INTELLIGENT POWER FACTOR CORRECTOR FOR INDUSTRIAL LOADS

PROJECT REPORT

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

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CERTIFICATE

This is to certify that the project report entitled

INTELLIGENT POWER FACTOR CORRECTOR FOR INDUSTRIAL LOADS

Is the bonafide work done by

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Date: 9.3.2004

Head of the Department

Certified that the candidate ____________________ with

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TO WHOMSOEVER IT MAY CONCERN

This is to certify that the following Final year B.E. (EEE) bonafide students of Kumaraguru College of Technology, Coimbatore - 006 has successfully completed the project work titled "INTELLIGENT POWER FACTOR CORRECTOR FOR INDUSTRIAL LOADS" in our company for the following period from 26.11.2003 to 04.03.2004 under the supervision of Mr.M.Lakshminarayana, Manager - Works.

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During this period their conduct and character were found to be Very Good. We Wish them all the success in the future.

for SALZER ELECTRONICS LIMITED - UNIT II.,

M.LAKSHMINARAYANA
MANAGER - WORKS.

ACKNOWLEDGEMENT

Acknowledgement

The satisfaction that accompanies the successful completion of any task would be incomplete without the mention of the people whose constant guidance and encouragement crowns all effort with success.

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We would like to express our gratitude to our guide, **Mr. V.DURAISAMY, M.E., (Ph.D.).,** Asst Professor, Department of Electrical and Electronics, Kumaraguru College of Technology, who guided us throughout the project and encouraged us to successfully complete our work. Our thanks to him for his immense help and guidance during the course of the project.

We take pleasure in thanking **Mr. LAKSHMINARAYANA B.E.,** SALZER ELECTRONICS, for providing us with technical assistance and guiding us in this project.

We also extend our heartiest thanks to all other members of staff, supporting staff and family members without whose help this project would not have attained this form.

ABSTRACT

Abstract

Power factor is an indicator of health and efficiency of any power system. Power factor has to be regulated in industrial sectors to avoid paying high tariffs. In most of the industries, power factor correction is done manually. Poor power factor causes increased losses and also penalizes the customer. This explains the importance of our project in industrial environment. The reliability of this system is very low that it cannot adopt itself to the ever-growing demand for energy. Thus we go for an intelligence system that continuously monitors power factor and corrects it automatically.

Control of power factor leads to efficient usage of power. Penalty prevention will not only improve the industry's economy, but also automates the entire plant, thus avoiding human errors.

Voltage and current waveforms are sampled using instrument transformers. Then by using voltage and current sensing circuit actual values are measured. Precision rectifier unit is used for this purpose. Power factor is measured by finding the time difference between the high of voltage and current waveforms. The measured power factor is compared with a preset value and capacitor banks are switched on depending upon the difference between actual preset value and measured value. The micro controller is programmed using Hitech C. It is suitably programmed such that all parameters are measured accurately and displayed on the LCD.

The contents of microcontroller are transferred to the computer for reference and analysis. A suitable VB coding is written for the display of different parameters like current, voltage, power factor and status of the capacitor banks. The circuits are designed to give a highly accurate result.

This user-friendly system is very reliable and flexible. The power factor can be limited to any value, since the coding in PIC is not protected. Thus this system monitors power factor and corrects it automatically.

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INTRODUCTION

1. INTRODUCTION

1.1 Power factor

Power factor is the ratio between the KW and the KVA drawn by an electrical load where the KW is the actual load power and the KVA is the apparent load power. It is the cosine of the phase angle between the voltage and current waveforms. It is defined as the ratio of the current drawn that produces real work to the total current drawn from the source or supplier of the energy, such as the electric utility.

It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system. All current will cause losses in the supply and distribution system.

A poor power factor can be the result of either a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or distorted / discontinuous current waveform.

Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder or induction furnace. A distorted current waveform can be the result of a rectifier, variable speed drive, switched mode power supply, discharge lighting or other electronic load. A poor power factor due to an inductive load can be improved by the addition of power factor correction, but a poor power factor due to a distorted current waveform requires a change in equipment design or expensive harmonic filters to gain an appreciable improvement.

1.2 Need for power factor correction

The electrical energy is almost exclusively generated, transmitted and distributed in the form of alternating current. Therefore question of power factor comes to the picture immediately. Power factor plays an important role in ac circuits since power consumption depends on this factor, which explains its importance

- To reduce the losses in transmission line by improving the power factor of the system particularly in the industrial environment.
- To prevent many industries from paying fines and high tariff to the electricity board, due to the low power factor.
- Most of the loads (e.g. induction motors, arc lamps) are inductive in nature and hence have low lagging power factor. This low power factor is highly undesirable as it causes an increase in current resulting in additional losses of active power in all elements of power system from power generation system down to utilization devices.

1.3 Methods of power factor correction

Power Factor Correction (PFC) allows power distribution to operate at its maximum efficiency. There are two types of PFC, Active PFC and Passive PFC. All of our power supplies are either Active PFC Power Supplies or Passive PFC Power Supplies.

Active PFC

The preferable type of PFC is Active Power Factor Correction (Active PFC) since it provides more efficient power frequency. Because Active PFC uses a circuit to correct power factor, Active PFC is able to generate a theoretical power factor of over 95%. Active Power Factor Correction also markedly diminishes total harmonics, automatically corrects for AC input voltage, and is capable of a full range of input voltage. Since Active PFC is the more complex method of Power Factor Correction, it is more expensive to produce an Active PFC power supply.

Passive PFC

The most common type of PFC is Passive Power Factor Correction (Passive PFC). Passive PFC uses a capacitive filter at the AC input to correct poor power factor. Passive PFC may be affected when environmental vibration occurs. Passive PFC requires that the AC input voltage be set manually. Passive PFC also does not use the full energy potential of the AC line.

Traditional way of power factor control requires the human involvement, which is bound to errors, as the humans are not optimal at all times. Also most of the applications today are getting more and more automated, because of the human errors.

Power factor correction can be done with the help of microprocessors. But external memory has to be interfaced, and there are no inbuilt features like timers, A/D converters, and separate data memory. The number of instructions is more in microprocessor. When external memory is interfaced then the system size increases. Also the execution time is more.

The use of microcontroller overcomes all these disadvantages. It reduces the size of the equipment, and the control and correction of power factor is easy, automatic and quick so that "power quality" is maintained without human intervention.

1.4 Advantages of power factor correction

- Power factor correction allows power distribution to operate at its maximum efficiency.
- Power factor is a measure of how effectively the current is being converted into useful work output, and more particularly, it is a good indicator of the effect of the load current on the efficiency of the supply system.
- A load with a power factor of 1.0 result in most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system.
- Depending upon the utility we may be able to save energy costs.
- Reduction in I^2R losses and to maintain better voltage regulation.
- To reduce electrical cost.
- To reduce load losses of distribution system.
- To increase systems capacity.

Methods to improve power factor

- Replacement of existing motor with more energy efficient ones with high power factor.
- Specify and use of high power factor lighting ballast.
- Assure that motors are properly sized for their application and duty cycle.
- Install capacitor – their leading power factor will counter balance the inductive lagging power factor.
- Having a bad power factor means that the distribution system is drawing more current than what is required to accomplish the real work, and that the load losses of the distribution system are greater. All utilities penalize customer with low power factor

METHODOLOGY

2. METHODOLOGY

2.1 Problem description

Many loads are highly inductive in nature such as motors, transformers, ballast that reduces power factor. When power factor is below a certain value, then the firm has to pay compensation charges. These charges are high and vary depending upon the total power consumption of electrical energy. The important constraints are continuously monitoring power factor and turning on the capacitor banks whenever the value falls below the specified value.

2.2 Working procedure

The main constraints are calculating line voltage, line current, power factor, status of capacitors and displaying their value and status in the LCD display and computer. The following are the steps involved in measuring these values and displaying them.

- Both the microcontroller and the LCD used in our project uses +5 volt power supply. Also the op amp used here requires a dual power supply. This requires +12 volts and – 12 volts. Suitable voltage regulators are used for this purpose. Thus power supply circuitry is designed.

- The PIC microcontroller has got 5 ports. One port is connected to the LCD display. Another port is connected to RS 232C IC for the purpose of interface. One port is used for turning on the relays. The first two pins of the ad channel are used for measuring voltage and current.

- The voltage sensing circuit used here calculates the voltage. The voltage is first reduced to a lower value using a voltage divider circuit. This is then given to a inverting amplifier which acts us a precision amplifier. Thus ac voltage is converted to a equivalent dc voltage. An inverting amplifier is used to convert the negative to positive output. The working of current sensing is very much similar to that of a voltage sensing circuit.

- The pulsating thus obtained from voltage and current sensing circuitry is fed to the first two pins of ad channel. Suitable factor is chosen to convert the current and voltage value to actual measured value. It is then displayed on the LCD.

- The power factor is determined by finding the time difference between the highs of voltage and current. Then this time difference is converted into equivalent power factor value. Timer facilities are in built in the microcontroller itself.

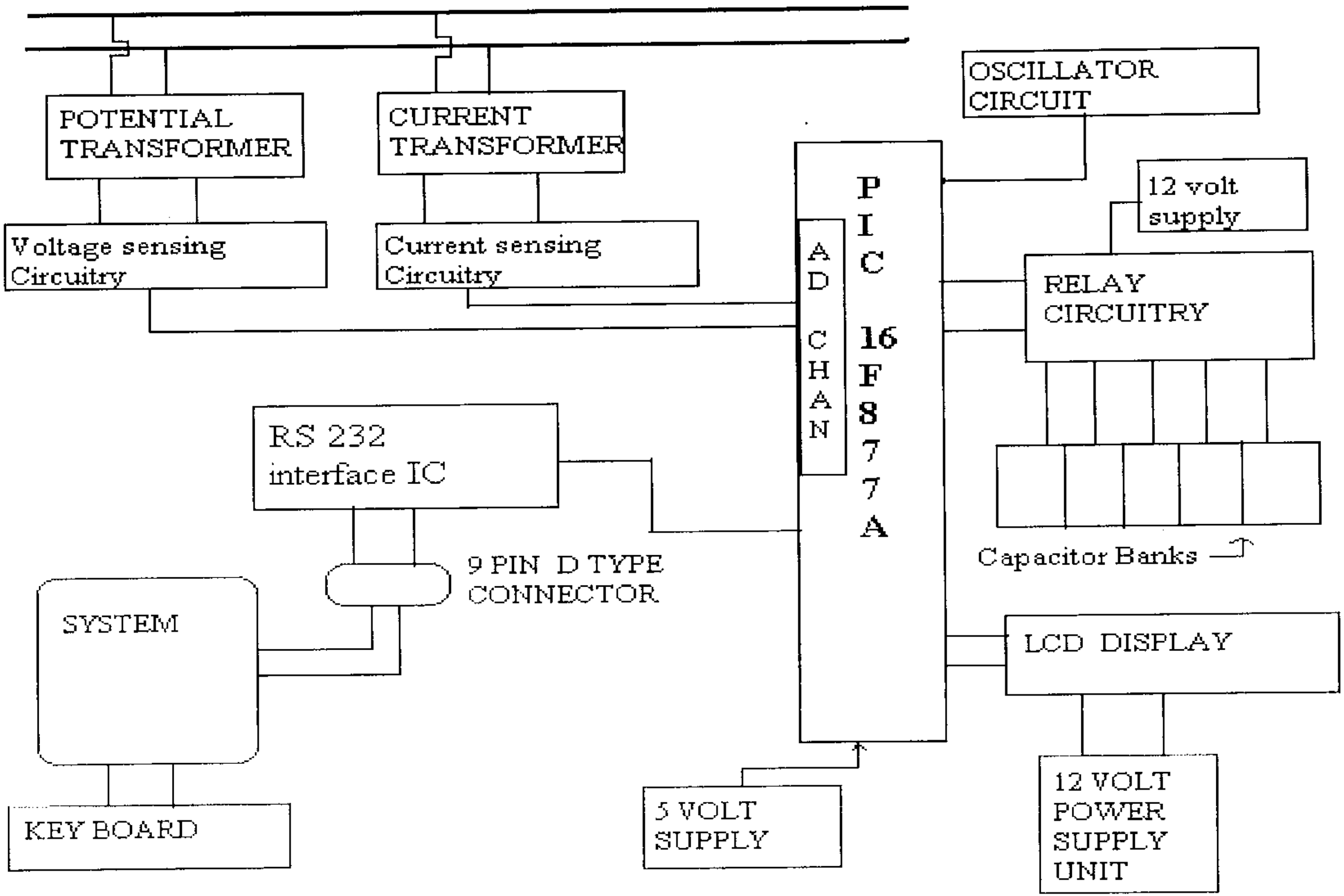
- The PIC is programmed using Hitech C. the program is converted to machine language by using software called MPLAB.

- The relays are turned using transistors, which are used as switches. The relays have coils, which are normally closed or normally open. When this coil is exited the switch is closed that connects the capacitors. The other end of the capacitor is connected to the line. Thus relay closes the circuit. A free wheeling diode is connected parallel to the relay coil, for continuous operation or otherwise switch oscillates for a finite time.

- The data's are transferred to the computer via RS 232C IC. The D type 9 pin connector interfaces the computer and micro controller. A suitable VB coding is written to display the current voltage power factor value and the status of the capacitor banks. The baud rate can be fixed using function keys.

Thus the power factor is measured and displayed on the LCD display and computer.

BLOCK DIAGRAM



PROJECT DESCRIPTION

3. PROJECT DESCRIPTION

Intelligent power factor corrector corrects the power factor automatically. The model designed has got the following sub systems,

- Design of power supply (5v & 12v).
- Design of AC Voltage sensing circuitry
- Design of AC Current sensing circuitry
- Relay triggering circuitry
- PIC Microcontroller
- RS 232 interface- Design

Apart from these designs current transformers and potential transformers are used for sampling current and voltage waveforms. Also transformers are required for the purpose of designing power supply (both 5v and 12v).

The above designs explain the hardware part of the project. Apart from this, there is also software design. In software design there are two parts as follows,

- PIC microprogramming
- VB coding for system display

PIC microcontroller is programmed in C language. Then the C program is converted to machine language using MPLAB SOFTWARE. C is used for programming because of its flexibility and simplicity. It is converted to machine language and copied to microcontroller using emulator.

VB coding is required to display the data from the PIC microcontroller to system. Simple windows are used for this purpose.

MICROCONTROLLER

3.1 Microcontroller

Microcontroller is a semiconductor device, which has many, built in features to support any application. Microcontroller differs from microprocessor in many features. Microprocessor has many operational codes for moving data from external memory to the CPU. But Microcontroller has fewer codes. Microprocessors have one or two bit handling instructions. But Microcontroller has many. Microcontroller has got many built in features. Microcontroller works faster than microprocessor because of rapid movement of bit within the chip. Microcontroller can function as a computer with the addition of no external parts. This project uses PIC Microcontroller. PIC stands for Peripheral Interface Controller. There are many features and packages. The different series are 16,17, 18, 19, etc. this project uses PIC 16f877 microcontroller.

3.1.1 Special features

- Improved architecture - Harvard architecture
- Built in 3 timers
- In built A/D converters
- Separate program and data memory
- High frequency operation
- Flexible programming
- Instruction pipelining
- 5 I/O programmable ports
- Easy interfacing facilities

Architecture

PIC microcontroller based devices have following architectural features to attain the high performance

- Harvard architecture
- Long word instructions
- Single word instructions
- Single cycle instructions
- Instruction pipelining
- Reduced instruction set
- Register file architecture
- Orthogonal (symmetric) instructions

Harvard architecture

Harvard architecture has the program memory and data memory as separate memories and they are accessed from separate buses. This improves bandwidth over traditional von Neumann architecture in which program and data are fetched from the same memory using the same bus. These separated buses allow one instruction to execute while the next instruction is fetched.

Instruction pipeline

The instruction pipeline is a two stage pipeline, which overlaps the fetch and execution of instructions.

Reduced instruction set

When an instruction set is well designed and highly orthogonal (symmetric), fewer instructions are required to perform all needed tasks. With fewer instructions, the whole set can be more rapidly learned.

Central processing unit

The CPU is responsible for using the information in the program memory to control the operation of the device. Many of these instructions operate on data memory. It is responsible for fetching the correct instruction for execution, decoding that instruction, and then executing that instruction. The CPU sometimes works in conjunction with the ALU to complete the execution of arithmetic and logical operations. The CPU controls the program memory address bus, the data memory address bus, and accesses to the stack.

Arithmetic and logical unit

PICmicro MCUs contain an 8-bit ALU and an 8-bit working register. The ALU is a general purpose arithmetic and logical unit. It performs Arithmetic and Boolean functions between the data in the working register and any register file. The ALU is 8-bits wide and is capable of addition, subtraction, shift and logical operations. Depending on the instruction executed, the ALU may affect the values of the Carry, Digit Carry, and Zero bits in the status register.

The status register contains the arithmetic status of the ALU, the RESET status and the bank selects bits for data memory.

3.1.2 Memory organisation

Memory organization has two blocks

- Program memory
- Data memory

Each block has its own bus, so that access to each block can occur during the same oscillator cycle. The data memory can further be broken down into General purpose RAM and the Special Function Registers (SFRs).

Program memory organisation

Mid- Range MCU devices have a 13-bit program counter capable of addressing an 8K X 14 program memory space. The width of the program memory bus is 14 bits. Since all instructions are a single word, a device with an 8k x 14 program memory has a space for 8K of instructions. This makes it much easier to determine if a device has sufficient program memory for a desired application.

Program counter

The program counter (PC) specifies the address of the instruction to fetch for execution. The PC is 13 bits wide. The low byte is called the PCL register. This register is readable and writable. The high byte is called the PCH register. This register contains the PC<12:8> bits and is not directly readable or writable.

Reset vector

On any device, a reset forces the Program Counter to address 0h

Interrupt vector

When an interrupt is acknowledged the PC is forced to address 0004h

Stack

Stack contains the return address from this branch in program execution

Program memory paging

Some devices have program memory sizes greater than 2K words, but the CALL and GOTO instructions only have a 11 bit address range.

Data memory organisation

Data memory is made up of the Special Function Registers (SFRs) area, and the General purpose Registers (GPR) area. The SFRs control the operation of the device, while GPRs are the general areas for data storage and scratch pad operations. The GPR area is banked to allow greater than 96 bytes of general purpose RAM to be addressed.

General purpose registers

GPRs are not initialized by a power on reset and are unchanged on all other resets. The register file can be accessed either directly, or using the File Select Register FSR, indirectly.

Special function registers

The CPU and Peripheral Modules use the SFRs for controlling the desired operation of the device. These registers are implemented as static RAM. The SFRs can be classified into two sets, those associated with the 'core' function and those related to the peripheral functions.

Banking

The data memory is partitioned into four banks. Each bank contains General Purpose Registers and Special Function Registers. Switching between these banks requires the RP0 and RP1 bits in the STATUS register to be configured for the desired bank when using direct addressing. The IRP bit in the STATUS register is used for indirect addressing.

ACCESSED BANK	DIRECT (RP1:RP0)	INDIRECT (IRP)
0	0 0	0
1	0 1	0
2	1 0	1
3	1 1	1

3.1.3 A/D converters

The analog-to-digital converter module has up to eight analog inputs. The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the Vref pin. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode.

The A/D module has three registers. These registers are
A/D result register (ADRES)
A/D control register0 (ADCON0)
A/D control register1 (ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The I/O pins can be configured as analog inputs (one I/O can also be a voltage reference) or as digital I/O.

When the A/D conversion is complete, the result is loaded into the ADRES register, the GO/DONE bit is cleared, and A/D interrupt flag bit, ADIF is set. After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channel must have their corresponding TRIS bits selected as an input. After this acquisition time has elapsed the A/D conversion can be started.

The following steps should be followed for doing an A/D conversion,
1. Configure the A/D module
- Configure the analog pins/ voltage reference / and digital I/O (ADCON1)
- Select A/D input channel (ADCON0)
- Select A/D conversion clock (ADCON0)
- Turn on A/D module (ADCON0)

2. Configure A/D interrupt (if desired)

- Clear the ADIF bit
- Set the ADIE bit
- Set the GIE bit

3. Wait the required acquisition time

4. Start conversion

- Set the GO / DONE bit (ADCON0)

5. Wait for A/D conversion to complete, by either

- Polling for the GO/DONE bit to be cleared

  Or

- Waiting for the A/D interrupt

6. Read A/D result register (ADRES), clear the ADIF bit, if required

7. For next conversion, go to step 1 or step 2 as required. The A/D conversion time per bit is defined as Tad. A minimum wait of 2 Tad is required before next acquisition starts.

3.1.4 Timers

Timer 1

Timer1 module is a 16 bit timer & counter consisting of two 8-bit registers which are readable and writable. It increments from 0000h to FFFFh and rolls over to 0000h.

It can be operated in one of the following three modes

- as a synchronous timer
- as a synchronous counter
- as a asynchronous counter

The operating mode is selected by clock selection bit TMR1CS and the synchronization bit (T1SYNC). In timer mode, it increments for every instruction cycle and in counter mode it increments on every rising edge of the external clock input.
It can be turned on and off using the TMR1ON control bit.

Timer mode

Selected by clearing TMR1CS bit, the input clock to timer is Fosc/4. The synchronize control bit has no effect since internal clock is always synchronized.

Synchronous counter mode

Counter mode is selected by setting TMR1CS bit. The timer increments on every rising edge of clock input on the T1OS1 pin when oscillator enable bit is set, or when T1OSCEN bit is cleared. If T1SYNC bit is cleared, then the external clock input is synchronized with internal phase clocks.

Asynchronous counter mode

This type of mode is achieved setting the T1SYNC to high which asychronizes the external clock input. The timer continues to run during sleep mode, which can be used to implement real-time clock.

Timer 2

Timer2 is an 8 bit timer with prescaler, a postscaler and period register. The overflow time is the same as a 16-bit timer. The TMR2 register is readable and writable and is cleared on all device resets. It increments from 00h on reset increment cycle.

The match output of TMR2 goes to two sources

- Timer 2 postscaler
- SSP clock input

When postscaler overflows, TMR2 is also routed to synchronous serial port (SSP) module.

Timer 0

It has the following features

- 8 bit timer / counter
- Readable and writable
- Clock source selectable to be external or internal
- Interrupt on overflow from FFh to 00h
- Edge select for external clock

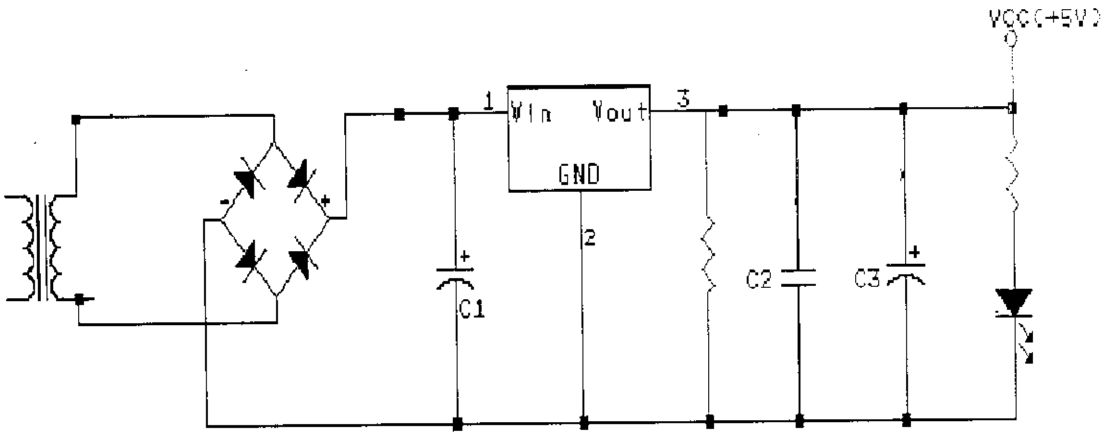
Timer mode is selected by clearing TOCS bit. Counter bit is selected by setting the TOCS bit. In counter mode, timer 0 will increment either on every rising or falling edge. The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h. The response of the timer to the clock pulse can be made as positive edge trigger or negative edge triggered.

HARDWARE DESCRIPTION

3.2 Hardware description

3.2.1 Design of power supply circuitry

Power supply unit



As we all know any invention of latest technology cannot be activated without the source of power. So in this fast moving world we deliberately need a proper power source which will be apt for a particular requirement. All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from _+5v to _+12.

We are utilizing for the same, the cheapest and commonly available energy source of 230v - 50Hz and stepping down, rectifying, filtering and regulating the voltage. This will be dealt briefly in the forth-coming sections.

Step down transformer

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230V / 15-0-15v is used to perform the step down operation where a 230V AC appears as 15V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in our project is 2A. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuitries.

Rectifier unit

In the power supply unit, rectification is normally achieved using a solid state diode. Diode has the property that will let the electron flow easily in one direction at proper biasing condition. As AC is applied to the diode, electrons only flow when the anode and cathode is negative. Reversing the polarity of voltage will not permit electron flow.

A commonly used circuit for supplying large amounts of DC power is the bridge rectifier. A bridge rectifier of four diodes (4*IN4007) are used to achieve full wave rectification. Two diodes will conduct during the negative cycle and the other two will conduct during the positive half cycle. The DC voltage appearing across the output terminals of the bridge rectifier will be somewhat less than 90% of the applied rms value. Normally one alteration of the input voltage will reverse the polarities. Opposite ends of the transformer will therefore always be 180 deg out of phase with each other.

For a positive cycle, two diodes are connected to the positive voltage at the top winding and only one diode conducts. At the same time one of the other two diodes conducts for the negative voltage that is applied from the bottom winding due to the forward bias for that diode. In this circuit due to positive half cycle D1 & D2 will conduct to give 10.8V pulsating DC. The DC output has a ripple frequency of 100Hz. Since each alternation produces a resulting output pulse, frequency = 2*50 Hz. The output obtained is not a pure DC and therefore filtration has to be done.

Filtering unit

Filter circuits usually consisting of a capacitor acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to 'short' the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output. A load resistor R1 is connected so that a reference to the ground is maintained. C1R1 is for bypassing ripples. C2R2 is used as a low pass filter, i.e. it passes only low frequency signals and bypasses high frequency signals. The load resistor should be 1% to 2.5% of the load.

1000µf / 25v = for the reduction of ripples from the pulsating.

10µf / 25v = for maintaining the stability of the voltage at the load side.

O.1µf = for bypassing the high frequency disturbances.

Voltage regulators

The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. Power supplies without regulators have an inherent problem of changing DC voltage values due to variations in the load or due to fluctuations in the AC liner voltage. With a regulator connected to the DC output, the voltage can be maintained within a close tolerant region of the desired output. IC7812 and 7912 is used in this project for providing +12V and –12V DC supply.

Specifications

Resistors R1 and R2 maintain line load regulation.

At the secondary side of the transformer,

Applied voltage = 15V

Conducting drop across the diodes = 2*0.6 = 12 V

Without capacitor:

Vavg = (15-1.2) V = 13.8c pulsating DC

Frequency = 100Hz

With capacitor:

V = Vavg * 1.414(form factor)

= 19.51v

Frequency = o Hz

With 7812 voltage regulator:

V0 = +12V

With 7912 voltage regulator:

V0 = -12V

3.2.2 AC voltage and current sensing circuitry

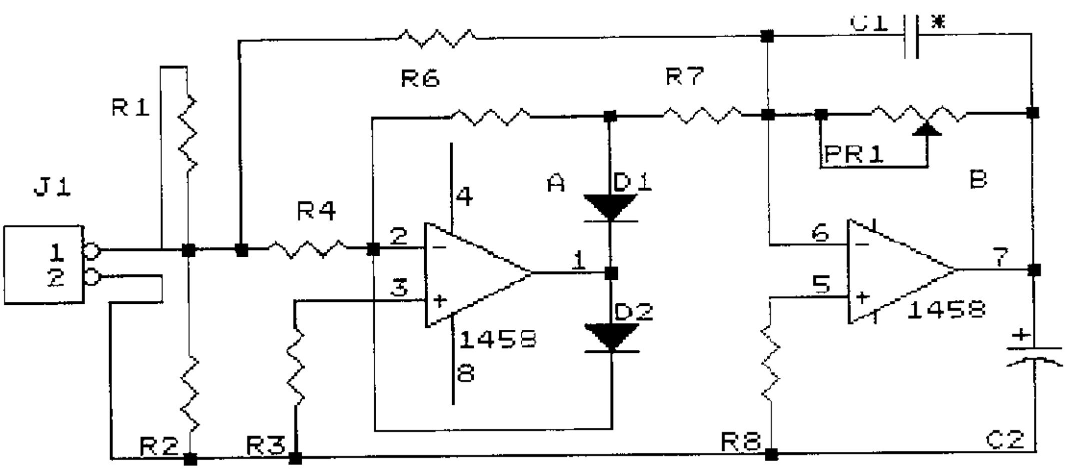
Voltage measurement

In case of voltage measurement, two PT's are connected across two phases of the transformer under test. The PT is rated at 230V / 6V.The ac output voltage of the PT is rectified, filtered and converted into pure dc 5V.

In the rectifier circuit, A1 is an inverting rectifier. The output from A1 is added to the original input signal in A2 (summing mixer). Negative alternations of Ein results in no output at E1 due to the rectification. Ein feeds A2 through a 20K ohms resistor and E1 feeds A2 through a 10K ohms resistor.

The net effect of this scaling is that, for equal amplitudes of Ein and E1, E1 will produce twice as much current flow into the summing point. This fact is used as an advantage here, as the negative alternation of E1 produces twice the input current of precisely half the amplitude which E1 alone would generate due to the subtraction of Ein. It is the equivalent of having E1 feed through a 20K ohms input resistor and having Ein non-existent during this half cycle and it results in a positive going output at A2.

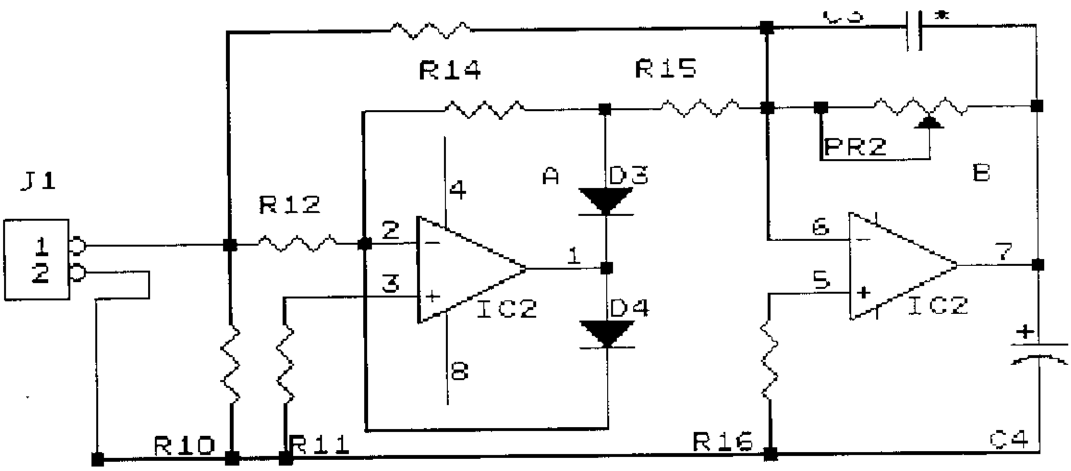
AC VOLTAGE SENSING CIRCUITRY



Now the output dc voltage obtained is pulsating and hence passed through a buffer amplifier with provision for filtering out the ripples. Thus at the output of the buffer circuit we get pure dc of 5V.

Current measurement

AC CURRENT SENSING CIRCUITRY



Two CT's are connected in series with two phases of the transformer under test. The CT is rated at 5A/0.5A.A shunt resistor of value 1 ohm is connected across the CT. Hence we have 0.5V ac given as the input to the rectifier unit and by a similar procedure as seen in the previous case, we get pure dc 0.5V at the output stage.

The output 0.5V dc is converted into 5V dc by means of suitable buffer arrangement.

3.2.3 Design of relay circuitry

Electromechanical relays

Relays are electromagnetic switches, which provide contact between two mechanical elements. Relays have a coil, which works on 12V dc power supply and provides DPDT action as an output. In general, relays provide potential free contacts which can be used for universal functions like DC, AC voltage switching and to control bigger electrical switchgears.

The electromechanical relays are based on the comparison between operating torque / force and restraining Torque / force. The VA burdens of such relays are high.

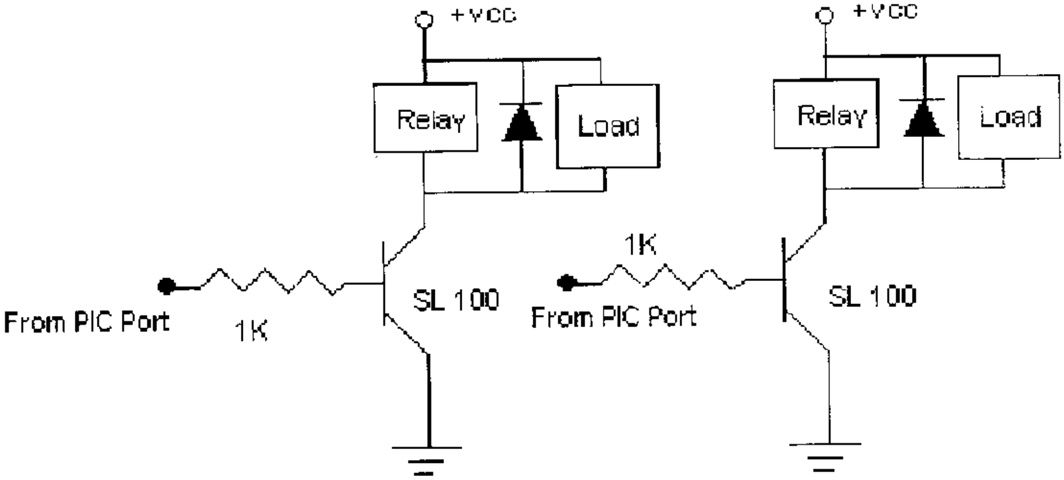
The characteristics of these relays have some limitations. Each relay can perform only one protective function. Such relays are used for simple and less costly protection purposes. For important and costly equipment installation static relays are preferred.

Protective relaying is necessary for almost every electrical plant and no part of the power system is left unprotected.

The choice of protection depends upon several aspects such as

- Type and rating of the protected equipment
- Its importance
- Location and cost
- Probable abnormal conditions between generators and final load points

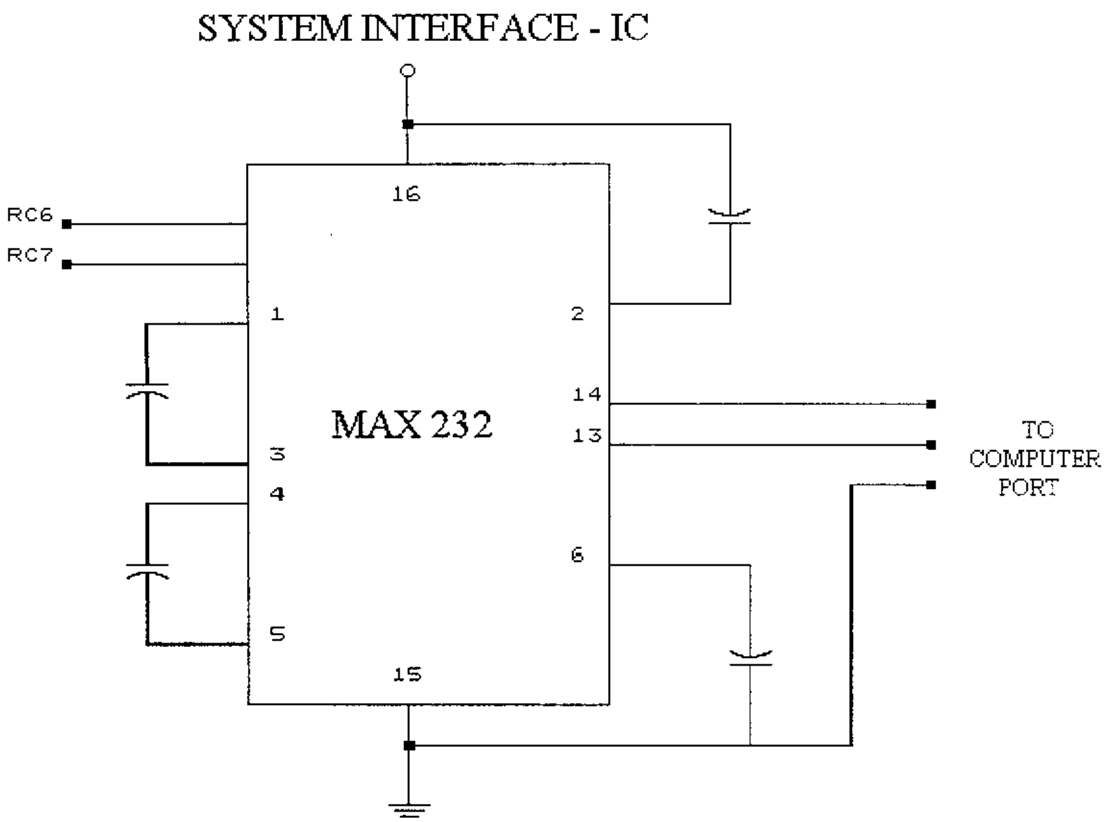
RELAY DRIVER CIRCUITRY



There are several electrical equipment and machines of various ratings. Each need certain adequate protection. The protective relaying, senses the abnormal conditions in a part of the power system and isolates that part from the healthy part of system.

The relays used in this project are compact, self-contained devices, which respond to abnormal conditions (relays can distinguish normal and abnormal conditions).

3.2.4 RS 232 interface



The most common communication interface for short distance is RS-232. RS-232 defines a serial communication for one device to one computer communication port, with speeds up to 19,200 baud. Typically 7 or 8 bits (on/off) signal are transmitted to represent a character or digit. The 9-pin connector is used.

Max 232

Each of the two transmitters is a CMOS inverter powered by +10V internally generated supply. The input is TTL and CMOS compatible with a logic threshold of about 26% of Vcc. The input if an unused transmitter section can be left unconnected: an internal 400KΩ pull up resistor connected between the transistor input and Vcc will pull the input high forming the unused transistor output low.

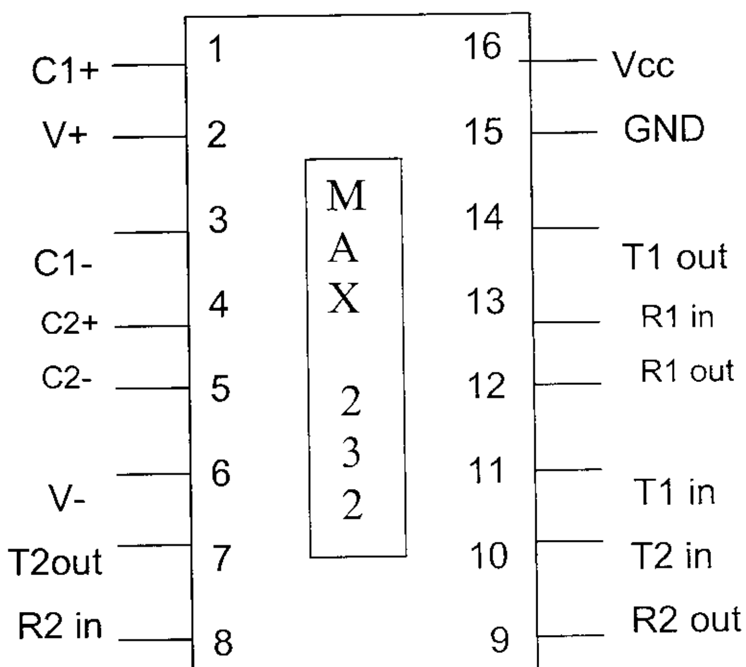
The open circuit output voltage swing is guaranteed to meet the RS232 specification ÷ 5v output swing under the worst of both transmitter driving the 3KΩ minimum load impedance, the Vcc input at 4.5V and maximum allowable ambient temperature typical voltage with 5KΩ and Vcc = +. 9V.

The slow rate at output is limited to less than 30V / µs and the powered done output impedance will be a minimum of 300Ω with +2V applied to the output with Vcc = 0V.The outputs are short circuit protected and can be short circuited to ground indefinitely.

Receiver section

The two receivers fully conform to RS232 specifications. Their input impedance is between 3KΩ either with or without 5V power applied and their switching threshold is within the +3V of RS232 specification. To ensure compatibility with either RS232 IIP or TTl / CMOS input. The MAX232 receivers have VIL of 0.8V and VIH of 2.4V the receivers have 0.5V of hysterisis to improve noise rejection. The TTL\CMOS compatible output of receiver will be low whenever the RS232 input is greater than 2.4V. The receiver output will be high when input is floating or driven between +0.8V and -- 30V.

Pin diagram of max 232



Electrical characteristics of max 232

Vcc = 6V

V+ = 12V

V- = 12V

Input voltage

T1in, T2in = -0.3 to (Vcc+ 0.3v)

R1in, R2in = +30v or –30v

Output voltage

T1out, T2out = ((V+)+0.3V) to ((V-)+0.3v)

R1out, R2out = -0.3V to (Vcc+0.3V)

Power dissipation = 375mW

Output resistance = 300Ω

3.2.5 Instrument transformers

Instrument transformers are used in the measurement and control of alternating current circuits. Direct measurement of High voltage or heavy currents involves large and expensive instruments, relays, and other circuit components of many Designs. The use of instrument transformers, however, makes it possible to use relatively small and inexpensive instruments and control devices of standardized designs. Instrument transformers also protect the operator, the measuring devices and the control equipment from the dangers of high voltage. The use of instrument transformers results in increased safety, accuracy and convenience.

There are two distinct classes of instrument transformers:

1. Potential transformer

2. Current transformer

Potential transformers

The potential transformer operates on the same principle as a power or distribution transformer. The main difference is that the capacity of a potential transformer has ratings from 100 to 500 volt amperes (VA).The low voltage side is usually wound for 115 V. The load on the low voltage side usually consists of not only the potential coils of various instruments but may also include the potential coil of relays and other control equipments. In general the load is relatively light and is not necessary to have PT's with a capacity greater than 100 to 500VA.

The high voltage primary winding of a PT has the same voltage rating as the primary circuit. Assume that it is necessary to measure the voltage of a 3.3KV, single phase line. The primary of the PT is rated at 3.3KV and the low voltage secondary is rated at 110V. The ratio between the primary and the secondary winding is 3300 / 110 or 30 / 1

A voltmeter connected across the secondary of the PT indicates a value of 110V. To determine actual voltage on the higher voltage circuit, the instrument readings of 110V must be multiplied by 30. 110*30 = 3300V. In some cases, the voltmeter is calibrated to indicate the actual value of voltage on the primary side. As a result, the operator is not required to apply the multiplier to the instrument reading and the possibility of error is reduced.

This PT has subtractive polarity. (All instrument PT's now manufactured have subtractive polarity). One of the secondary leads of the transformers in figure is grounded to eliminate high voltage hazards. PT's have highly accurate ratios between the primary and secondary voltage values. Generally the error is less than 0.5%.

Current transformers

Current transformers are used so that ammeters and the Current coils of other instruments and relays need not be connected directly to high voltage lines. In other words, these instruments and relays are insulated from high voltages. CT's also step down the current in a known ratio. The use of CT means that relatively small and accurate instruments, relays and control devices of standardized design can be used in circuits.

The CT has separate primary and secondary windings. The primary winding which consists of few turns of heavy wire, wound on a laminated iron core is connected in series with one of the line wires. The secondary winding consists of a greater number of turns of a smaller size of wire. The primary and secondary windings are wound on the same core.

The current rating of the primary winding of a CT is 100A. The primary winding has three turns and the secondary winding has 60 turns. The secondary winding has the standard current rating of 5A, therefore the ratio between the primary and secondary current is 100 / 5 or 20 / 1. The primary current is 20 times greater than the secondary current.

Since the secondary winding has 60 turns and the primary winding has 3 turns, the secondary winding has 20 times as many turns as the primary winding. For a CT, then the ratio of primary to secondary currents is inversely proportional to the ratio of primary to secondary turns.

CT is used to step down current in a 3300V, Single phase circuit. The CT is rated at 100 to 5 A and the ratio of current step down is 20 to 1. In other words, there are 20 A in the primary winding for each ampere in the secondary winding. If the ammeter at the secondary indicates 4A, the actual current in the primary is 20 times this value ie 80 A.

The CT in the figure has polarity markings in that the two high voltage primary leads are marked H1 and H2, and the secondary leads are marked X1 and X2. When H1 is instantaneously positive, X1 is positive at the same moment. Some CT manufacturers mark only the H1 and X1 leads. When connecting the CT's in circuits, the H1 lead is connected to the line lead feeding from the source while the H2 lead is connected directly to the ammeter. Note that one of the secondary leads is grounded as a safety precaution to eliminate high voltage hazards.

Caution

The secondary circuit of a transformer should never be opened when there is current in the primary winding. Then the entire primary current is an exciting current which induces a high voltage in the secondary winding. This voltage can be enough to endanger human life.

SOFTWARE DESCRIPTION

3.3 Software description

3.3.1 PIC programming

PIC 16f877A is programmed with the help of software called Hitech C. This is then converted to hex decimal value using software called MPLAB. These values are stored in the form of zeros and ones in the program memory. Emulator is the hardware required to do the process of converting the c to machine language. Following is the algorithm and flowchart for writing the c program.

Algorithm

STEP1: Start the program.

STEP2: Set the ports either input or output depending upon the requirement.

STEP3: Move suitable values to adcon registers to set it as input ports.

STEP4: Enable the peripheral and global interrupts.

STEP5: Send both data and command to the LCD display with suitable delay.

STEP6: Turn on the timer during the high of input signal.

STEP7: The measured voltage value is multiplied by a factor to display the actual value.

STEP8: Similarly actual current value is also displayed in the LCD.

STEP9: Power factor is measured by finding the time difference between voltage and current wave forms.

STEP10: This data is also send to LCD for display.

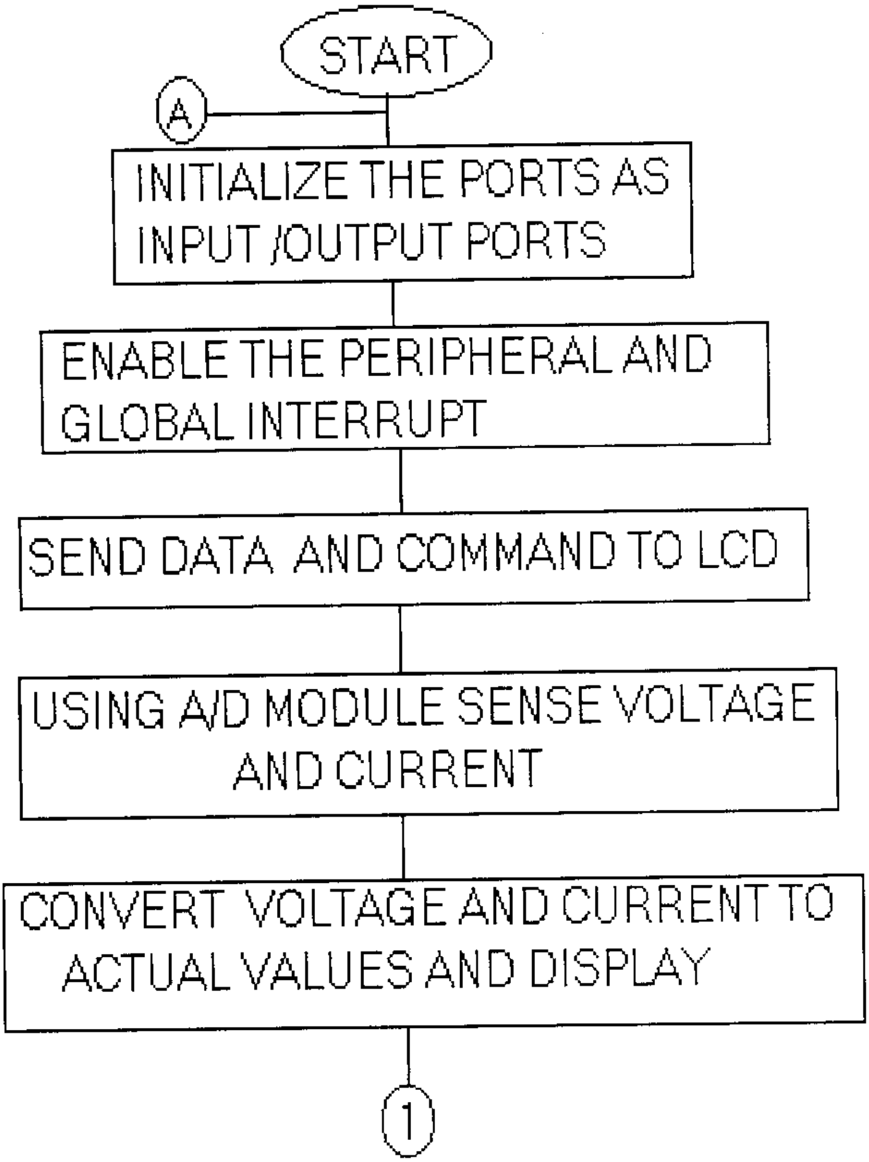
STEP11: Capacitor banks are turned on depending upon the difference between the actual and preset value.

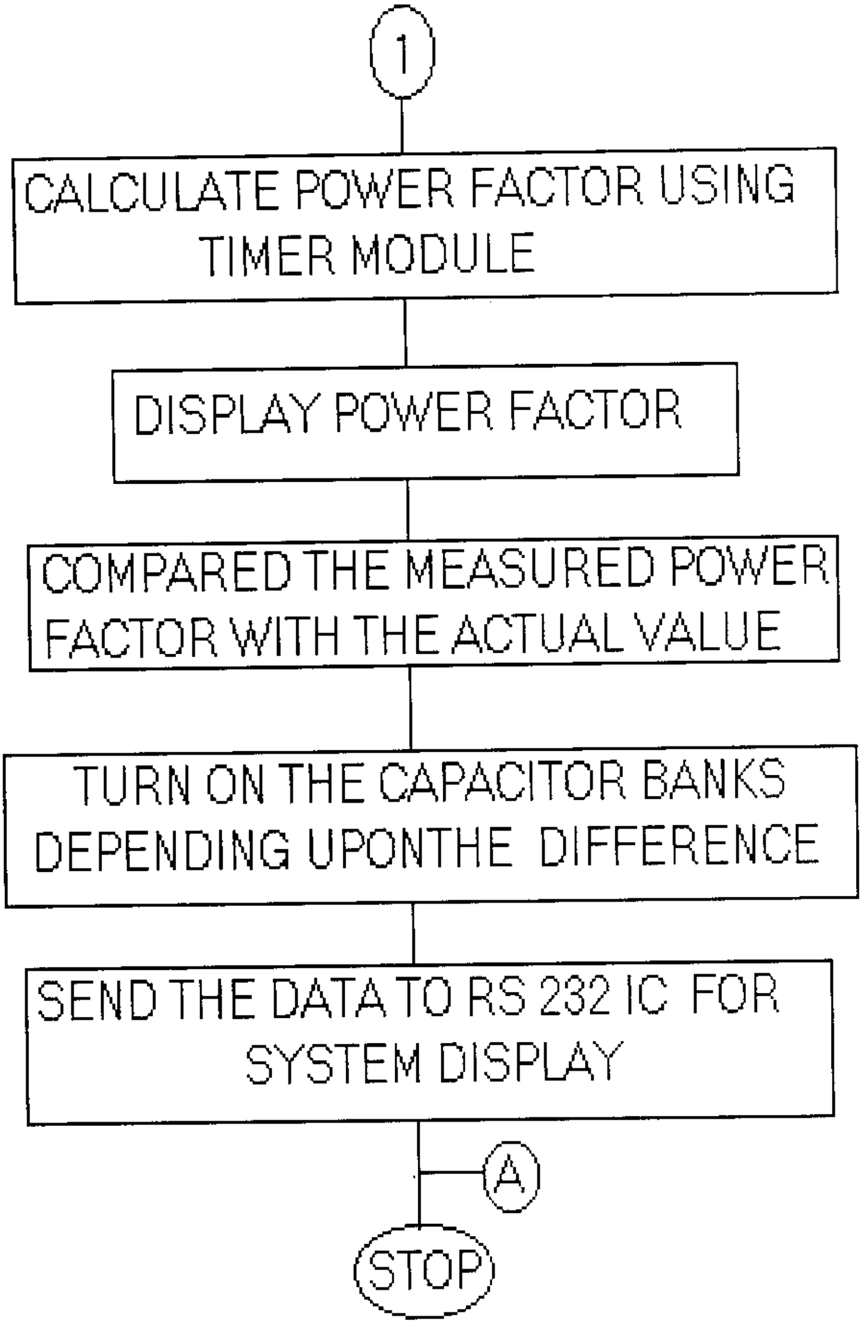
STEP12: Send these data to the RS 232 IC for system display.

STEP13: Continue the above-mentioned steps as long as power interrupt exists.

STEP14: Stop the program.

FLOW CHART:


START
A
INITIALIZE THE PORTS AS INPUT /OUTPUT PORTS
ENABLE THE PERIPHERAL AND GLOBAL INTERRUPT
SEND DATA AND COMMAND TO LCD
USING A/D MODULE SENSE VOLTAGE AND CURRENT
CONVERT VOLTAGE AND CURRENT TO ACTUAL VALUES AND DISPLAY
1


1
CALCULATE POWER FACTOR USING TIMER MODULE
DISPLAY POWER FACTOR
COMPARED THE MEASURED POWER FACTOR WITH THE ACTUAL VALUE
TURN ON THE CAPACITOR BANKS DEPENDING UPONTHE DIFFERENCE
SEND THE DATA TO RS 232 IC FOR SYSTEM DISPLAY
A
STOP

3.3.2 Visual basic coding

The VB program is written in order to display the value of the current, voltage power factor and status of the capacitor banks. The data from the max 232 IC are continuously send to the PC at a presettable baud rate. These data's are set within a pair of braces. Now these data's are received in the COM port 1 of the CPU. These data's should be first read and then displayed on the system.

Two variables are used to determine the starting brace and the ending brace. Now the value between these braces are retrieved separately and displayed continuously. Depending upon the final value in the data send the statuses of the capacitor banks are displayed. The following is the algorithm and flowchart involved in the VB coding.

ALGORITHM

STEP1: Start the program.

STEP2: Initialize two variables to determine the starting and ending braces.

STEP3: Determine the characters between these braces.

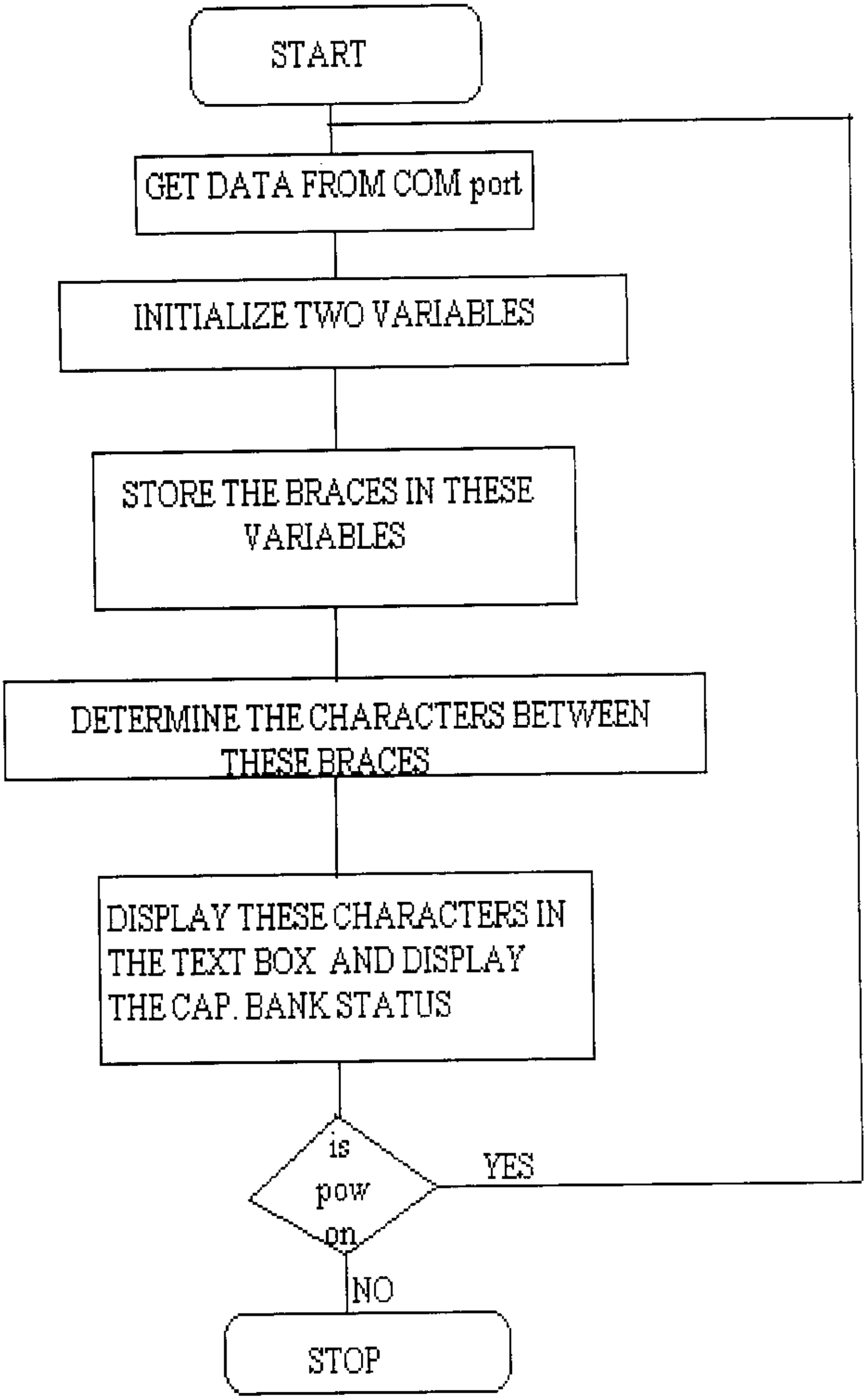
STEP4: Read the current, voltage, power factor values and display the value in the appropriate text box.

STEP5: Read the last data to check the status of capacitor banks.

STEP6: Display the status of the capacitor banks.

STEP7: Stop the program.

FLOW CHART:



START
GET DATA FROM COM port
INITIALIZE TWO VARIABLES
STORE THE BRACES IN THESE VARIABLES
DETERMINE THE CHARACTERS BETWEEN THESE BRACES
DISPLAY THESE CHARACTERS IN THE TEXT BOX AND DISPLAY THE CAP. BANK STATUS
is pow on
YES
NO
STOP

4. RESULTS AND DISCUSSIONS

The main aim of the project is to reduce the monthly compensation charges for not maintaining the power factor up to 0.85. The industry consumes a huge electrical energy of about 50000 units. Thus the amount to be paid is about 200000 to 250000. Now if the power factor is less than 0.85 then the company has to pay fine to the Electricity board.

Let us consider the power factor is around 0.77. Then the company has to pay a compensation charge of 7 % of the monthly bill. This is approximately about 14000/- plus the charges for energy consumption. This calculation is shown for a month. When this calculation is done for a year, it will account to nearly 150000/-.

When a high power factor is maintained then rebate is paid by the electricity board Suppose if the power factor of 0.95 is maintained then the rebate is 9000/- per month. When this calculation is shown for a year, the rebate approximates to around 90000/-. Thus by maintaining high power factor the company can make a lot of savings. A table provided below shows the compensation and rebate charges for different power factors.

Penalty charges

Current consumption charges

1 – 1500 units = Rs. 4.00 / unit

1501 & > = Rs. 4.70 / unit

Fixed charge bimonthly = Rs. 60.00

Tax = 5 %

For 1 KW = Rs 80.00 (minimum)

Penalty

POWER FACTOR	% OF CONSUMPTION CHARGE
0.84	1.0
0.83	2.0
0.82	3.0

0.80	5.0
0.79	6.0
0.78	7.0
0.77	8.0
0.76	9.0
0.75	10.0
0.74	16.5
0.73	18.0
0.72	19.5
0.71	21.0
0.70	22.5
0.69	24.0
0.68	25.5
0.67	27.0
0.66	28.5
0.65	30.0
0.64	31.5
0.63	33.0
0.62	34.5
0.61	36.0
0.60	37.5
0.59	39.0
0.58	40.5
0.57	42.0
0.56	43.5
0.55	45
0.54	46.5
0.53	48
0.52	49.5
0.51	51
0.50	52.5

- The charges refer to the present penalty charges as on 1.3.2004
- When power factor is below 0.85 lag and up to 0.75 lag 1% of current consumption charges for every reduction of 0.01 in power factor
- When pf is below 0.75 lag, the charges are 1.5% of consumption charges

Rebate

POWER FACTOR	% REBATE FROM COMPENSATION CHARGES
0.91	0.5
0.92	1.0
0.93	1.5
0.94	2.0
0.95	2.5
0.96	3.0
0.97	3.5
0.98	4.0
0.99	4.5
1.00	5.0

- When power factor exceeds 0.90 lag, a rebate of 0.5 % of the current consumption charges for every increase in 0.01 power factor is allowed.

Capacitor bank selection

There are two ways to correct poor power factor. One way is to use a capacitor and the other way is to use a synchronous condenser. The choice depends upon the application and our budget. If the load is less than 500 KVAR, capacitors can be used. If the load is more than 500KVAR, then synchronous condenser should be considered.

Consider a motor ¾ HP having power factor of 0.85. Current rating is 10 amperes and voltage rating is 115 volts.

Apparent power = V * I

Active power = V * I * COS$

Reactive power = SQRT((apparent ^2) - (active^2))

The value of reactive power from the above calculation gives the power factor correction needed.

$Q = E^2 / X$

$X = E^2 / Q$

$C = 1 / 2 \pi f X$

Thus the capacitance value is determined.

Inference

- Capacitance would be reduced as the square of the voltage
- Power factor correction capacitors are often rated in KVar instead of micro farads, in order to indicate the reactive power injected in the system

SCOPE FOR FURTHER WORK

5. SCOPE FOR FURTHER WORK

Maximum demand indicator can be incorporated in the system by changing the software part of the PIC microcontroller. This helps in preventing the penalty paid to the electricity board due to exceeding the limit of maximum demand. Sometimes when the demand crosses the maximum demand, the tariff nearly doubles. This system definitely prevents this and improves the company's economy.

Also presence of harmonics is one big problem in devices that draws non-sinusoidal current. Due to this power factor value is lowered. Using circuits like harmonic filter that eliminates non-sinusoidal currents completely can prevent this.

A keyboard can be interfaced with the microcontroller to set the value of power factor and maximum demand. Thus the value can be preset to any value, depending upon the requirement.

Instead of capacitors synchronous condensers can be used if the load is more than 500KVAR because it is capable of handling large swings in power factor value. Thus from above discussion it is clear that both displacement factor and distortion power factor are considered, thus maintaining nearly unity power factor.

Power factor correction can also be done for 3 phase lines since industries use 3 phase lines. Use of one microcontroller is sufficient. The number of sensing circuits is increased to find out voltage and current of 3 phase lines. Power factor of any line can be easily determined.

CONCLUSION

6. CONCLUSION

This intelligent system measures voltage, current, and power factor and displays the values accurately. Also the system corrects the power factor automatically by comparing it with some preset value. Thus nearly unity power factor is maintained using this system.

The demand for electricity is continuously increasing while the generation is limited by many constraints. Therefore effective utilization of electricity is of utmost importance. For this purpose, maintaining power factor at an optimum level becomes imperative. Moreover, 'Unit Saved Is Unit Generated'.

Intelligent power factor correction will be the trend in the near future. Many industries will adapt to this system, since it is economical, fast, and reliable. This user efficient system can be installed in hospitals, apartments, etc to maintain high power factor.

REFERENCES

REFERENCES

- "Operational amplifier and linear integrated circuits", by James M.Fiore, Jaico publishing centre, 2002
- "Regulated power supplies", by Irving M. Gottliels, ITT, third edition, 1985
- "Electrical measurements fundamentals concepts applications", Martin U Reissland, 1989
- "The complete guide to Visual Basic 6", by Clayton Walnum, Prentice Hall Of India Private Ltd, New Delhi, 1999.
- "Visual Basic 6 how to program", by Deitel and TR. Nieto, Peason Education Ltd, 2002
- "C with assembly language" Steven Holzner, BPB book centre, 1990
- www.ee.tamu.edu
- www.elec-toolbox.com
- www.endocnoice.com
- www.imphotonics.com
- www.tpub.com/neets

APPENDIX

APPENDIX – A

Coding

PIC programming

```
#include <pic.h>
#include <stdio.h>
#include "delay.c"
#include <string.h>

static void interrupt IntRoutine();
void LCD_SendData(unsigned char dat);
void LCD_SendCmd(unsigned char cmd);
void CheckBusy();
int Cnt = 0,Oflow=0,ipf=0,dval=0;
short int Flag = 0,Set=0,Hr=0,Lr=0;
int Adval=0;
float Acv=0,Acc=0,Pf=0;
short int First=0,Second=0,Third=0,Fourth=0;
char St[15];
void Send();
void Mscrn();

void main()
{
        TRISA = 0xff;
        TRISB = 0x00;
        PORTB = 0x00;
        TRISD = 0xf0;
        PORTD = 0x00;
        TRISE = 0x00;
        TRISC = 0x80;
        PORTD = 0x0f;
        PORTC = 0x03;
        ADCON0 = 0x81;
        ADCON1 = 0x82;
        SPBRG = 64; // 9600 @ 10 Mhz Brgh = 1
        TXEN = 1;
        SYNC = 0;
        BRGH = 1;
        SPEN = 1;
        CREN = 1;
        T1CON = 0x00;
        TMR1IF = 0;
        TMR1IE = 1;
        TMR1L = 0;
        TMR1H = 0;
```

```
GIE = 1; //       ; Enable global interrupts
LCD_SendCmd(0x38);
DelayMs(100);
LCD_SendCmd(0x38);
DelayMs(100);
LCD_SendCmd(0x38);
DelayMs(100);
LCD_SendCmd(0x38);
DelayMs(100);
CheckBusy();
LCD_SendCmd(0x06);
CheckBusy();
LCD_SendCmd(0x0c);
CheckBusy();
LCD_SendCmd(0x01);
CheckBusy();
LCD_SendCmd(0x02);
Mscrn();
for(;;)
{
if(RD4)
{
        TMR1ON = 0;
        TMR1L = 0;
        TMR1H = 0;
        TMR1ON = 1;
}
if(RD5)
{
        TMR1ON = 0;
        Hr = TMR1H;
        Lr = TMR1L;
}
        ADCON0 = 0x91;
        DelayUs(50);
        ADGO = 1;
        while(ADGO) continue;
        Adval = (ADRESH * 256) + ADRESL;
        Acv = (float)Adval;
        Acv = Acv / 4.01;
        CheckBusy();
        LCD_SendCmd(0x82);

        dval = (int)(Acv*10);
        St[4] = (dval % 10)+0x30;
        St[3] = '.';
        dval /= 10;
        St[2] = (dval % 10)+0x30;
```

```
dval /= 10;

St[0] = (dval % 10)+0x30;
CheckBusy();
LCD_SendData(St[0]);
CheckBusy();
LCD_SendData(St[1]);
CheckBusy();
LCD_SendData(St[2]);
CheckBusy();
LCD_SendData(St[3]);
CheckBusy();
LCD_SendData(St[4]);
ADCON0 = 0x99;
DelayUs(50);
ADGO = 1;
while(ADGO) continue;
Adval = (ADRESH * 256) + ADRESL;
Acc = (float)Adval;
Acc = Acc * 5.0;
if(Acc < 100) Acc = 0.0;
CheckBusy();
LCD_SendCmd(0x8a);
dval = (int)(Acc*10);
St[9] = (dval % 10)+0x30;
St[8] = '.';
dval /= 10;
St[7] = (dval % 10)+0x30;
dval /= 10;
St[6] = (dval % 10)+0x30;
dval /= 10;
St[5] = (dval % 10)+0x30;
CheckBusy();
LCD_SendData(St[5]);
CheckBusy();
LCD_SendData(St[6]);
CheckBusy();
LCD_SendData(St[7]);
CheckBusy();
LCD_SendData(St[8]);
CheckBusy();
LCD_SendData(St[9]);
Pf = (float)((Hr * 256) + Lr);
Pf = Pf / 6.1;
if(Acc < 100)
{
St[13] = ' ';
St[12] = 'C';
St[11] = 'Z';
```

```
}
else
{
dval = (int)(Pf * 100);
St[13] = (dval % 10)+0x30;
dval /= 10;
St[12] = (dval % 10)+0x30;
St[11] = '.';
dval /= 10;
St[10] = (dval % 10)+0x30;
}
CheckBusy();
LCD_SendCmd(0xC6);
CheckBusy();
LCD_SendData(St[10]);
CheckBusy();
LCD_SendData(St[11]);
CheckBusy();
LCD_SendData(St[12]);
CheckBusy();
LCD_SendData(St[13]);
if(Pf < .200)
{
        PORTD = 0x0f;
}
else if(Pf < .350)
{
        PORTD = 0x0e;
}
else if(Pf < .400)
{
        PORTD = 0x0d;
}
else if(Pf < .450)
{
        PORTD = 0x0c;
}
else if(Pf < .500)
{
        PORTD = 0x0b;
}
else if(Pf < .550)
{
        PORTD = 0x0a;
}
else if(Pf < .600)
{
        PORTD = 0x09;
}
```

```
            {
                    PORTD = 0x08;
            }
            else if(Pf < .700)
            {
                    PORTD = 0x07;
            }
            else if(Pf < .750)
            {
                    PORTD = 0x06;
            }
            else if(Pf < .800)
            {
                    PORTD = 0x05;
            }
            else if(Pf < .850)
            {
                    PORTD = 0x04;
            }
            else if(Pf < .900)
            {
                    PORTD = 0x03;
            }
            else if(Pf < .925)
            {
                    PORTD = 0x02;
            }
            else if(Pf < .950)
            {
                    PORTD = 0x01;
            }
            else
            {
                    PORTD = 0x00;
            }

            Send();
            DelayMs(100);
        }
}
void Send()
{
                    while(!TXIF) continue;
                    TXREG = '{';
                    DelayUs(10);
                    while(!TXIF) continue;
                    TXREG = St[0];
                    DelayUs(10);
```

```
DelayUs(10);
while(!TXIF) continue;
TXREG = St[2];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[3];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[4];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[5];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[6];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[7];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[8];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[9];
DelayUs(10);

while(!TXIF) continue;
TXREG = St[10];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[11];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[12];
DelayUs(10);
while(!TXIF) continue;
TXREG = St[13];
DelayUs(10);
while(!TXIF) continue;
Cnt = (PORTD & 0x0f);
if(Cnt <= 9)
TXREG = Cnt + 0x30;
else
TXREG = Cnt + 0x37;
DelayUs(10);
while(!TXIF) continue;
TXREG = '}';
DelayUs(10);
```

```
{
        if(TMR1IF)
        {
        TMR1IF = 0;
                Flag = 1;
        }
}
void CheckBusy()
{
        TRISB = 0xff;
        do
        {
        RE0 = 0;
        RE1 = 1;
        RE2 = 1;
        DelayUs(20);
        RE2 = 0;
        }while(RB7);
        TRISB = 0x00;
        PORTB = 0x00;
}


void LCD_SendCmd(unsigned char cmd)
{
        PORTB = cmd;
        RE0 = 0;
        RE1 = 0;
        RE2 = 1;
        DelayUs(20);
        RE2 = 0;
}
void LCD_SendData(unsigned char dat)
{
        PORTB = dat;
        RE0 = 1;
        RE1 = 0;
        RE2 = 1;
        DelayUs(20);
        RE2 = 0;
}
void Mscrn()
{
        CheckBusy();
        LCD_SendCmd(0x01);
        CheckBusy();
        LCD_SendCmd(0x80);
        CheckBusy();
        LCD_SendData('V')
```

```
    LCD_SendData(':');
    CheckBusy();
    LCD_SendCmd(0x88);
    CheckBusy();
    LCD_SendData('I');
    CheckBusy();
    LCD_SendData(':');
    CheckBusy();
    LCD_SendCmd(0xC2);
    CheckBusy();
    LCD_SendData('P');
    CheckBusy();
    LCD_SendData('f');
    CheckBusy();
    LCD_SendData(':');
}
```

VB coding

```
Private Sub Form_Load()
MSComm1.PortOpen = True
End Sub

Private Sub Timer1_Timer()
Rstr = MSComm1.Input

v1 = InStr(1, Rstr, "{")
v2 = InStr(v1 + 1, Rstr, "}")

If v1 > 0 And v2 > 0 Then

Rstr = Mid$(Rstr, v1 + 1, v2 - v1 - 1)
Text1.Text = Left$(Rstr, 5)
Text2.Text = Mid$(Rstr, 6, 5)
Text3.Text = Mid$(Rstr, 11, 4)
v3 = Val("&h" & Right$(Rstr, 1))

If (v3 And &H1) = &H0 Then
Label5.Caption = "Cap. Bank 1 Off"
Else
Label5.Caption = "Cap. Bank 1 On"
End If

If (v3 And &H2) = &H0 Then
Label6.Caption = "Cap. Bank 2 Off"
Else


Label6.Caption = "Cap. Bank 2 On"
```

```
If (v3 And &H4) = &H0 Then
Label7.Caption = "Cap. Bank 3 Off"
Else
Label7.Caption = "Cap. Bank 3 On"
End If

If (v3 And &H8) = &H0 Then
Label8.Caption = "Cap. Bank 4 Off"
Else
Label8.Caption = "Cap. Bank 4 On"
End If

End If

End Sub
```

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

Devices Included in this Data Sheet:

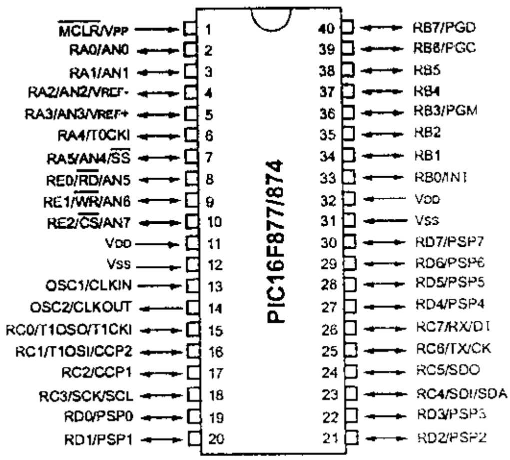
- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

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

PDIP

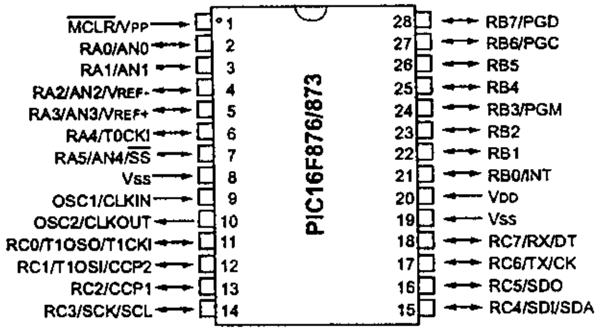


Peripheral Features:

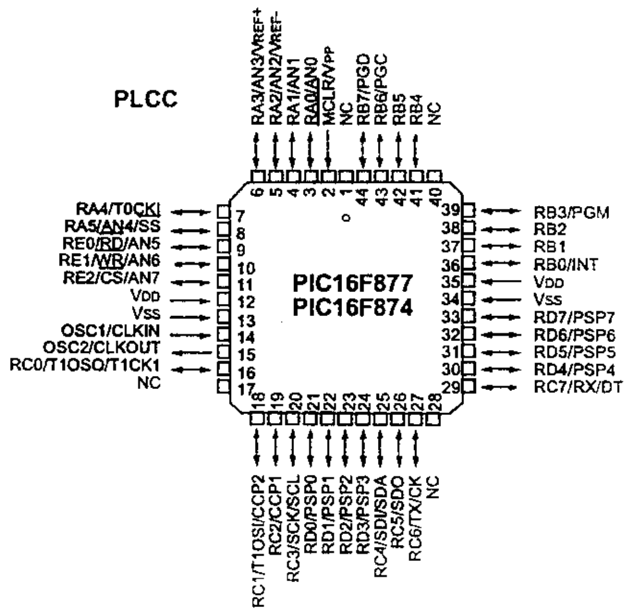
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. 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 I^2C™ (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)

Pin Diagrams

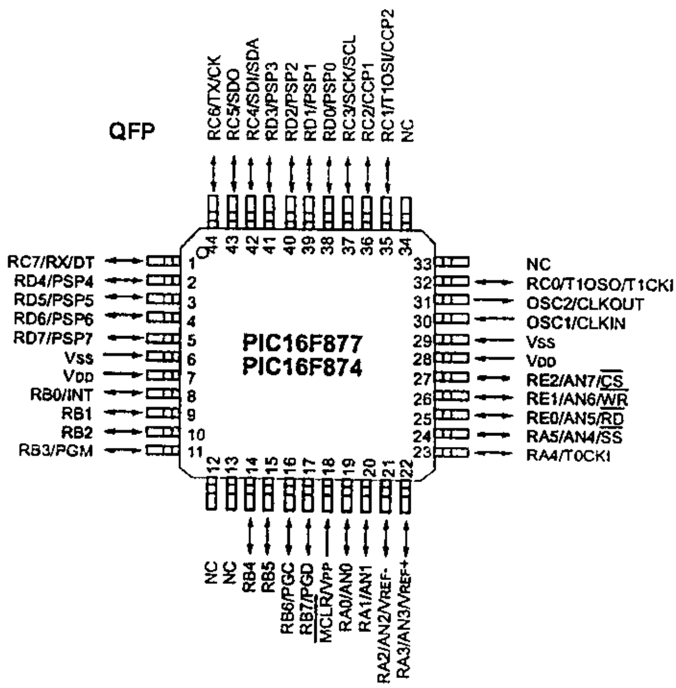
PDIP, SOIC



PLCC



QFP



1.0 DEVICE OVERVIEW

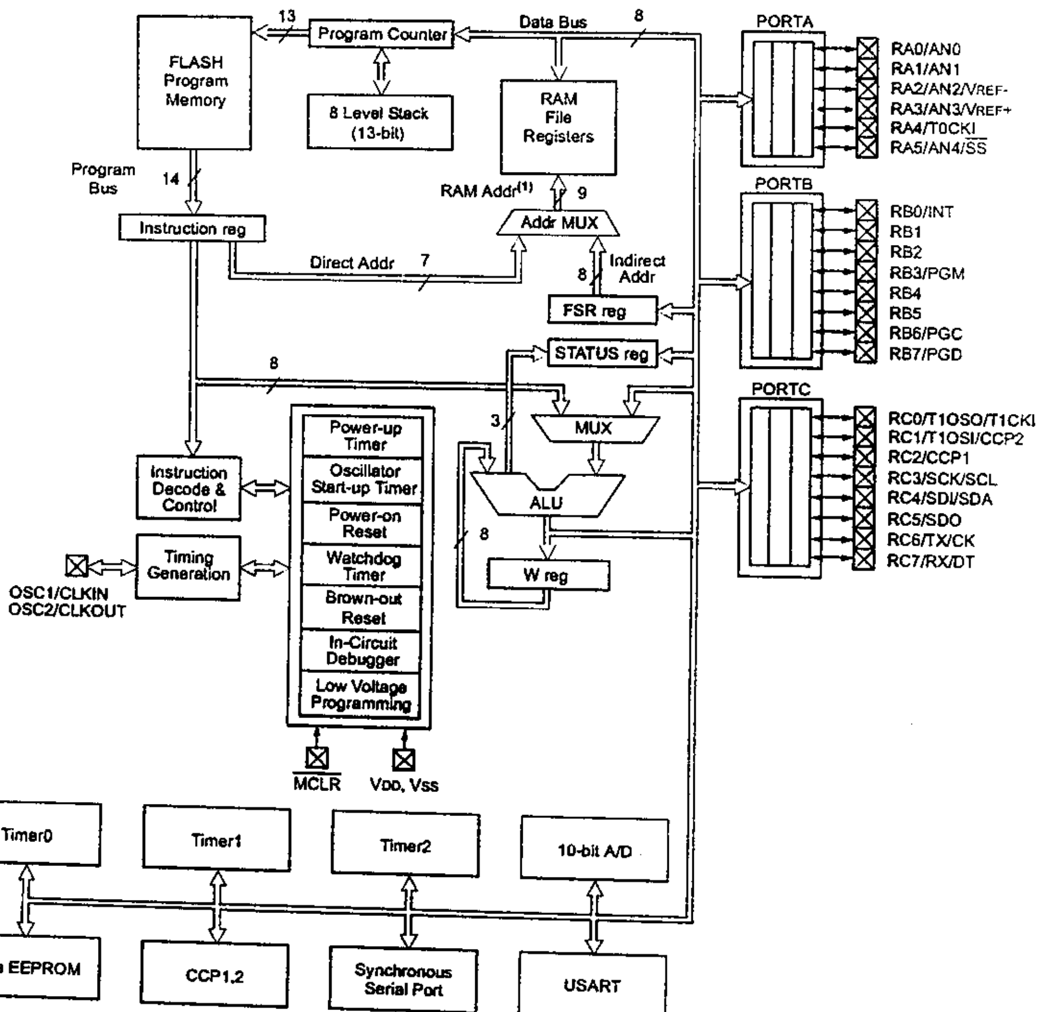
This document contains device specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

There are four devices (PIC16F873, PIC16F874, PIC16F876 and PIC16F877) covered by this data sheet. The PIC16F876/873 devices come in 28-pin packages and the PIC16F877/874 devices come in 40-pin packages. The Parallel Slave Port is not implemented on the 28-pin devices.

The following device block diagrams are sorted by pin number; 28-pin for Figure 1-1 and 40-pin for Figure 1-2. The 28-pin and 40-pin pinouts are listed in Table 1-1 and Table 1-2, respectively.

FIGURE 1-1: PIC16F873 AND PIC16F876 BLOCK DIAGRAM

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes
PIC16F876	8K	368 Bytes	256 Bytes

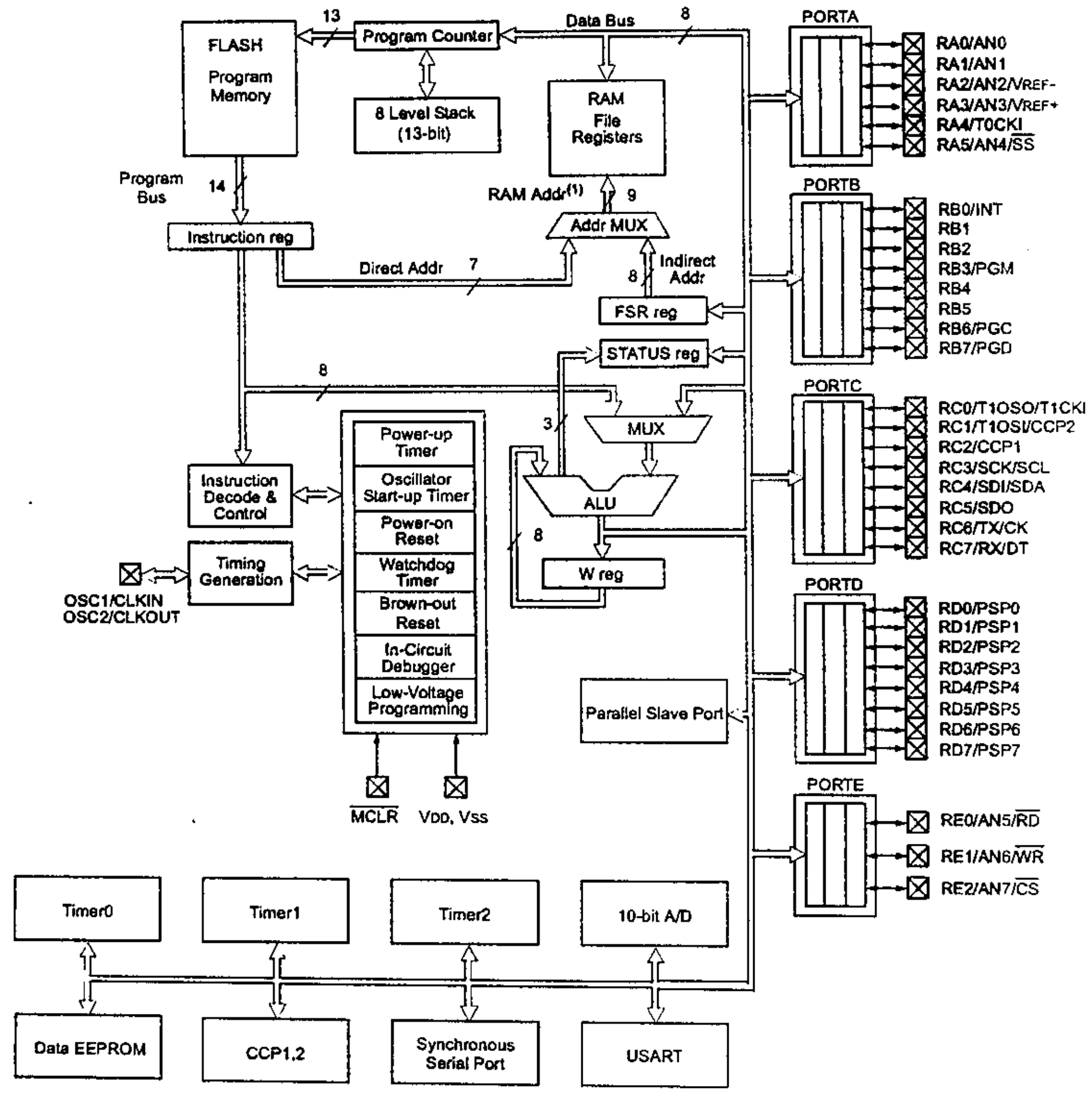


Note 1: Higher order bits are from the STATUS register.

Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

FIGURE 1-2: PIC16F874 AND PIC16F877 BLOCK DIAGRAM

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

TABLE 1-1: PIC16F873 AND PIC16F876 PINOUT DESCRIPTION

Pin Name	DIP Pin#	SOIC Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	9	9	I	ST/CMOS(3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	10	10	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	1	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	2	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	4	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	5	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	7	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	21	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3/PGM	24	24	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	25	25	I/O	TTL	Interrupt-on-change pin.
RB5	26	26	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	27	27	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	28	28	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	11	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI/CCP2	12	12	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	13	13	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/ PWM1 output.
RC3/SCK/SCL	14	14	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^2C modes.
RC4/SDI/SDA	15	15	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	16	16	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	17	17	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	18	18	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
VSS	8, 19	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	20	P	—	Positive supply for logic and I/O pins.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	37	41	14	I/O	TTL	Interrupt-on-change pin.
RB5	38	42	15	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
VSS	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
VDD	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

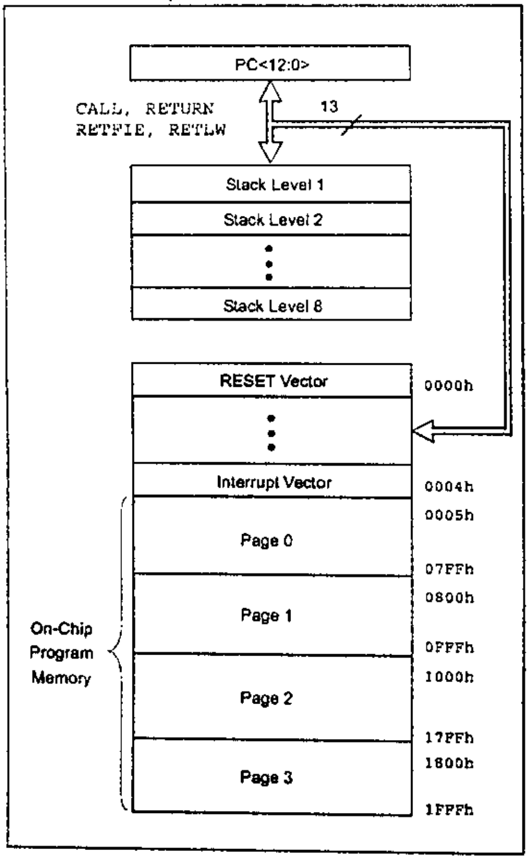
Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

2.0 MEMORY ORGANIZATION

There are three memory blocks in each of the PIC16F87X MCUs. The Program Memory and Data Memory have separate buses so that concurrent access can occur and is detailed in this section. The EEPROM data memory block is detailed in Section 4.0.

Additional information on device memory may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

FIGURE 2-1: PIC16F877/876 PROGRAM MEMORY MAP AND STACK

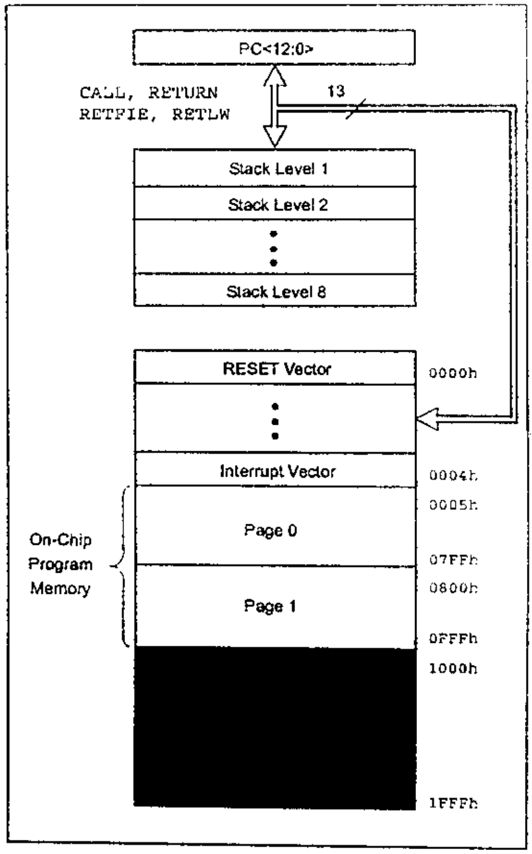


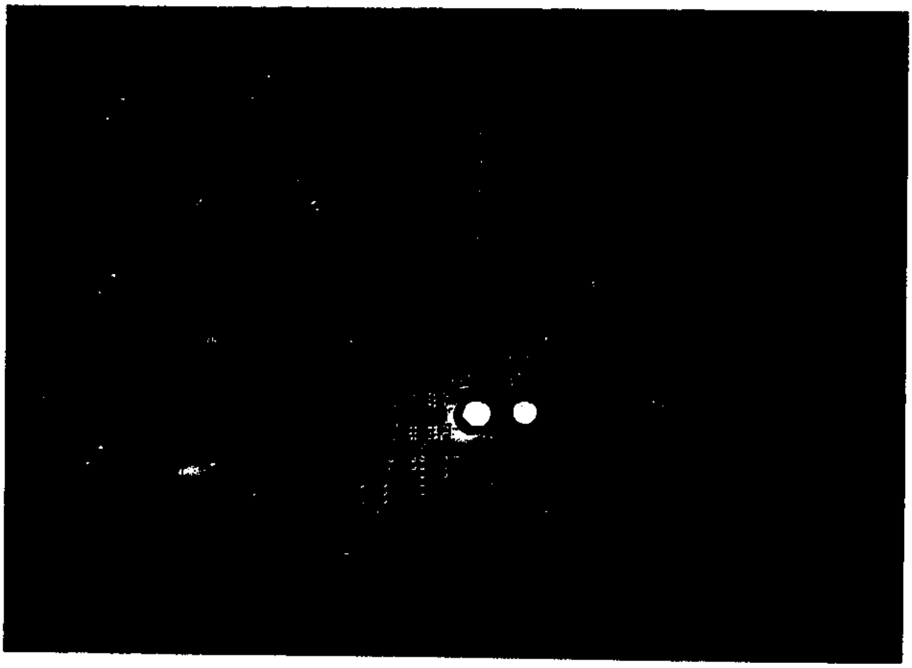
2.1 Program Memory Organization

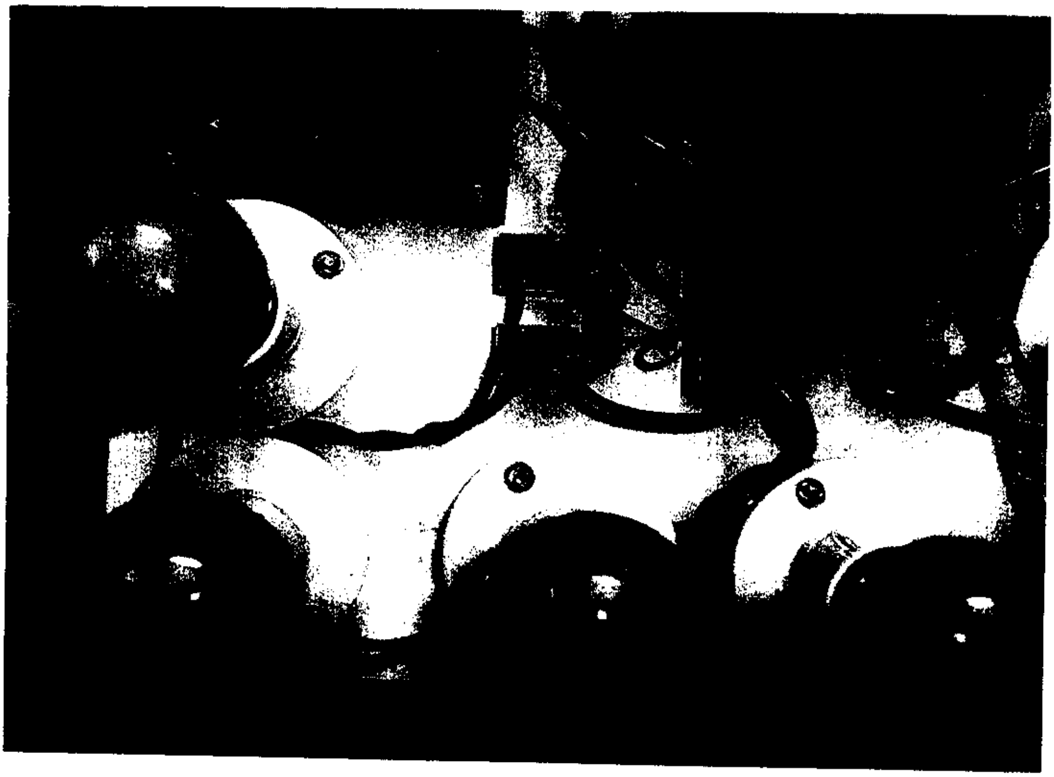
The PIC16F87X devices have a 13-bit program counter capable of addressing an 8K x 14 program memory space. The PIC16F877/876 devices have 8K x 14 words of FLASH program memory, and the PIC16F873/874 devices have 4K x 14. Accessing a location above the physically implemented address will cause a wraparound.

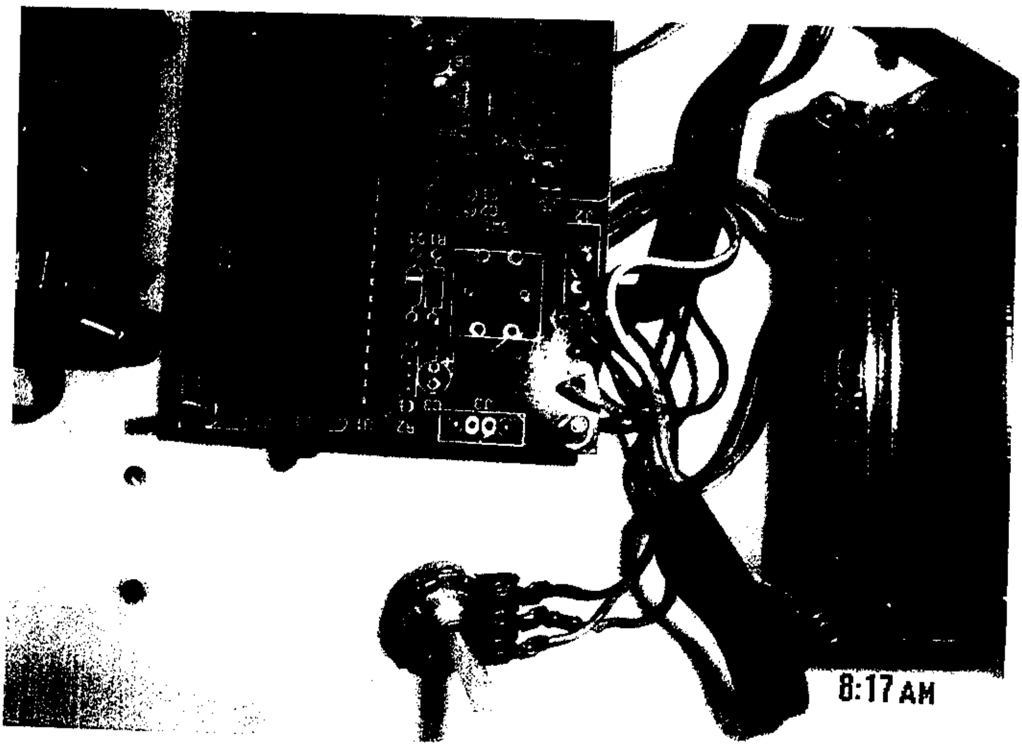
The RESET vector is at 0000h and the interrupt vector is at 0004h.

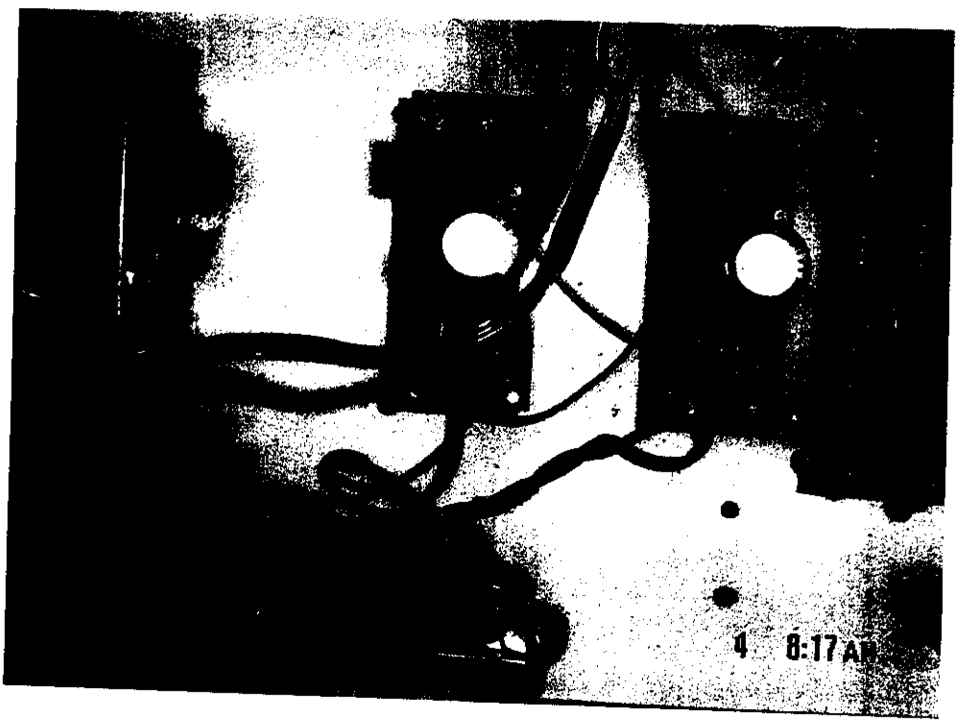
FIGURE 2-2: PIC16F874/873 PROGRAM MEMORY MAP AND STACK








8:17 AM


4 8:17 A