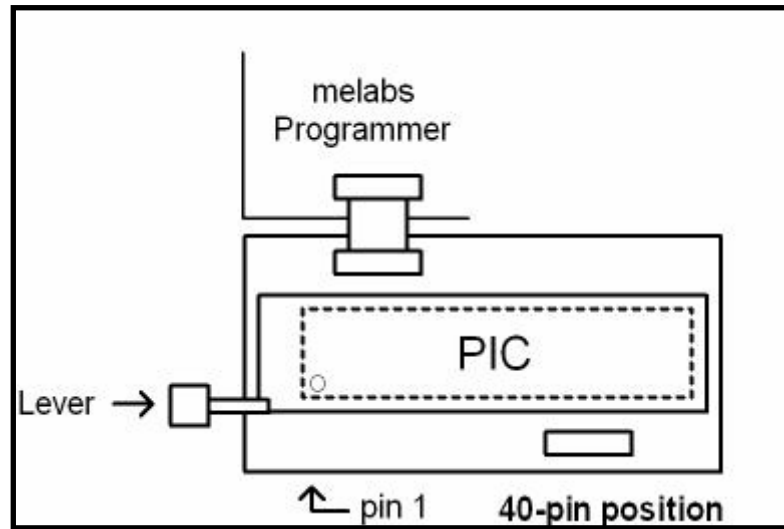
the melabs Programmer software by double-clicking on the melabs Programmer icon on the desktop or selecting melabs Programmer from the Start menu. All the melabs Programmer files must be in the same directory MEPROG.EXE resides in and the melabs Programmer directory should be in your path so that Windows can find the device drivers.

Once the programming tool-bar is displayed, select the LPT port the melabs EPIC™ Programmer is connected to or the serial COM port the melabs Serial Programmer is connected to or the USB port the melabs USB / U2 Programmer is connected to on the File|Port menu. Next, select the device type you wish to program using the drop-down device selector box. Click the Open button or File|Open with the mouse to open your object (.HEX) file. Double-click on the appropriate file to load it. Once the file has been loaded, make sure the proper device characteristics are selected in the Configuration window. See the Microchip data book for the device for information on the configuration fuses.



**Figure 2.11:** Window For Melabs Programmer





**Figure 2.12:** Zif (Zero Insertion Force) Connection For Pic 40 Pins

