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# MICROCONTROLLER BASED VOLTAGE AND CURRENT MEASURING DEVICE

**Sreeram V**
Alumni, CUSAT,
College of Engineering Adoor,
Kollam, Kerala, India

## ABSTRACT

*Measurement plays a significant role in achieving goals and objectives of engineering because of the feedback information supplied by them. The advancement of science and technology is dependent upon parallel progress in measurement techniques. As per the modern measuring instrument requirements aiming high sensitivity, faster response, greater flexibility, low cost and less time consumption there has been a tremendous intrusion of electronic components in this area. Among them the microcontrollers play a vital role.*

*This research paper aims at introducing a prototype of voltage and current measuring device so as to monitor a load in a simple and less expensive manner. In this paper, the parameters are measured with the help of PIC microcontroller (16F877A). The current and voltage signals are acquired from the load circuit by using current and voltage sensing circuits. The outputs of the sensing circuit are fed to the 10 bit ADC of a PIC microcontroller. The voltage and current signals are processed and their instantaneous values are displayed on LCD screen. An indication for under voltage and over voltage is also provides in display. So this device helps in effectively monitoring the status of a load circuit*

**KEYWORDS:** *Voltage and current measuring device, microcontroller based device*

## 1. INTRODUCTION

The efficient operation of an electrical system depends on the measurement and monitoring of various circuit parameters of the system. In order to have proper control over the system, it is essential that the voltage and current of that system have to be monitored. Also, the measurement of voltage and current at the load terminal in a circuit is essential to judge the overall performance of the load. This project focuses on the design and implementation reliable measuring system using a PIC microcontroller. The voltage and current in a load circuit is monitored, measured and are displayed on a liquid crystal display. The advantage of using PIC microcontroller is that it has an inbuilt 10bit ADC and have sufficient ports for interfacing the sensing and annunciation circuits.

The current sensor and voltage sensing circuits in-put analogue values to the microcontroller and it is then converted to digital value by the inbuilt ADC. The circuit is designed with a safety mechanism that if there is any variation in the input voltage such as low voltage or high voltage, an alarm system will be enabled.

## 2. DIGITAL MEASURING DEVICE

The prime requirement of a measuring device is the sense the respective parameters in a circuit. In this project, the device measures the voltage and current at the load terminals using voltage and current sensing circuits. The outputs of these circuits are brought to digital level so that it suits the input level of the PIC16F877A micro-controller. The LCD display in the device acts as the human interface of the system, which shows the instantaneous rms voltage and current values.

A buzzer is provided in the device for the indication of low voltage and under voltage conditions. A regulated power supply is used for providing working voltage for the circuit components such as PIC microcontroller, current sensor, LCD display and buzzer

### 2.1. BLOCK DIAGRAM DESCRIPTION

The basic block diagram of digital measuring device consist of a power supply, voltage sensing circuit, current sensing circuit, PIC microcontroller , LCD display and a buzzer. Here the in-puts are fed to the voltage sensing circuit and cur-rent sensing circuit. The output consists of LCD and buzzer. Fig 1 shows the basic block diagram of the circuit.

#### 2.1.1. Power Supply

A stable regulated dc power supply is essential for the operation of LCD display, PIC microcontroller, current sensor and buzzer. The 230V ac input voltage is transformed to 12V ac by a step down transformer. The output of the transformer is fed to a bridge rectifier (DF10M). A 5 V regulator, 7805 is used for obtaining a constant dc output voltage of the power supply.

#### 2.1.2. Voltage Sensing Circuit

Voltage sensing circuit is used to acquire the voltage applied to the load. The project devices a step down transformer (230/12-0-12),a voltage divider network and a capacitor charging circuit for sensing the voltage. The voltage signal is stepped down to a desired value using the transformer and voltage divider network. This signal is applied to the microcontroller through a capacitor charging circuit for further processing.

#### 2.1.3. Current Sensing Circuit

Current sensing circuit is used to acquire the load current signal. It is connected in series with the load. It consists of a current sensor (ACS706ELC), deferential amplifier circuit and a capacitor charging circuit. The output of current sensor is 350mV for 1A current. LM358 op-amp is used in the deferential amplifier circuit. This signal is applied to the microcontroller through a capacitor charging circuit for further processing.

#### 2.1.4. Microcontroller

PIC is a family of modified Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC is referred to "Peripheral Interface Controller". PICs are popular among both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. A 16F877A PIC microcontroller is used in the circuit. It is a 40 pin IC with 5 I/O ports. It has 35 single-word instructions with wide operating voltage range 2.0 V to 5.5 V. The maximum clock input is 20MHz. Its machine cycle consist of 4 clock pulses.

#### 2.1.5. LCD Module

A liquid crystal display (LCD) is an electronically modulated optical amplification device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystal and arrayed in front of a light source (backlight) or reflector. LCDs like 16 2, 24 2, 32 2, 20 4 etc. are available commonly. It is often utilized in battery powered electronic de-vices because it uses very small amounts of electric power. Small monochrome displays have a passive-matrix structure employing super-twisted pneumatic (STN) or double-layer STN (DSTN) technology. Each row or column of the display has a single electrical circuit. The pixels are addressed one at a time by row and column addresses. This type of display is called passive-matrix addressed because the pixel must retain its state between refreshes without the benefit of a steady electrical charge. As the number of pixels increases, this type of display becomes less feasible. Very slow response time and poor contrast are typical characteristics of passive-matrix addressed LCDs.

In this paper a 16 x 2 alphanumeric is used as the display device. It has three control lines plus the 8 data lines. The data lines are DB0 – DB7 and the control lines are RS,R/W and E. The logic supply voltage is in the range of 4.5-5.5V.

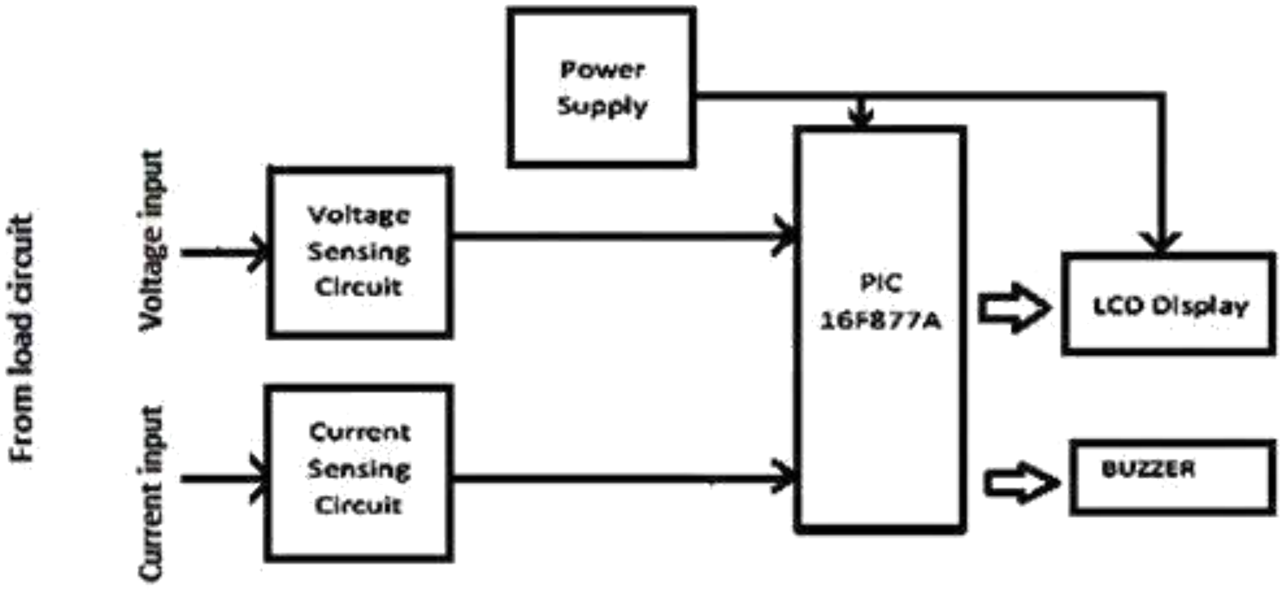


**Figure 1: Basic block diagram of digital measuring device.**

The minimum supply current is 3mA. The LCD is interfaced to the PIC microcontroller and displays the instantaneous voltage and current.

### 2.1.6. Buzzer

A buzzer can be mechanical, electromechanical, magnetic, electromagnetic, electro-acoustic or piezoelectric audio signaling device. A piezoelectric buzzer can be driven by an oscillating electronic circuit or other audio signal source. In this paper a piezoelectric buzzer is switched on when the voltage falls below 200V or raised above 240V.

## 3. DEVELOPMENT OF HARDWARE

A detailed description of power supply, voltage sensing circuit, current sensing circuit, PIC microcontroller interfacing, LCD, buzzer etc. are discussed in this chapter. The circuit has been developed for measuring the range of maximum 5A current and 290V across the load

### 3.1. POWER SUPPLY

The power supply consists of a step down trans-former, bridge rectifier, capacitor filter, and a regulator IC. The Fig.2 shows the power supply.

### 3.1.1. Transformer

Transformer is a static ac machine that transfers electrical energy from one circuit to another without any change in frequency, by the principle of electromagnetic induction J.B.Gupta . It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in cur-rent. The physical basis of a transformer is mutual induction between two-circuits linked by a common magnetic flux. In its simplest form, it consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance. The two coils possess high mutual inductance. When one coil is connected to a source of rated alternating voltage, an alternating flux is set up in the laminated core, which is linked with the other coil that produces a mutually-induced emf (according to Faraday's Law of Electromagnetic Induction). If the second coil circuit is closed, a current flows in it, hence electric energy is transferred (entirely magnetically) from first coil to the second coil. The first coil, to which electric energy is fed from the ac supply mains, is called primary winding and the other from which energy is drawn out is called secondary winding. Except for air-core trans- formers, the coils are commonly wound around a single iron-rich core, or around separate but magnetically-coupled cores.

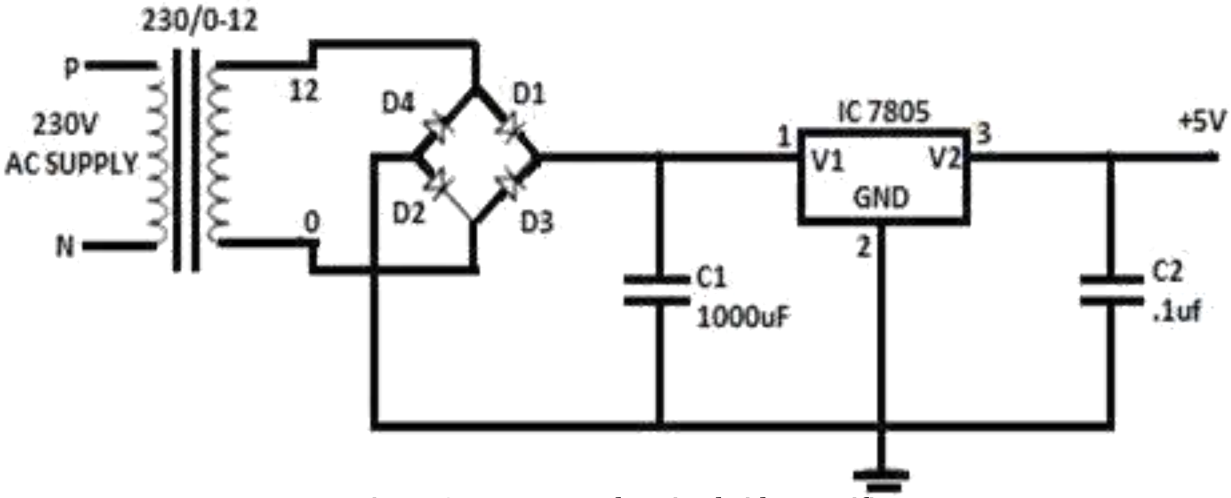


**Figure 2: Power supply using bridge rectifier**

Voltage may be stepped up or down depending on the design of the primary and secondary windings. A 230/0-12V transformer is used in the circuit to step down high voltage ac to a desired low voltage of 12V so that it lies in the input range of voltage regulator

### 3.1.2. Bridge Rectifier

In a bridge rectifier circuit 310 (1984) , four diodes are connected in the form of a Wheat-stone bridge where the two junctions of the bridge are connected to the secondary of a transformer and the other two are connected to the load. For a bridge rectifier circuit, when the upper end of the transformer secondary winding is positive, say during first half cycle of the input supply, diodes D1 and D2 are forward biased and this diodes carry the load current. During this half of in-put cycle diodes D3 and D4 are reverse biased. During the second half of input cycle the lower end of ac supply become positive, diodes D3 and D4 are forward biased and current flows to the load through these diodes. The direction of load current remains the same during both half cycle of the input supply voltage. This circuit not only produces a DC output from an AC input, but also provides a "reverse polarity protection".

In this paper, DF10M bridge rectifier is used. It has a glass passivated die construction. The main feature of this rectifier is that it has low forward voltage drop and high current capability. The peak surge overload current rating is 50A. It is designed for printed circuit board applications. Its main specifications are:

Peak Non-Repetitive Forward Surge Current - 50A

Peak Reverse Current - 10 A

Peak Reverse Repetitive Voltage - 1000V

Peak Reverse Voltage (rms) - 700V

### 3.1.3. Capacitor Filter

Capacitor filter is the simplest form of filter circuit. The filter action of this circuit depends upon the fact that the capacitor stores energy during the conduction period and delivers this energy to the load during the inverse or non-conducting period. In this way, the time during which the cur-rent passes through the load is prolonged and the ripple is considerably decreased. A 1000 F (C1) capacitor is used as a filter by connecting it in parallel to the load circuit and a 0.1 F (C2) capacitor
is connected across the regulator for eliminating the noise. With this capacitor filter arrangement the ripple has been limited to a level of 3% in the output circuit.

### 3.1.4. Voltage Regulator

A voltage regulator is a device that maintains a relatively constant output voltage even though its input voltage is varying. The voltage regulator is needed to keep voltages within the prescribed range that can be tolerated by the electrical equipment connected to its output circuit. A voltage regulator functions by comparing its output volt-age to a fixed reference and minimizing this difference with a negative feedback loop.

The 7805 family is commonly used as voltage regulator in electronic circuits which requires a regulated power supply, due to their ease-of-use and low cost. For ICs in this family, the 7805 has a 5 volt output, while the 7812 produces 12 volts. The 7805 series are positive voltage regulators: they produce a voltage that is positive relative to a common ground.

7805 ICs have three terminals named as input, output and ground. The output of bridge rectifier is fed to the input terminal of the regulator and 5V dc regulated supply is obtained from output terminal. The negative terminal is common and is grounded.

## 3.2. VOLTAGE SENSING CIRCUIT

The voltage sensing circuit consists of a 230/12-0-12 step down transformer, voltage divider net-work and a capacitor circuit. The primary of the transformer is connected across the load so that the voltage across the load is stepped down to a low value is obtained at its secondary. This volt-age is reduced to a safe value through a voltage divider network. The potentiometer used in the voltage divider network helps in calibration of the sensing circuit. Fig 3 shows a voltage sensing circuit. The capacitor is used for obtaining a stable dc output. Hence the voltage sensing circuit in-puts a fixed dc analog input corresponding to the peak of the input voltage, to the ADC of PIC microcontroller.

### 3.2.1. Diode 1N4148

The 1N4148 is a general-purpose discrete diode with high switching speed. It has modest maxi-mum current rating and a reverse voltage rating. The 1N4148 is a standard silicon switching diode. It is a commonly used signal diode. This is useful for bread boarding of circuits. The 1N4148 is useful in switching applications up to about 100 MHz with a reverse recovery time of not more than 4 ns.

Maximum repetitive reverse voltage, $V_{RRM}$ = 100 V
Average rectified forward current, $I_O$ = 200 mA
Maximum direct forward current, $I_F$ = 300 mA
$V_F$ = 1.0 V at 10 mA.
non-repetitive peak forward surge current, $I_{F\,SM}$ = 1.0 A (pulse width = 1 s), 4.0 A (pulse width = 1 s)
power dissipation, $P_D$ = 500 mW
reverse-recovery time, $T_{RR}$ < 4 ns

## 3.3. CURRENT SENSING CIRCUIT

The current sensing circuit consists of a current sensor (ACS706ELC), a deferential amplifier circuit and a capacitor charging circuit. The current sensing circuit is connected in series with the circuit. A preset resistance is used for calibration of the meter.

### 3.3.1. Current Sensor

A current sensor is a device that detects electric current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output. It can be then utilized to display the measured current in an ammeter or can be stored for further analysis in a data acquisition system or can be utilized for control purpose.

The sensed current and the output signal can be:

Alternating current input,

- Analog output, which duplicates the wave shape of the sensed current

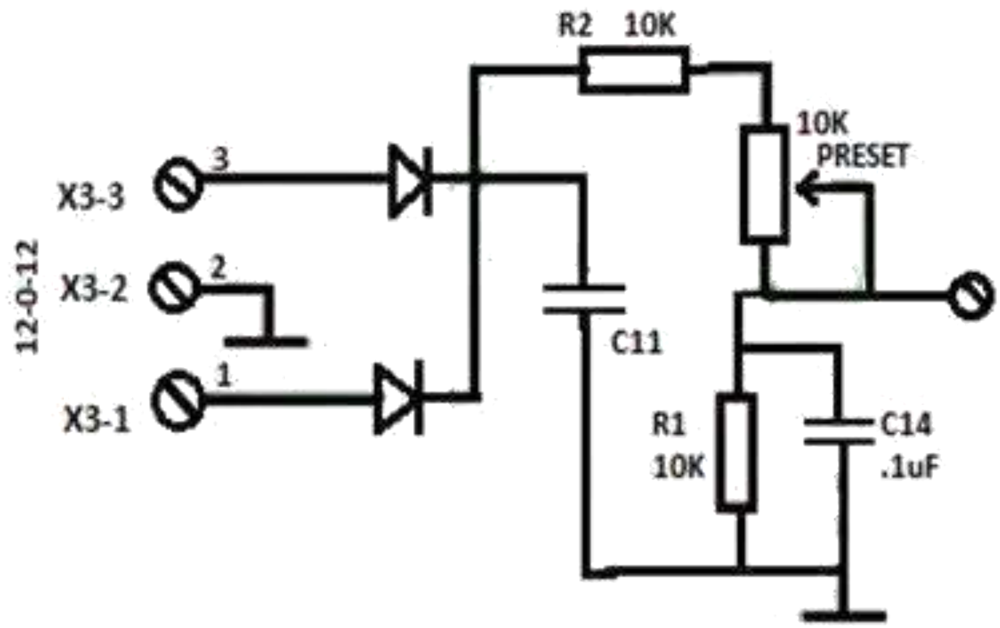


**Figure 3: Voltage sensingcircuit**

- Bipolar output, which duplicates the wave shape of the sensed current
- Unipolar output, which is proportional to the average or RMS value of the sensed current.

Direct current input,

- Unipolar, with a unipolar output, which duplicates the wave shape of the sensed current
- Digital output, which switches when the sensed current exceeds a certain threshold

Here a current sensor (ACS706ELC) is used for sensing current. The output voltage is proportional to ac peak and dc currents. The output of current sensor is 350mV for 1A current. It is an excellent replacement for sense resistors. Its single supply operation range varies from 4.5 to 5.5V

### 3.3.2. Deferential Amplifier

A deferential amplifier is a type of electronic amplifier that amplifies the deference between two input voltages but suppresses any voltage common to the two inputs. It is an analog circuit with two inputs $V_{in}$ and $V+_{in}$ at pins 5 and 7 of the current sensor and one output $V_{out}$ in which the output is ideally proportional to the deference between the two voltage $V_{out} = A(V^+_{in} - V_{in})$ where A is the gain of the amplifier. Many electronic devices use deferential amplifiers internally. The output of an ideal deferential amplifier $V_{out}=A_d(V^+_{in} - V_{in})$ Where $V^+_{in}$ and $V_{in}$ are the input voltages and $A_d$ is the deferential gain. In practice, however, the gain is not quite equal for the two inputs. This means, for instance, that if $V+_{in}$ and $V_{in}$ are equal the output will not be zero, as it would be in the ideal case. A more realistic expression for the output of a deferential amplifier thus includes a second term.

$$V_{out} = A_d(V^+_{in} - V_{in}) + A_c(V^+_{in} + V_{in})/$$

$2A_c$ is called the common-mode gain of the amplifier. As deferential amplifiers are often used to null out noise or bias-voltages that appear at both inputs, a low common-mode gain is usually desired. The current sensing circuit is shown in the fig 4.

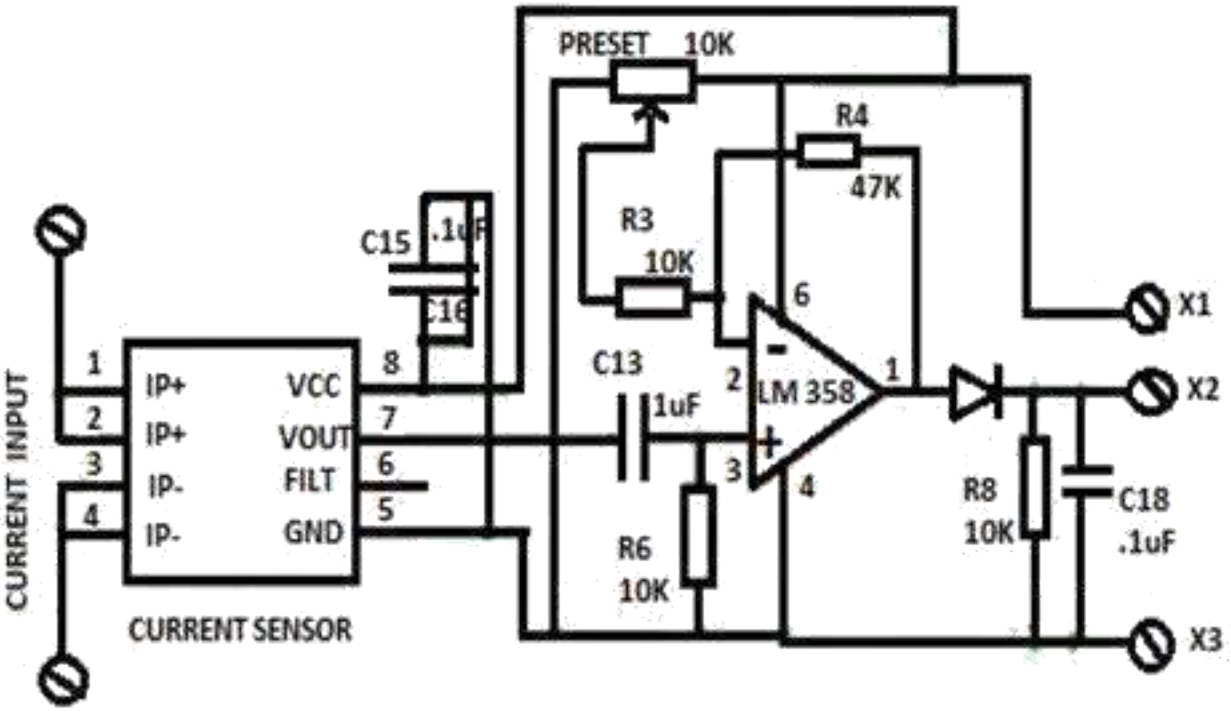


**Figure 4: Current sensing circuit**

The common-mode rejection ratio (CMRR), usually defined as the ratio between deferential-mode gain and common-mode gain, indicates the ability of the amplifier to accurately cancel volt-ages that are common to both inputs. The common-mode rejection ratio is defined as:

CMRR= $10\log_{10}(A_d/A_c)^2 = 20\log_{10}(A_d/A_c)$ In a perfectly symmetrical deferential amplifier, $A_c$ is zero and the CMRR is infinite. Note that a deferential amplifier is a more general form of amplifier than one with a single input; by grounding one input of a deferential amplifier, a single-ended amplifier results

## 3.4. PIC MICROCONTROLLER

PIC is referred to "Peripheral Interface Controller". PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. A 16F877A PIC microcontroller is used in the circuit. It is a 40 pin IC with 5 I/O ports. It has 35 single-word instructions with wide operating voltage range 2.0 V to 5.5 V. The maximum clock input is 20MHz. Its machine cycle consist of 4 clock pulses. Fig 5 shows the pictorial representation of PIC16F877A.

### 3.4.1. Features

The main, peripheral and special features of a PIC IC are listed below Mazidi :

**Main Features**

Operating speed: DC – 20 MHz clock input DC – 200 ns instruction cycle

Memory: Up to 8K x 14 words of Flash Pro-gram Memory,

Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory Low-power, high-speed Flash/EEPROM technology

Fully static design

Wide operating voltage range (2.0V to 5.5V) Commercial and Industrial temperature ranges

**Peripheral Features**

Timer 0: 8-bit timer/counter with 8-bit prescaler


**Figure 5: PIC16F877Amicrocontroller**

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

Synchronous Serial Port (SSP) (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

Special Microcontroller Features

100,000 erase/write cycle Enhanced Flash program memory typical

1,000,000 erase/write cycle Data EEPROM memory typical

Data EEPROM Retention > 40 years

Self-reprogrammable under software control In-Circuit Serial Programming (ICSP) via two Pins

Single-supply 5V In-Circuit Serial Programming

Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation

Power saving Sleep mode

Selectable oscillator options

In-Circuit Debug (ICD) via two pins

### 3.4.2. Pin-out diagram

The IC has 40 pin and all this pins are shown in Fig 6

### 3.4.3. Pin Description

The brief description of each pin is shown in Table 1

### 3.4.4. Architecture

Program Counter and Stack

PC is used to keep the track of the program execution by holding the address of the current instruction. The counter is automatically incremented to the next instruction during the current instruction execution. The PIC16F87XA family has an 8-level deep stack.

Capture/Compare/PWM Modules

Each Capture/Compare/PWM (CCP) module contains a 16-bit register which can operate as a:

- 16-bit Capture register
- 16-bit Compare register
- PWM Master/Slave Duty Cycle register r

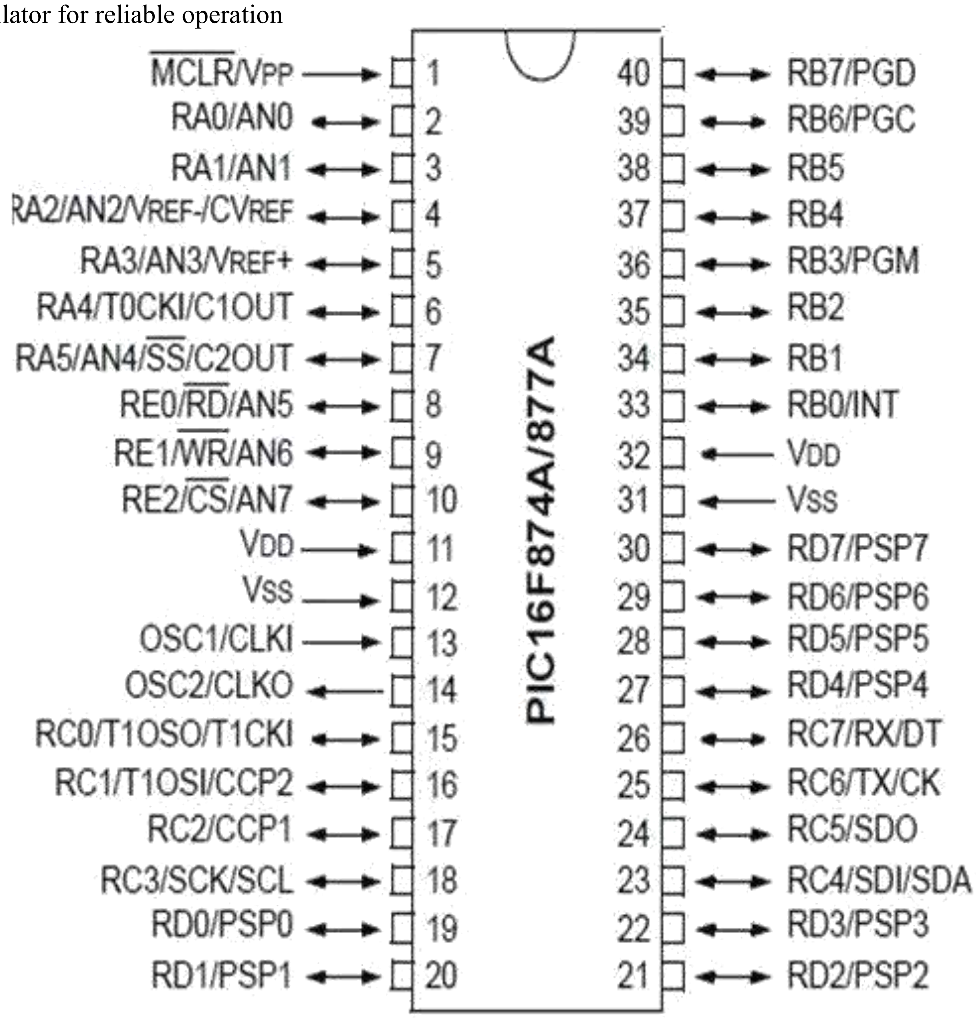


**Figure 6: Pin-out of PIC16F877A**

Both the CCP1 and CCP2 modules are identical in operation, with the exception being the operation of the special event trigger.

Master SSP (MSSP) Module

The Master Synchronous Serial Port (MSSP) module is a serial interface, useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be serial EEPROMs, shift registers, display drivers, A/D converters, etc. The MSSP module can operate in one of the two modes:

- Serial Peripheral Interface (SPI) or
- Inter-Integrated Circuit (I2C) or
- Full Master mode
- Slave mode (with general address call)r

**Table 1: Pin description ofPIC16F877A**

| Pin number | Pin name | Description |
|---|---|---|
| 1 | MCLR | active low reset to the device |
| 2-7 | RA0-RA5 | 5 bit analog input pins (PORT A) |
| 33-40 | RB0-RB7 | 7 bit digital input/output pins (PORT B) |
| 15-18 | RC0-RC7 | 7 bit digital input/output pins (PORT C) |
| 23-26 | | |
| 19-22 | RD0-RD7 | 7 bit digital input/output pins (PORT D) |
| 27-30 | | |
| 8-10 | RE0-RE2 | 3 bit analog input/output pins (PORT E) |
| 13 | OSC1 | oscillator crystal or external clock input |
| 14 | OSC2 | oscillator crystal or external clock output |
| 12,31 | VSS | reference ground |
| 11,32 | VDD | positive supply |

Addressable Universal Synchronous Asynchronous Receiver Transmitter

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules (USART is also known as a Serial Communications Interface or SCI). The USART can be configured as a full-duplex asynchronous system that can communicate with peripheral devices, such as CRT terminals and personal computers, or it can be configured as a half-duplex synchronous system that can communicate with peripheral devices, such as A/D or D/A integrated circuits, serial EEPROMs etc. The US-ART can be configured in the following modes:

- Asynchronous (full-duplex)tor
- Synchronous r

The USART module also has a multi-processor communication capability using 9-bit address detection.

### Analog-To-Digital Converter (A/D) Module

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the 40/44-pin devices. The conversion of an analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low voltage reference input that is software selectable to some combination of VDD, VSS, RA2 or RA3. The A/D converter has a unique feature of being able to operate while the device is in Sleep mode. To operate in Sleep, the A/D clock must be derived from the A/D's internal RC oscillator

### Power-Up Timer (PWRT)

The Power-up Timer provides a fixed 72 ms nominal time-out on power-up only from the POR. The Power-up Timer operates on an internal RC oscillator. The chip is kept in Reset as long as the PWRT is active. The PWRT's time delay allows VDD to rise to an acceptable level. A configuration bit is provided to enable or disable the PWRT.

### Oscillator Start-Up Timer (OST)

The Oscillator Start-up Timer (OST) provides a delay of 1024 oscillator cycles (from OSC1 in-put) after the PWRT delay is over (if PWRT is enabled). This helps to ensure that the crystal oscillator or resonator has started and stabilized. The OST time-out is invoked only for XT, LP and HS modes and only on Power-on Reset or wake-up from Sleep.

### Brown-Out Reset (BOR)

The configuration bit, BODEN, can enable or disable the Brown-out Reset circuit .If VDD falls below VBOR (about 4V) for longer than TBOR (about 100 S), the brown-out situation will re-set the device. If VDD fall a Reset may not occur. Once the brown-out occurs, the device will remain in Brownout Reset until VDD rises above VBOR. The Power-up Timer then keeps the device in Re-set for TPWRT (about 72 m S). If VDD should fall below VBOR during TPWRT, the Brown-out Reset process will restart when VDD rises above VBOR with the Power-up Timer Reset.

### Watchdog Timer (WDT)

The Watchdog Timer is a free running, on-chip RC oscillator which does not require any external components. This RC oscillator is separate from the RC oscillator of the OSC1/CLKI pin. During normal operation, a WDT time-out generates a device Reset (Watchdog Timer Reset). If the device is in Sleep mode, a WDT time-out causes the device to wake-up and continue with normal operation (Watchdog Timer Wake-up). The TO bit in the Status register will be cleared upon a Watchdog Timer time-out. The WDT can be permanently disabled by clearing configuration bit, WDTE.

### 3.4.5. Architectural Block Diagram

Fig 7 shows detailed architectural block diagram of a PIC16F877A. Harvard computer model, The memory of this chip which was referred to earlier is its data memory. Separate memories for program and data. Each with its own busses

The major advantage with this architecture is that while an instruction is being executed the next one can be fetched. The execution speed is doubled Its program memory has 14 bits in each location All instructions fit in one program memory location Data memory data bus has 8 wires and address bus has 9 wires. Program memory data bus has 14 wires and address bus has 13 wires

A Register is the same as a memory location An assembler is a program which translates assembly code into machine code and writes this code in an output file. This output file has the extension *.HEX. Almost all assembly instructions involve a movement between the data memory and a working register in the CPU which is called W

An instruction is in other words completely defined with a number between 0x0000 and 0x3FFF Every instruction in PIC16F877 is represented by a 14 bit binary number. If the instruction involves a move to or from a data memory location the address of this memory location will be contained in the instruction.

### 3.5. RELAYS

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switch-ing mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a power circuit using a low-power signal or where several circuits must be controlled by one signal. Solid-state relays con-trol power circuits with no moving parts, instead using a semiconductor device to perform switch-ing. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults. In electric power systems these functions are performed by digital instruments still called "protective relays".

A relay switch can be divided into two parts: input and output. The input section has a coil which generates magnetic field when a small volt-age from an electronic circuit is applied to it. The output section consists of contacts which connect or disconnect mechanically. In a basic relay there are three contacts: normally open (NO), normally closed (NC) and common (COM). At no input state, the COM is connected to NC. When the operating voltage is applied the relay coil gets energized and the COM changes contact to NO. Different relay configurations are available like SPST, SPDT, DPDT etc, which have different number of changeover contacts. By using proper selection of contacts, the electrical circuit can be switched on and off.

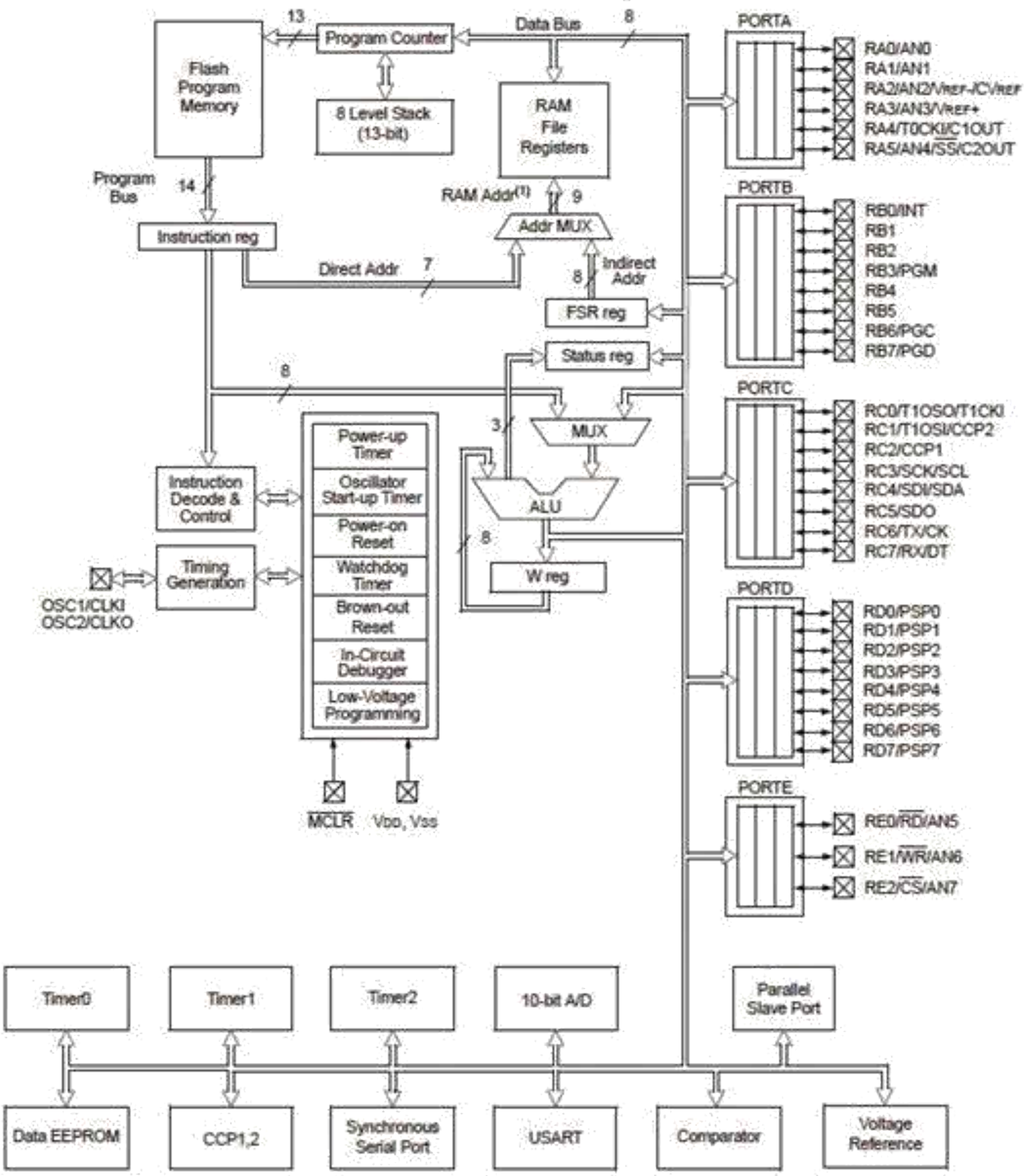


**Figure 7: Architectural Block diagram of PIC16F877A**

### 3.6. CRYSTAL OSCILLATORS

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators, but other piezoelectric materials including polycrystalline ceramics are used in similar circuits.

Quartz crystals are manufactured for frequencies from a few tens of kilohertz to hundreds of megahertz. More than two billion crystals are manufactured annually. Most are used for consumer devices such as wristwatches, clocks, radios, computers, and cellphones. Quartz crystals are also found inside test and measurement equipment, such as counters, signal generators, and oscilloscopes. A 20MHz crystal oscillator is used in the circuit for providing stable clock signal for the PIC microcontroller.

### 3.7. TRANSISTOR

A transistor is a semiconductor (three terminal) device mainly used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor terminals (input terminals) changes the current through another pair of terminals (out-put terminals). Because the controlled (output) power can be higher than the controlling (input) power with proper voltage biasing. Hence a transistor acts as amplifier to the input signal.

In this paper BC547 is used to drive the buzzer for indication. BC547 is an NPN bipolar junction transistor. BC547 is mainly used for amplification and switching purpose. It has a maximum current gain of 800. Its equivalent transistors are BC548 & BC549.

The transistor terminals require a fixed DC voltage to operate in the desired region of its characteristics curves. This is known as the biasing. For amplification applications, the transistor is biased such that it is partly on for all input conditions. The input signal at base is amplified and taken at the emitter. BC547 is used in common emitter configuration for amplifier. The voltage divider is the commonly used biasing mode. For switching applications, transistor is biased so that it remains fully on if there is a signal at its base. In the absence of base signal, it gets completely off. Here a BC547 transistor is used to drive the buzzer and it is also used for the switching purpose for relay mechanism.

### 3.8. LIQUID CRYSTAL DISPLAY

In this paper the output is displayed in an LCD screen. A 16x2 alphanumeric LCD module is used for displaying all the measured values. These displays contain two internal byte-wide registers, one for command and the other for characters to be displayed. There are three control signals namely R/W, RS, En and 8 data lines are used for interfacing with the PIC. In the circuit four data buses (DB4-DB7) and two control lines (RS, E) are used. All other data buses and control lines are grounded. A 16x2 LCD Module is shown in Fig 8

#### 3.8.1. LCD pin details

The LCD discussed in this section has 16 pins.
The functions of each pin is discussed below[6].

VCC, VSS and VEE

While Vcc and Vss supplies +5V and ground respectively, VEE is used to control LCD contrast.

Register Select(RS)

There are two very important registers inside the LCD. The RS pin is used for their selection as follows. If RS=0, the instruction command code register is selected, allowing the user to send a command such as clear display, cursor at home, and so on. If RS=1 the data register is selected, allowing the user to send data to be displayed on the LCD.

Read/write(R/W)

R/W input allows the user to write information to the LCD or read information from it. R/W=1 when reading; R/W=0 when writing.

Enable (E)

The enable pin is used by the LCD to latch information presented to its data pins. When data is supplied to data pins, a high-to-low pulse must be applied to the En pin in order for the LCD to latch in the data present at the data pins. This pulse must be a minimum of 450 ns wide.

D0-D7

The 8-bit data lines D0-D7, are used to send information to the LCD or read the contents of the LCD's internal registers. The Table 2 below gives the pin description.

By making RS signal 0 we can send different commands to display. These commands are used to initialize LCD, to select display pattern, to shift cursor or screen etc.


**Figure 8: A 16x2 LCD Module**

### 3.8.2. LCD Interfacing

The fig 9 shows the LCD interfacing. Here Port D of the microcontroller is used as the 8-bit data bus for interfacing with the LCD. Here only 4 pins are used for interfacing and only 4 bits data are transferred. The pin 21 is connected to the pin 4(RS) of the LCD and pin 22 is connected to the pin 6(E) of the LCD. Only four pins of the LCD display are used for data transferring and the other four pins are grounded. R/W is grounded so as to write the data in the LCD display. VSS is also grounded. VDD is the supply pin. The Fig.9 shows the LCD connections.

## 4. CIRCUIT DESCRPTION

The hardware design and description of the circuits are detailed in this chapter. The working voltage for PIC microcontroller, current sensor, LCD display and buzzer is provided using a power supply module. It consists of 230/12V step down transformer, DF10M bridge rectifier, voltage regulator 7805 and capacitor filter. The output of power supply is a regulated +5v dc voltage. A voltage sensing circuit, current sensing circuit, LCD display and a buzzer is interfaced with the microcontroller PIC 16F877A. The voltage sensing circuit is connected parallel to the load and it measures voltage across the load. This circuit consist of a 230/12-0-12 transformer 4148 diode, voltage divider network and a capacitor charging network. The transformer and voltage divider network step downs high voltage across the load to a low value i.e. <5V, which do not damages the PIC microcontroller. The output is fed to pin 2 of the PIC microcontroller. Current sensing circuit consists of current sensor 16F877A and deferential amplifier network and it is connected in series to the load which measures the current in the circuit. A deferential amplifier is connected to the output side of the current sensor. The output of the deferential amplifier is 350 mV for 1A current. Its output is fed to the pin 3 of the IC 16F877A.

LCD display shows the corresponding voltage and current in the circuit. In the circuit 4 data buses (DB4-DB7) and 2 control lines(RS,E) are used. All other data buses and control lines are grounded. A 12V relay is used to switch the power supply. The buzzer is used for providing an alarm system. If any over voltage or under voltage condition arises in the circuit the alarm system will be switched on. Fig 10 shows the detailed circuit diagram of various blocks used for this mini paper.

### 4.1. DESIGN OF COMPONENTS

The design of various components used in the circuit is discussed below.

**Table 2: LCD pin description**

| Pin | Symbol | I/O | Descriptions |
|---|---|---|---|
| 1 | Vss | - | Ground |
| 2 | Vdd | - | +5V power supply |
| 3 | Vo | - | Power supply to control contrast |
| 4 | RS | 1 | RS = 0 to select command register<br>RS = 1 to select data register |
| 5 | R/W | 1 | R/W = 0 for write<br>R/W = 1 for read |
| 6 | E | I/O | Enable |
| 7 | DB0 | I/O | The 8- bit data bus |
| 8 | DB1 | I/O | The 8 -bit data bus |
| 9 | DB2 | I/O | The 8 -bit data bus |
| 10 | DB3 | I/O | The 8 -bit data bus |
| 11 | DB4 | I/O | The 8 -bit data bus |
| 12 | DB5 | I/O | The 8 -bit data bus |
| 13 | DB6 | I/O | The 8 -bit data bus |
| 14 | DB7 | I/O | The 8 -bit data bus |
| 15 | A | - | +4.2V for LED/Negative Voltage Output |
| 16 | K | - | Power Supply for B/L (OV) |

### 4.1.1. 7805 Voltage regulator

It is used to get a constant 5V supply to drive PIC microcontroller, LCD display, current sensor and buzzer etc. Input voltage range of 7805 volt-age regulator is 7-25 and output voltage range is 4.8-5.2V. Desired output of the power supply is 5V. Hence LM 7805 regulator is selected for this purpose. Hence 12V output transformer is selected.

### 4.1.2. Transformer

Transformer is a device which converts high voltage supply to low voltage value or vice versa. The input range of the LM 7805 regulator is 7-25V.

Hence 12V output transformer is selected. The input of the transformer is supplied from 230V main supply. The circuit has a power rating of 1A. Hence a 230/0-12V, 1A step down trans-former is used in the power supply.

A 12-0-12 transformer is used in the voltage sensing circuit. The input of the transformer is 230V

### 4.1.3. Capacitor

The capacitor is used to filter out the ripples in the dc output of rectifier. The capacitor value is selected so that the ripple content in the output dc voltage is limited to 3%.

The working load dc voltage(WLDC) and out-put voltage $V_o$ can be calculated using $V_{dcNL}$ ( no load dc voltage) as 310 (2009),

and the output is 24V. Hence a 230/12-0-12 transformer is selected. The output of the transformer is connected to the voltage dividing network.

Hence 2 transformers are used in the circuit. A 230/0-12 transformer is used in the power sup-ply and a 230/12-0-12 transformer is used in the voltage sensing circuit.

$WLDC = V_{dcNL} + 20\% \, V_{dcNL}$

$V_{dcNL}$ is found as follows

The output voltage $V_o$ can be written as

$V_o = I_L / 200C$

So for $I_L = 1$ A and selecting C = 1000 F

$V_{Lmin} = 8$ V

$V_{dcF\,L} = V_{Lmin} + V_o / 2 = 8 + 5/2 = 10.5$ V

$V_{dcF\,L}$ is related with $V_{dcNL}$ as

$VdcNL = VdcF\,L + Ro\,IL$

$R_o$ value is between 6 to 10 . Assuming $R_o$ as 8

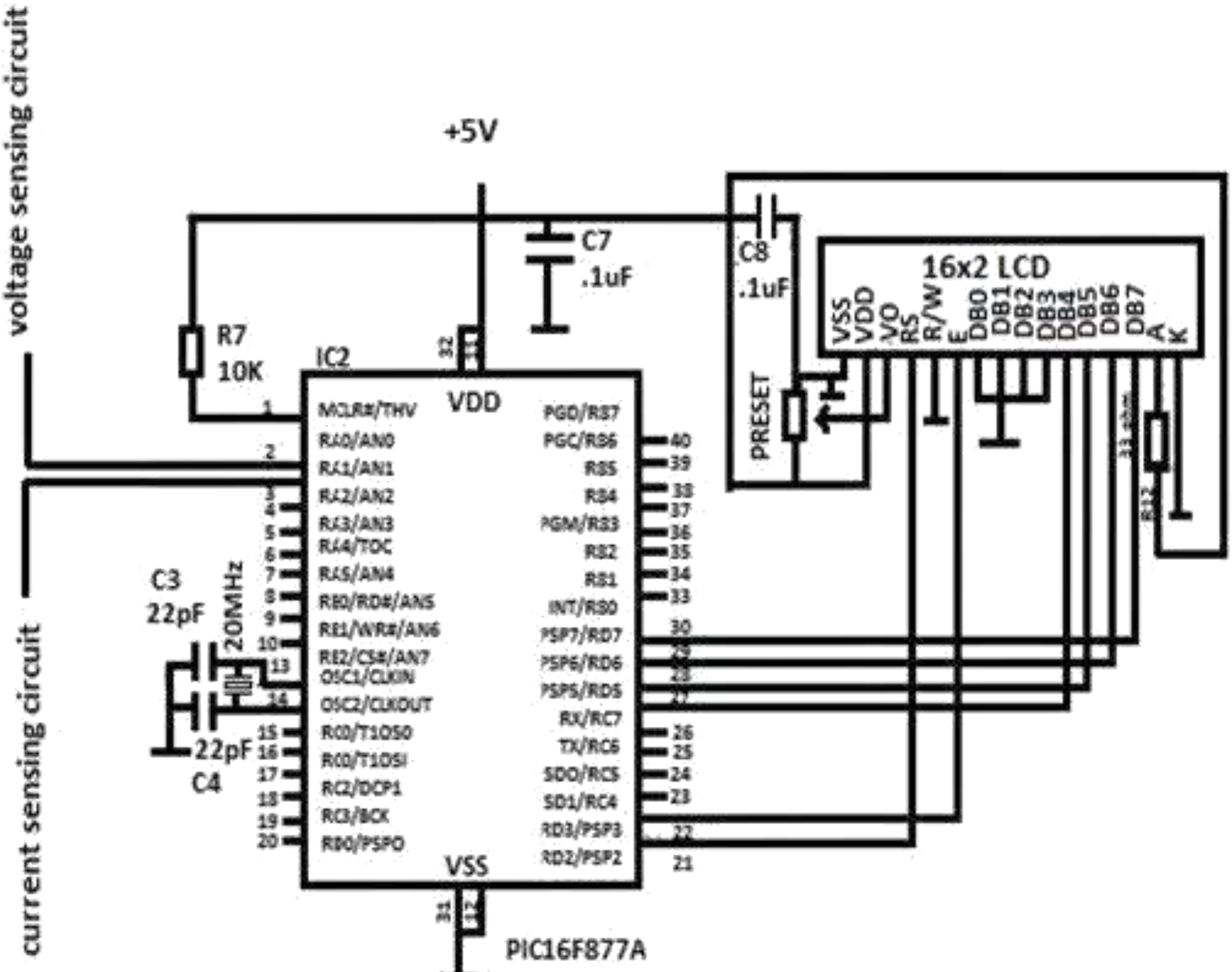


**Figure 9: Circuit schematic showing LCD interfacing**

$V_{dcNL}$ = 10.5 + 8 1= 18.5 V

The required WLDC is calculated as

WLDC = $V_{dcNL}$ + 20% $V_{dcNL}$ = 18.5 + 3.7 = 22.2 V

Always a higher value is desired. So a capacitor of 1000 f with WLDC of 25 V is chosen.

An output capacitor is required to suppress any spike or glitch in fixed output voltage that may oc-cur due to transient change in AC input. It's typ-ical value is 0.1 F as specified in 7805 datasheet.

The desired value of capacitor for crystal oscil-lator is between 10pF – 33pF as recommended in the data sheet, so 22pF capacitor is selected for the oscillator circuit.

### 4.1.4. Transistor

BC547 transistor is selected for the buzzer drive circuitso as to get 10mA current at collector side.

Selection of base resistor for BC547,

Forward current gain, $h_{fe}$ = 200 Collector current Ic= 100mA ,

Emitter current, Ie=100mA 200=0.0005mA R=V/I= 5/.0005= 10K

### 4.1.5. Voltage sensing circuit

R1=10K, R2=15K, Preset=10K

Now output of transformer= 12V

Maximum rectified output =12 1.41=16.92V

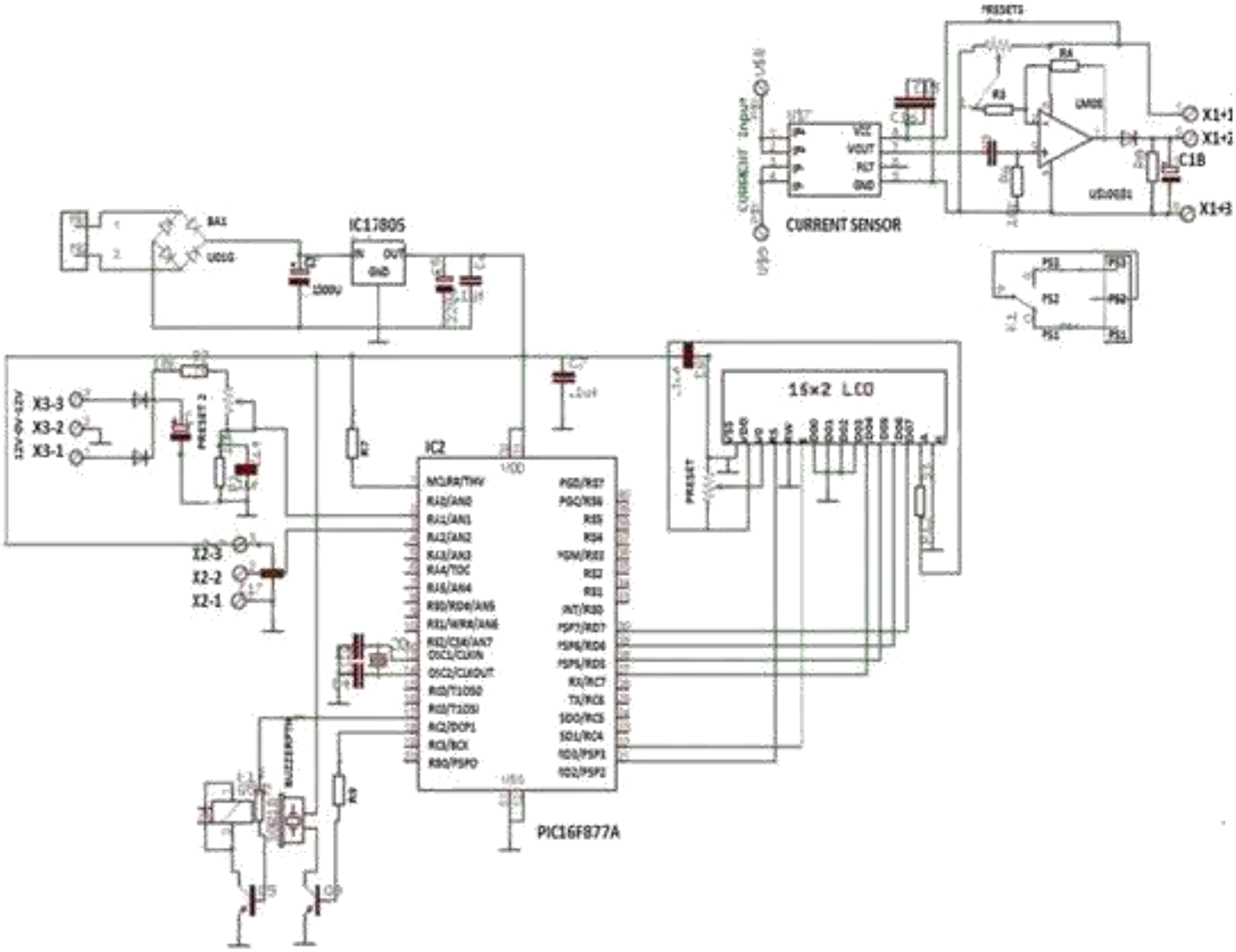


**Figure 10: Circuit diagram**

By using voltage divider rule, input voltage to pin 2(RAO ANO)

= (16.92 5.1) 20.3= 4V

Max ADC value for 10bit IC = 1024

ADC value=(Voltage on pin2(mV) Max ADC value)/Systemvoltage(mV)

= (Voltage on pin 2(mV) 1024) 5000

ADC value corresponding to 4V= (4000 1024) 5000=820

Max Pin voltage for IC (mV) = (1024 5000) 1024=5000mV=5V

i.e., max voltage that can be measured = (230 5) 4=290V

## 5. SOFTWARE DESCRIPTION AND SIMULATION RESULT

Software development is an important factor for programming a PIC microcontroller. The flowchart and the algorithm for developing the software is described in the following sections.

### 5.1. FLOWCHART

A flowchart is a type of diagram that represents an algorithm, workflow or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. Flowcharts are used in analyzing, designing, documenting or managing a process or program in various fields.

### 5.2. ALGORITHM

Algorithm is the method of writing the step by step instruction of the solution of a problem using any human language. It is a procedure or formulae for solving a problem and it aids in easier understanding of a program. The algorithm of the program is given below:

Step 1: Start

Step 2: Define ADC pins (AN0, AN1, AN3)

Step 3: Define variables voltage, current

Step 4: Initialize LCD display D0-D7,RS, E

Step 5: Enable output port C

Step 6: Read ADC value for voltage at pin 2 of the PIC

Step 7: Convert to voltage

ADC value= (Voltage on pin2(mV)*Max ADC value)/System voltage(mV)

Step 8: Read ADC value for current at third pin of the PIC

Step 9: Convert to current

ADC value= (Voltage on pin3(mV)*Max ADC value)/System voltage(mV)

Step 10: Display voltage, current in the LCD display.

Step 11: Check input voltage, and if output is above 240 volt or below 200 volt activate buzzer and go to step 6

### 5.3. SOFTWARES REQUIREMENTS

The software's which are used for this paper are MPLAB and PROTEUS PROFESSIONAL. Universal programmer WELLON is used to program the PIC microcontroller

#### 5.3.1. Mp lab

Mp lab Integrated Development Environment (IDE) is a free, integrated toolset for the development of embedded applications on PIC microcontrollers. It provides a broad range of development tools like C compiler, assemblers, debuggers, simulators linkers etc. for PIC microcontrollers. Hex code generated from Mp lab is used for programming the IC and also for circuit simulations.

#### 5.3.2. Proteus Professional

Proteus is a software for simulation, schematic capture and PCB design. This software allows us for modeling the circuit operation and is an invaluable analysis tool. Simulating a circuit's behavior before actually building it can greatly improve design efficiency. This also helps us to know if the circuit is working before we connect it in material.

#### 5.3.3. Wellon

It is a universal programmer used for a range of devices, including PIC microcontrollers, EEP-ROMs, AVR and other microcontrollers like AT89 series and flash memory. We can erase, check, and verify the data present in the IC using this soft-ware.

## 6. CONCLUSION

This paper work realizes an attempt to design a device which measures load parameters like volt-age and current using PIC microcontroller (PIC 16F877A) and display them in a single LCD module. There is a buzzer to indicate under voltage and over voltage conditions which helps in protection. The device monitors the load continuously displaying approximate peak values of voltage and current.

The proposed device is simple, less expensive and it makes the measurement effortless with very low power consumption. The analysis reveals that the device is efficient in monitoring the volt-age and current and can be enhanced to operate in other frequencies too by introducing a phase locked loop (PLL) mechanism. The device can be enhanced for measuring and monitoring 3-phase loads. Further development can be done by making provisions for power factor measurement and correction. The accuracy of the device can be improved by using Hall Effect transducers and proper signal conditioning circuits.

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