CONDENSATE SENSING DRAIN VALVE SYSTEM USING INFRARED SENSOR

Project Report

Submitted by

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Under the guidance of

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In partial fulfillment of the requirements for the award of the degree of

Bachelor of Engineering in Electronics and Communication Engineering of Bharathiar University, Coimbatore

Department of Electronics and Communication Engineering

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CERTIFICATE

This is to certify that the project report entitled

Condensate sensing drain valve system using infrared sensor

has been submitted by

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17.03.03

(Guide) **(Head of the Department)**

Certified that the above candidates were examined by us in the project work viva-voce examination held on 18.03.03 and the University register numbers are 9927D0144, 9927D0149 and 9927D0156

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This is to certify that the following final year B.E Electronics and Communication Engineering students of Kumaraguru College of Technology, Coimbatore have undergone and successfully completed a project in our organization.

1. **P.NAVEEN KUMAR**
2. **U. PREMITH**
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Project Title	**Condensate sensing drain valve system using infrared sensor**
Project period	**July 2002 to March 2003**
Department	**Research and Development (Electronics)**

During this period their attendance conduct and behaviour were found to be good.

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Acknowledgement

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Synopsis

Synopsis

This project involves the design of a control system for the condensate sensing drain valves used in air compressors. Condensate sensing drain valve is a device used to automatically drain the liquid condensate inside the compressor without the loss of air pressure. This process requires sensing the condensate level to allow or stop discharging of the condensate.

The system is designed to operate a relay that opens the drain valve when the upper condensate level is reached and closes it when the lower condensate level is reached. The condensate level is detected using an infrared sensing system. A pair of infra red transmitter and receiver is used to detect the condensate levels.

The output of the receiver is interfaced with a microcontroller. The microcontroller was programmed to operate a relay depending on the condensate level. The system also consists of a manual test drive facility, which is used to operate the drain valve manually. An LED indicator is used to indicate the draining of the liquid condensate.

Introduction

Compressed air is another form of energy used in various industrial and domestic applications. Compressor is a machine which utilizes electrical energy to produce air at a higher pressure than atmospheric pressure by reducing the volume of air by pressing or compressing it. Liquid condensate is formed when the moist atmospheric air is compressed. If this is not removed it affects the entire intended usage of the system.

Condensate is collected at various stages of manufacturing compressed air. The condensate is collected in dryer, compressed air tank, coolers, filters etc. Drain valve is a device used to remove the collected condensate.

Automatic condensate sensing drain valve is an intelligent system that enables draining of the condensate without loss of any air pressure. A sensor placed in the automatic drain valve system controls this draining of the condensate from the receiver tank.

Condensate sensing drain valve is supported with a level sensing system in order to detect the condensate levels. Previously used capacitive type sensor in the drain valve system had certain drawbacks and to over come this infrared sensor was developed. The condensate level is detected using an infrared sensing system. A pair of infrared transmitter and receiver is used to detect the condensate levels. The receiver detects the intensity of the signal that becomes low when the condensate obstructs the path of transmitted signal.

The output of the receiver is interfaced with a PIC12C508A microcontroller. This microcontroller is programmed to operate in three modes

- Sensor mode
- Manual test drive mode
- Timer mode

The relay opens the drain valve when the upper condensate level is reached and closes it when the lower condensate level is reached in sensor mode.

In case of failure of the sensor the system can be operated in the timer mode. In this mode the drain valve is periodically opened and closed to drain the condensate until the sensor starts working again. The system also consists of a manual test drive mode, which is used to operate the drain valve manually. An LED indicator is used to indicate the draining of the liquid condensate.

This system can work for all the types of condensates; hence it can be used for all types of compressors. The system is highly reliable and efficient. It saves energy, air loss is minimum, less noise pollution and electrical power required is also very less.

Project overview

2.1 Introduction

A drain valve system is one through which the condensate is removed from air receivers, refrigerator dryers, air filters etc. The condensate collected in the drain valve system may be of the following types

- Water
- Water + Oil
- Water + Oil + Dust

These condensate collected in the drain valve system will slowly raise its level in the drain valve tank. Condensate sensing drain valve works on sensing the level of condensate. Thus by maintaining an upper level and lower level of condensate, wastage of compressed air is saved which directly leads to saving electrical energy.

2.2 Drawbacks of present sensors

The capacitive type sensor previously detected the level of the condensate in the drain valve tank. In this type of sensor the condensate acts as a dielectric medium between a probe and the body of the drain valve tank.

This system had the following drawbacks

- Capacitive probe gets oily and gives false outputs.

- Capacitive sensor system was proved unreliable for condensate other than water.
- Deposition of oil on the probe led to a constant di-electric value and hence the change in the condensate level gets undetected.

In order to overcome the above stated problems an infrared sensing system was designed.

2.3 Infrared Sensor System

The infrared sensor consists of a pair of infrared transmitter and receiver. The infrared transmitter and receiver are fixed in the tank at both the upper and lower levels (fig 2.1). The infrared transmitter is designed using an astable multivibrator constructed using *555 timer IC*, the output of which is used to modulate an infrared led. The rays from the transmitter are focused on to a receiver that is placed at the opposite side. The receiver consists of an infrared detector that switches a transistor depending on the received signal. The amplitude of the output at the receiver end depends on the intensity of light falling on the detector.

The amplitude increases with increase in intensity. Maximum intensity of light is received when there is no condensate or when it passes through air and it decreases when infrared ray passes through condensate mixture. This decrease in intensity of the received rays is due to the following properties of light in a medium

- Scattering
- Absorption
- Attenuation

- Reflection
- Refraction

In the receiver side the output from the transistor switch is amplified using an opamp and this output is fed to a comparator. The comparator gives a voltage output when the intensity of light is maximum i.e. when the rays do not pass through the condensate. The output is zero when there is condensate. The output from the comparator is given as an input to an *8bit PIC 12C508A*. This microcontroller is programmed to operate a relay depending on the condensate level.

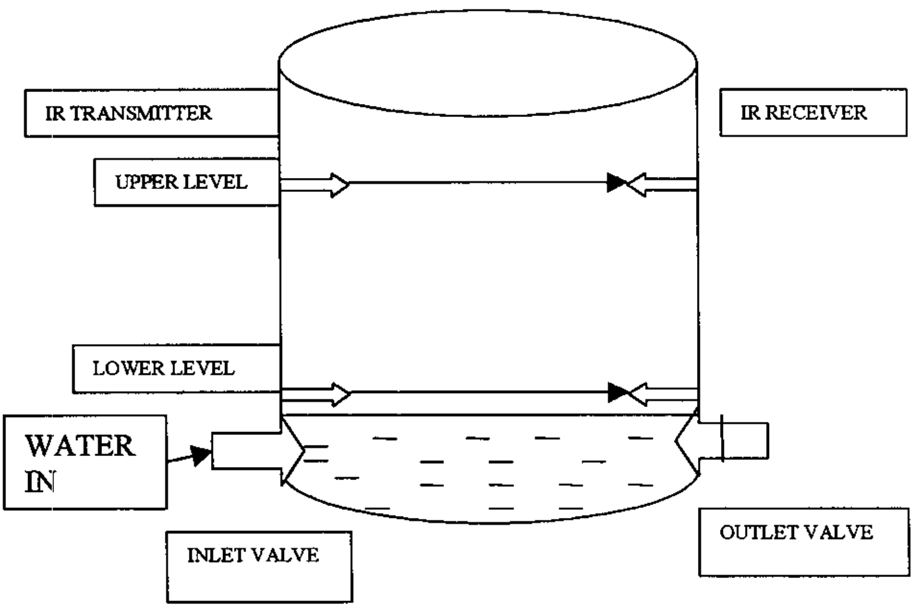


figure 2.1 Drain valve condensate levels

The relay opens the drain valve when the upper condensate level is reached and closes it when the condensate reaches the lower level.

In case of failure of the sensor, the PIC is programmed in such a way that the drain valve opens and closes periodically to drain the condensate until the sensor starts working again. The system also consists of a manual test drive facility, which is used to operate the drain valve manually .The functions of the valve are indicated by an LED indicator.

2.4 Conclusion

The microcontroller based drain valve system with infrared sensor is a versatile device, which works for all the types of condensates; hence it can be used for all types of compressors. The system is highly reliable, efficient and cost effective.

Compressor system description

3.1 Introduction

A compressor is an integral part of any industry that requires pneumatic applications. Various applications of compressed air, basic working of a compressor and the need for drain valve in compressors are briefly explained in this chapter.

3.2 Compressed Air

Air is present in the atmosphere at atmospheric pressure. This is pressed or compressed into a smaller volume to produce compressed air in a tank.

3.2.1 Usage of compressed air

Compressed air is used for a variety of applications in industries and household like

- To move objects or pneumatic cylinders
- To carry liquids Example: spray painting
- To rotate screwdrivers, rotary cylinder
- Conveying

3.2.2 Work done by compressed air

Compressed air exerts a force of constant value to every internal contact surface of the pressure containing equipment.fig3.1.

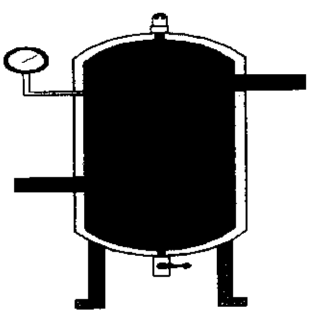


figure 3.1 forces exerted by compressed air.

- Liquid in a vessel will be pressurised and transmits this force.

- For every bar of gauge pressure, 10 Newtons are exerted uniformly over each square centimetre. The thrust developed by a piston due to this air pressure is the effective area multiplied by the pressure fig3.2.

$$\textbf{Thrust} = \frac{\pi D^2 P}{40} \quad \textit{Newtons}$$

Where

D = the bore of a cylinder in mm

P = the pressure in bar.

We require an answer in Newtons

1bar = 100000 N/m^2

D^2 is therefore divided by 1000000 to bring it to m^2 and P is multiplied by 100000 to bring it to N/m^2. The result is a division by 10 shown in the product 40 above

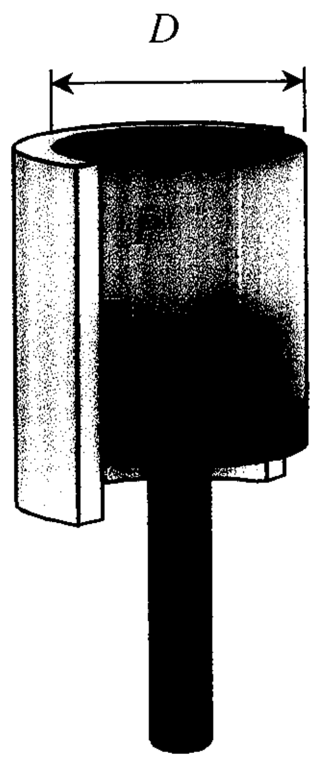


figure3.2
Compressed air
moving a piston

3.2.3 Application of compressed air

- Cement Industries
- Textile & Garments Industries
- Chemical Industries
- Paper and Printing Industries
- Food Industries
- Automobile Industry
- Film Industries

3.3 Compressor

Compressor is a device that is used to attain air at high pressure than atmospheric pressure. It converts electrical energy to mechanical energy. It is used in a variety of applications.

3.3.1 Working

In a compressor electrical energy is used to compress the air. This electrical energy is converted to mechanical energy when the compressed air is used to produce work. The air is sucked into a cylindrical tank using an electric motor. This air is then pressed down using a piston to reduce the volume of air till the required pressure level to produce compressed air. This air is then stored in a tank called receiver from where it is taken out for various application. The compressor when installed in a system manufacturing compressed air requires additional components like air dryers to remove moisture content in the compressed air and oil filters to remove oil particles. This is to ensure that compressed air is pure and does not contain impurities that otherwise will affect the application for which the compressed air is used. Since the compressed air coming out from the compressor is hot it has to be cooled using a cooler to ensure safe temperature levels.

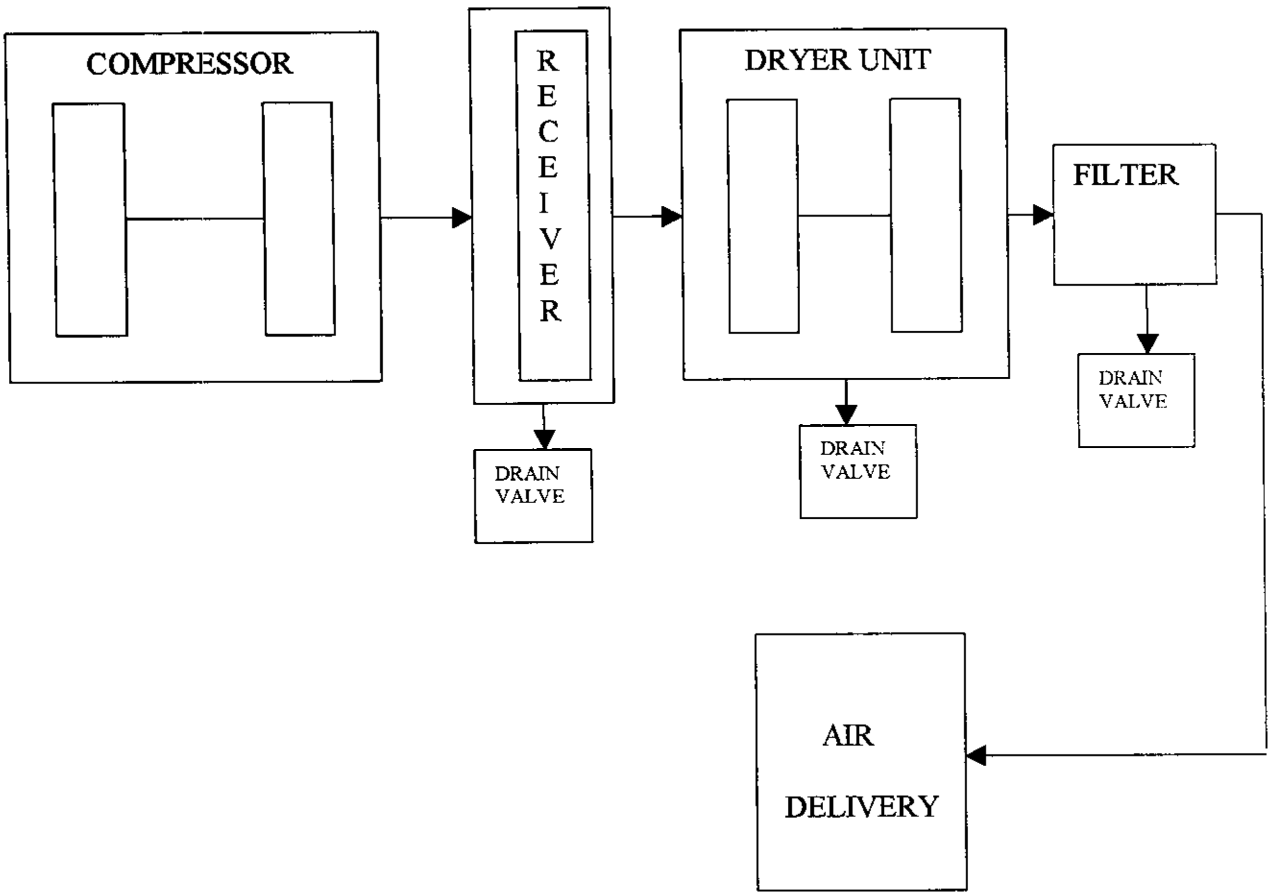


figure 3.3 GENERAL COMPRESSOR LAYOUT AND DRAIN VALVE PLACEMENTS

3.3.2 Types of compressors

Based on application compressors are classified into

- Lubricated
- Non lubricated

3.3.2.1 Lubricated compressors

Here the compressor piston is lubricated using a lubricating oil to reduce friction and ensure easy movement of piston inside the tank.

3.3.3.2 Non-lubricated compressors

Here the compressor piston is not applied with any lubricant. The piston free moves along the smooth walls of the cylindrical compressor tank.

3.3.3 Application of compressors

Compressors can be used for the following applications fig 3.4.

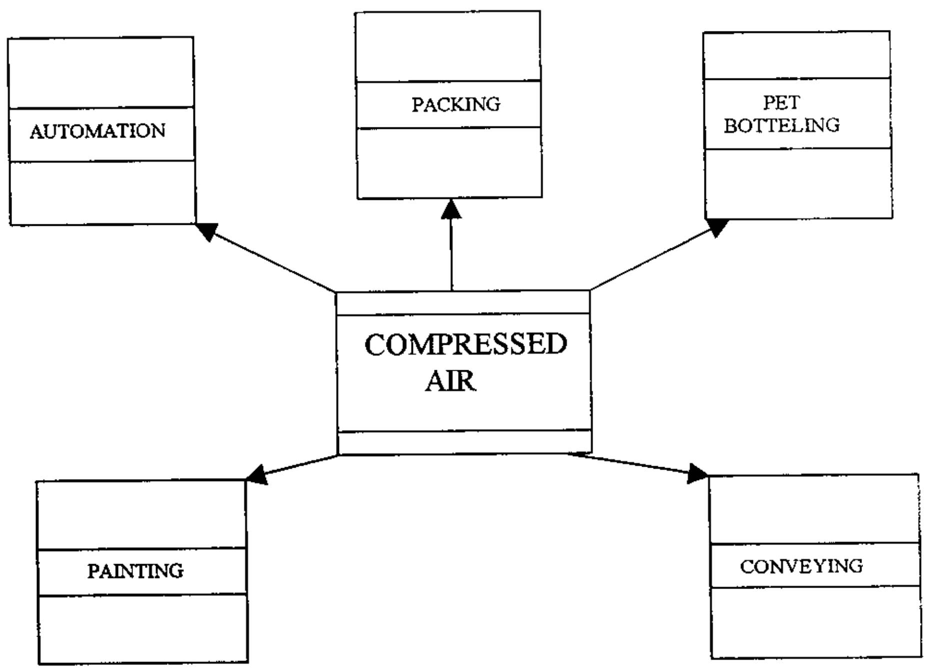


figure 3.4 Application of compressors

3.3.4 Components in compressed air

Since atmospheric air is directly sucked in by the compressor and compressed the compressed air consist of particles suspended in atmospheric air like water, oil and dust. These particles get deposited in the compressor. If these are not removed it can cause corrosion of the compressor tank and lose of energy. In lubricated compressors in addition to atmospheric particles lubricant is also collected in the receiver. Hence these are to be removed using suitable **treatment products.**

3.3.5 Advantages of treatment products

- Long-term reliability of instruments.
- No sudden break downs
- Reduce maintenance cost

3.3.6 Water in compressed air

Water forms the bulk of effluent formed when air is compressed. When air is compressed the holding capacity of air reduces and hence moisture in air condenses, as water is a non-compressible liquid. This water if not removed deposits at the bottom of the receiver causing corrosion.

When large quantities of air are compressed, noticeable amounts of water is formed fig 3.5. The natural moisture vapour contained in the atmosphere is squeezed out like wringing out a damp sponge.

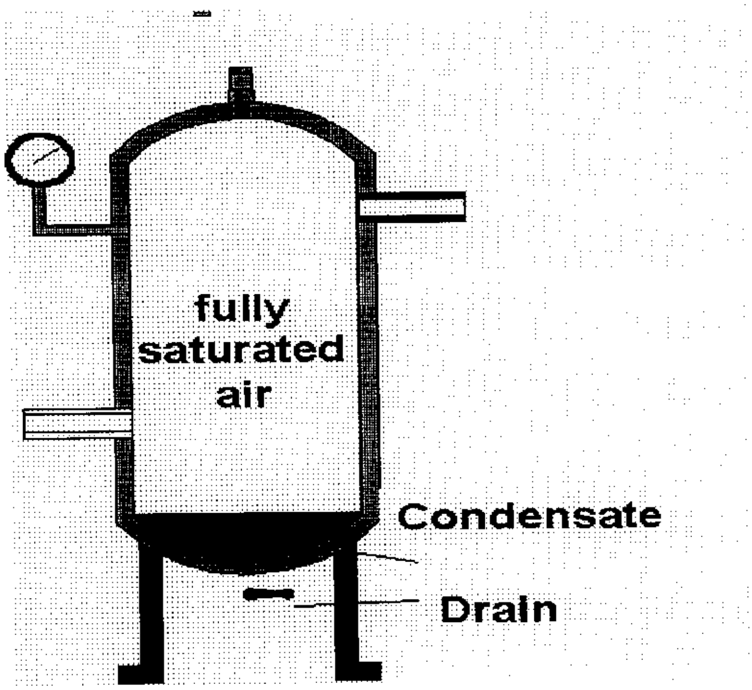


figure 3.5 Condensate formations

3.3.7 Relative humidity

The amount of water vapour contained in a sample of the atmosphere is measured as Relative humidity %RH. This percentage is the proportion of the maximum amount that can be held at the prevailing temperature fig 3.6.

At 20 degree Celsius

100% RH = 17.4 g/m3

50% RH = 8.7 g/m3

25% RH = 4.35 g/m3

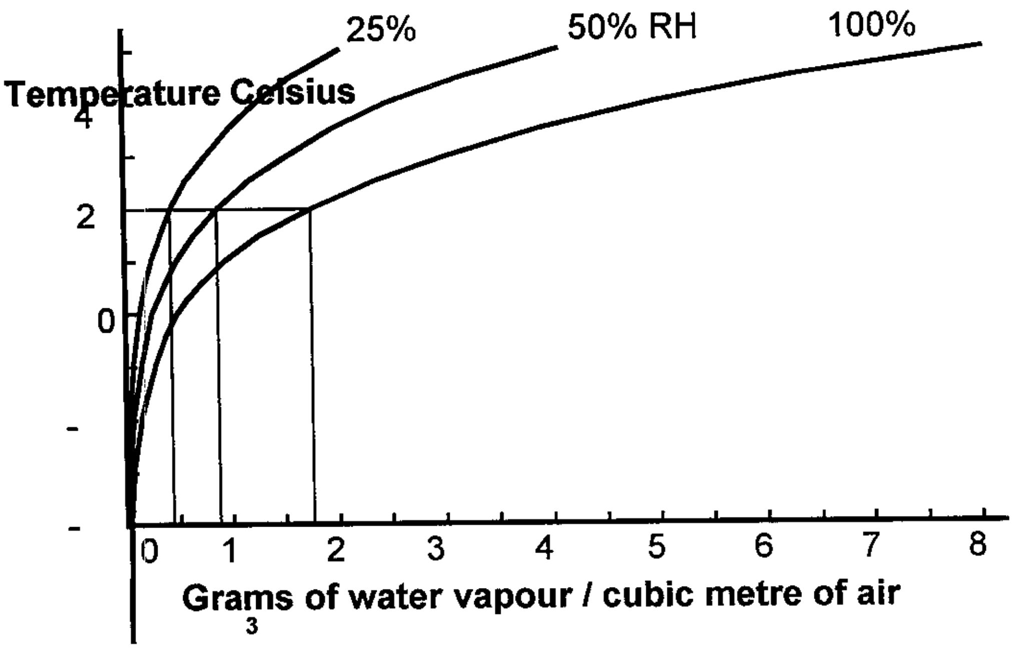


figure 3.6 temperature vs. moisture

For example

When air of 70% RH is subjected to 7Bar pressure, RH of the compressed air is increased to 490%, but practically only 100% can be present in the air hence remaining 390% is formed as the liquid condensate.

Oil also exhibits a similar property when air is compressed hence the condensate consists of water oil and solid particles in most cases. In lubricated type compressor the amount of oil will be very high in the compressed air.

3.4 Drain valve

A drain valve is a device, which is used to remove the condensate formed in the dryer, compressed air tank, coolers, filters etc. (fig 3.7)

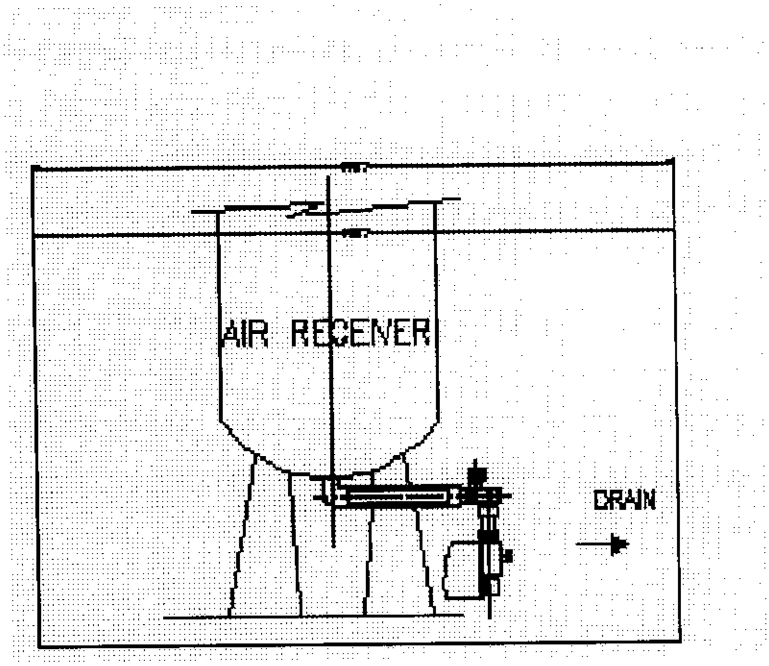


figure 3.7 Drain valve connected to a receiver

3.4.1 Uses of drain valve

- It prevents corrosion formed by the condensate.
- Increases system reliability.
- No sudden break downs
- Reduce maintenance cost.

3.4.2 Types of drain valve

1) Manual drain valve
2) Automatic drain valve

a) Timer based drain valve

b) Level sensing drain valve

- Conducting type
- Capacitive type

3.4.2.1 Manual drain valve

In this type the drain valve is operated using a manual switch. Condensate is periodically removed from the drain valve system by pressing a switch manually.

Constraints

In this type enormous energy is wasted as the valve is opened before the system gets filled with condensate. A lot of air also escapes due to this. A manual operator has to be allocated for this work alone.

3.4.2.2 Automatic drain valve

In this type, the valve is operated automatically thus eliminating manual operator. This system is more versatile and can be operated for long periods without any manual intervention. There are two types of automatic drain valves and they are,

a.) Timer based drain valve

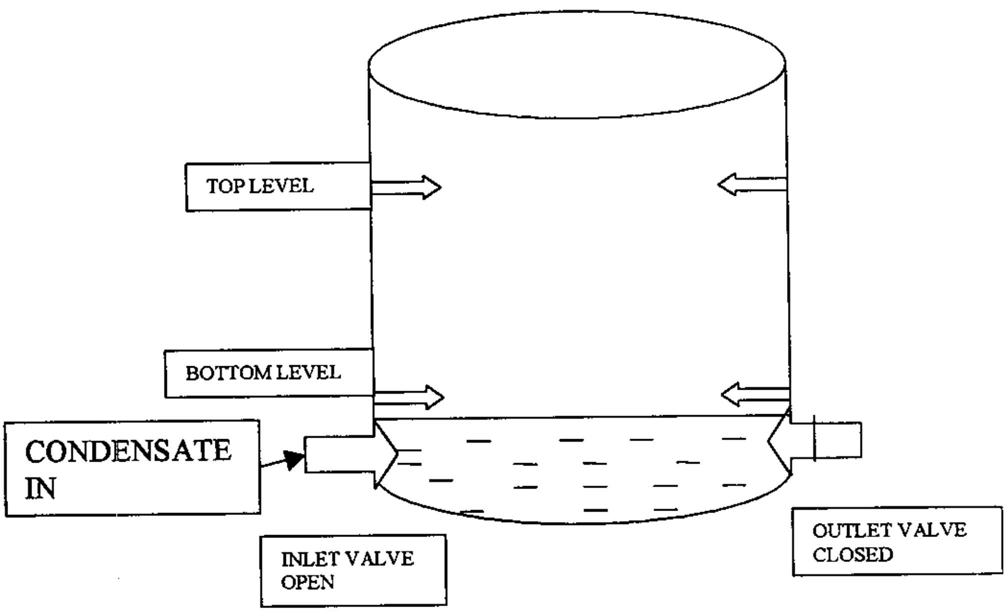
Here the drain valve is operated at regular intervals of time, which a microcontroller .The controller controls is programmed for the required time interval.

Constraints

As the drain valve opens at regular intervals of time air is wasted in most cases, as the tank may not be filled with condensate.

b.) Level based drain valves

Here the drain valve is opened depending on level of condensate in the tank, an upper level and lower level is set and the drain valve is opened when top level is reached and it is closed when bottom level is reached fig 3.8. This prevents any air loss as only condensate alone is drained out and not air. The levels are detected electronically and hence accuracy is more.



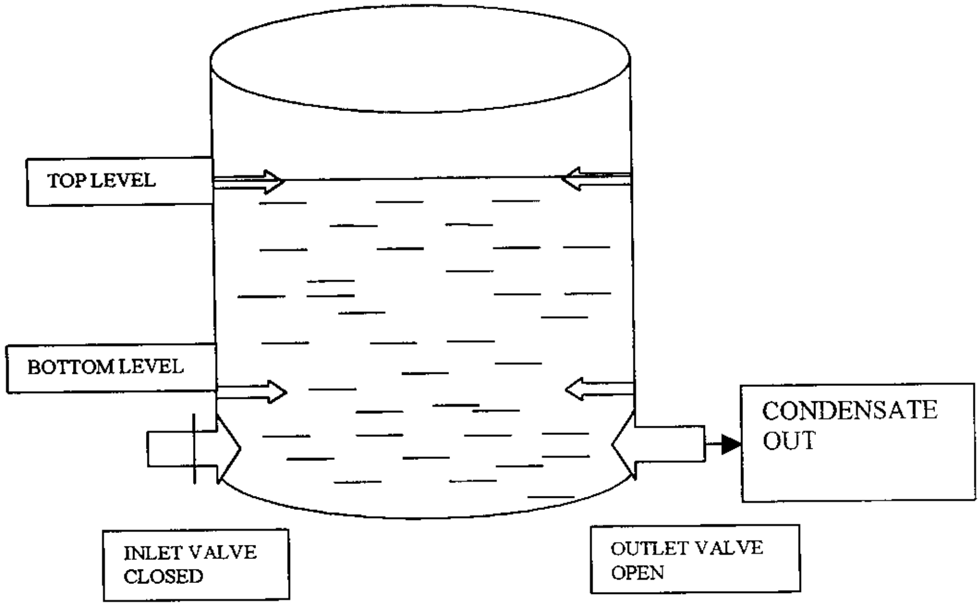


figure 3.8 level detection in a drain valve

Basic working of level based drain valves

- Condensate enters the tank
- Condensate level raises and sensing probe detects the condensate as it reaches the upper level.
- Sensing signal instructs the solenoid valve to be switched ON – Drain LED ON
- Diaphragm valve discharges the condensate till it reaches the lower level.

Advantages of level detection drain valve

- No loss of compressed air – Energy saving

- Less Noise – Only condensate is discharged
- Intelligent controller
- Alarm signal in case of solenoid coil failure and diaphragm valve failure – Alarm LED Blink
- Test switch – Manual Override

Depending on type of sensor used level detection drain valve can be divided into

i.) Conduction Type

In this type the levels are detected using the levels are detected using the principle of conduction. Here the condensate act as a medium for flow of current a suitable circuit is setup in such a way that the output is obtained when the conduction takes place. A pair of probes is kept on the upper level and lower level to detect the condensate.

Working

- Condensate enters the tank
- When the condensate reaches the upper level current flows from one probe to another
- A closed path for flow of current is formed and valve is opened
- When the condensate reaches just below the lower level probes current flow stops.
- An open path is formed and flow of current is obstructed and valve is closed.

This conducting type system had the following drawbacks

- Number of probe required is high.
- Conductive sensor system was proved unreliable for condensate other than water.

- Since oil is a non-conductor if oil content was more then probes failed to detect condensate level.

ii.) Capacitive type

Here the condensate acts as a dielectric medium between a probe and the body of the drain valve tank. This capacitance is used to produce a frequency using a suitable circuit. This capacitance varies with the amount of condensate inside the tank, which indirectly affects frequency. This frequency is detected to operate the drain valve.

Working

- Condensate enters the tank
- As the level of condensate increases frequency varies
- When the condensate reaches the upper level a particular frequency is produced
- This frequency is detected and valve is opened
- When the condensate reaches the lower level a another frequency is produced
- This frequency is detected and valve is closed.

The presently used system is the Capacitive Sensing type system, which works efficiently for a condensate of water+10% oil.

3.5 Conclusion

Level sensing drain valves are currently used for its energy saving feature. Sensor system presently used for level sensing is unreliable for condensates with more than 10% oil. A new sensing system that is reliable for all types of condensates is to be developed.

Sensor Analysis & Desig

Sensor design and analysis — Chapter 4

4.1 Introduction

Frequent drain valve system failures was detected in lubricating compressors using the capacitive type-sensing device. An in depth analysis of the sensor system showed that failure was due to.

- Capacitive probe gets oily and gives false outputs.
- Capacitive sensor system was proved unreliable for condensate other than water.
- Deposition of oil on the probe led to a constant di-electric value.
- Capacitance variations reduced due to oil coating on the probe.
- Frequency output of the system remained constant. Hence upper and lower level of the condensate went undetected.

An in depth analysis of the above systems led to propose a system which will enable to overcome the above constraints.

4.2 Sensor Designs

The following sensors were considered to overcome the above mentioned limitations.

4.2.1 Solenoid shaped probe

The probe used in the drain valve tank was designed in the shape of a solenoid coil (fig 4.1) in order to decrease the distance between the capacitor plates. This will enable to detect the small capacitance variations in the probe that is evident from the formula of capacitance of coaxial capacitor.

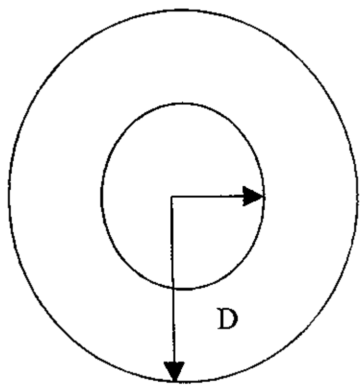


figure 4.1

$$C = 2\pi E / log(D/d)$$

This type of probe is being currently tested in the field and the response is better than the previous one, but much more reliable system is sort.

4.2.2 RF Sensor

Here a radio frequency wave is sent from one end of the tank; it pierces inside the tank, strikes the opposite side of the tank and returns back to the sensor. The time period it takes to travel inside the tank varies according to the type of the condensate through which it travels. Based on this difference in time periods the drain valve is operated.

This system failed since the difference in the time periods was very less as the size of the tank was small for the radio frequency to travel.

4.2.3 Ultrasonic sensor

An ultrasonic sensor is placed at the top of the tank; the ultrasonic waves strike the surface of the condensate and are reflected back. The level of the condensate is determined by the time taken by the wave to reach the sensor after reflection. Depending on the level of the condensate the drain valve is operated.

This system also was not implemented as the distance was too small and also the cost was prohibitive.

4.2.4 Light dependent resistor

Here a light is placed at the upper and lower level of the tank and light detectors are placed at the opposite ends. The amount light received at the detectors depends on the type of condensate through which it passes. Based on the intensity received the output varies and it operates the drain valve. This principle worked well but oil and dust particles sticking to the surface of the transmitter or receiver resulted in no change in intensity.

Hence an infrared transmitter and receiver were developed to work on the above principle since infrared waves can pierce through dust and thin films of oil layer.

4.3 Infrared sensor principle

The properties exhibited by infrared wave when it is propagated through a medium are used here to detect the level of the condensate in the drain valve tank.

Infrared rays were used for this application for the following reasons

- IR can pierce through small dust particles that may stick to the emitting surface unlike ordinary light.

- Effect of refraction and reflection was less compared to ordinary light enough to detect the condensate levels.

- IR was found to be cost effective, compared to other types.

4.3.1 System working

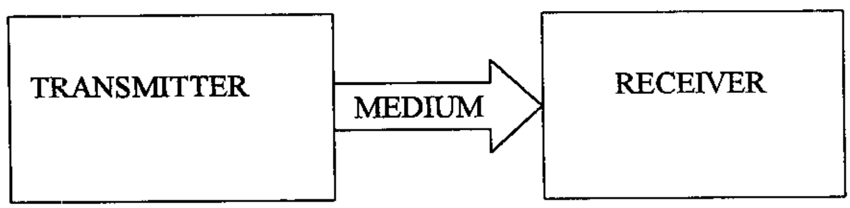


figure 4.2 Transmitter and receiver block

- As shown above an IR transmitter transmits the signal

- As the signal passes through the medium a part of it is lost depending on the medium type fig 4.2.

- The receiver is designed in such a way that the output varies with the amount of IR reaching it.

- Maximum intensity of light is received when the medium is air and hence output is maximum.

- But when the medium is liquid, losses are maximum this is due to following properties

1) Scattering
2) Absorption
3) Attenuation
4) Reflection
5) Refraction

4.3 Conclusion

Infrared sensor system was found to be best suited for this level sensing application. It was a cost effective, compact and reliable system. Testing in various types of condensates proved the system reliability.

Hardware description

5.1 Introduction

The hardware part consists of a transmitter part and a receiver part for each level. The infrared signal is transmitted which is analyzed at the receiver to detect the level of the condensate. The transmitter is an astable multivibrator using 555 timer. The receiver consists of detector, amplifier, comparator, switching transistor and a micro-controller figure 5.1.The microcontroller operates the drain valve depending the condensate level.

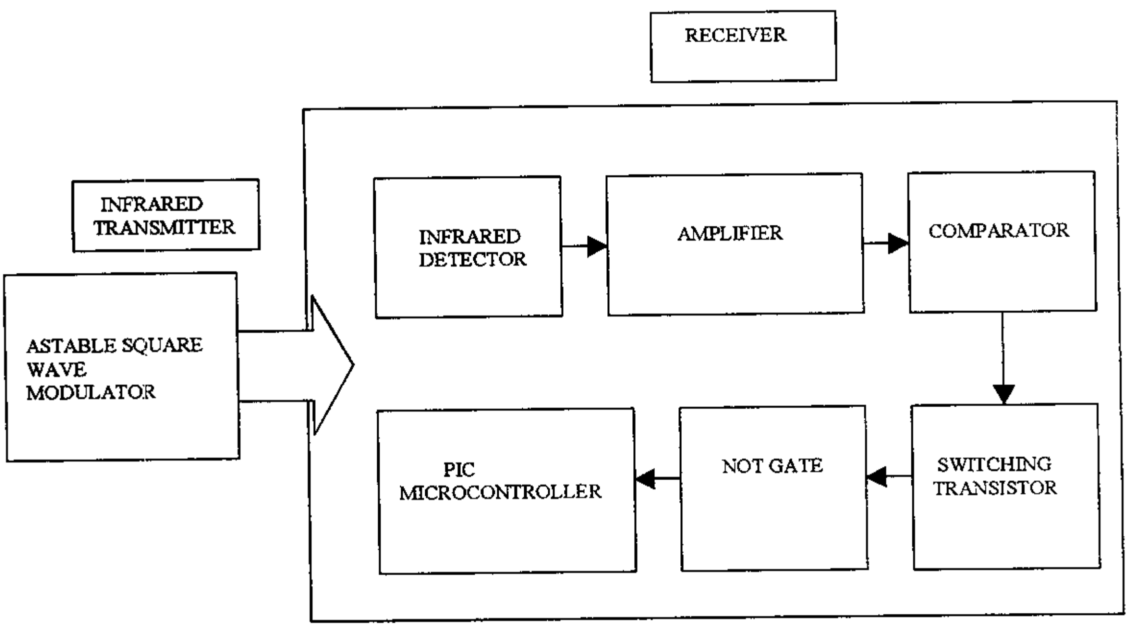


Figure 5.1 hardware block

5.2 Power supply

The power supply (fig 5.2) provides the regulated output voltage of +5V&-5V. The power supply consist of

- Transformer
- Bridge rectifier
- Filter
- Voltage Regulator

5.2.1 Transformer

The transformer is used to step down 230V A.C from the mains to 9VA.C. The transformer is centre-tapped type

5.2.2 Bridge rectifier

In the bridge circuit the sinusoidal input is converted into unidirectional waveforms. It is a full wave rectifier the peak inverse voltage of each diode is less.

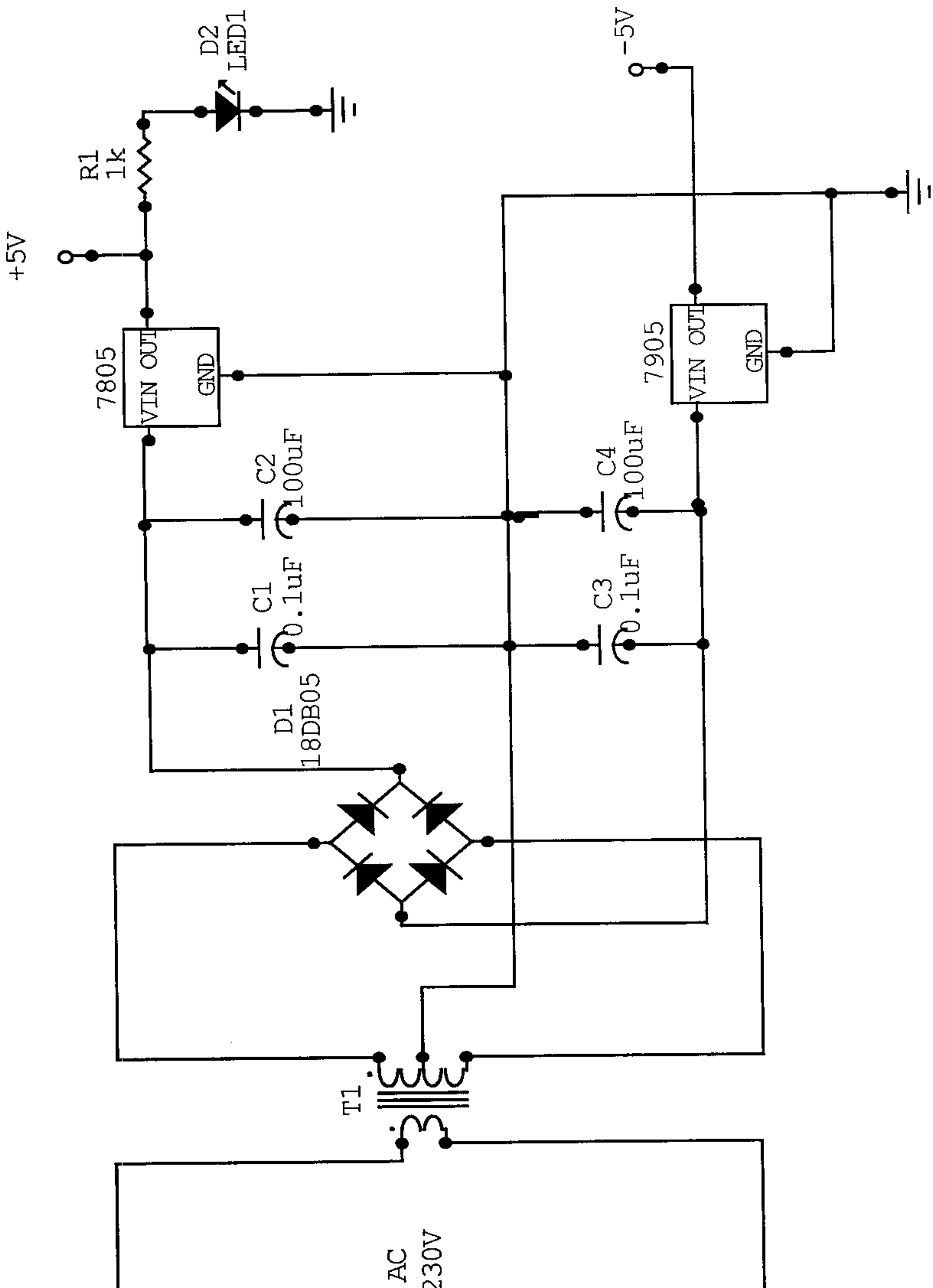
5.2.3 Filter

Filters are used to remove unwanted A.C. component from the dc output. Capacitive filter is used, as the capacitance value increases ripples decrease.

5.2.4 Voltage Regulator

A voltage regulator is a circuit that supplies a constant voltage regardless of changes in the load currents. IC voltage regulators are versatile and inexpensive. A 7805 IC is used to obtain positive 5 volts and 7905 IC is used to obtain negative 5 volts.

figure 5.2 Power supply



5.2 Infrared transmitter

Infra red transmitter circuit is constructed using 555 timer fig 5.3. The 555 timer is a highly stable device for generating accurate oscillation. Timer can be used with supply voltage varying from 5 to 18 v and thus is compatible with TTL and CMOS circuits. Here the IC555 timer in the astable mode is used.

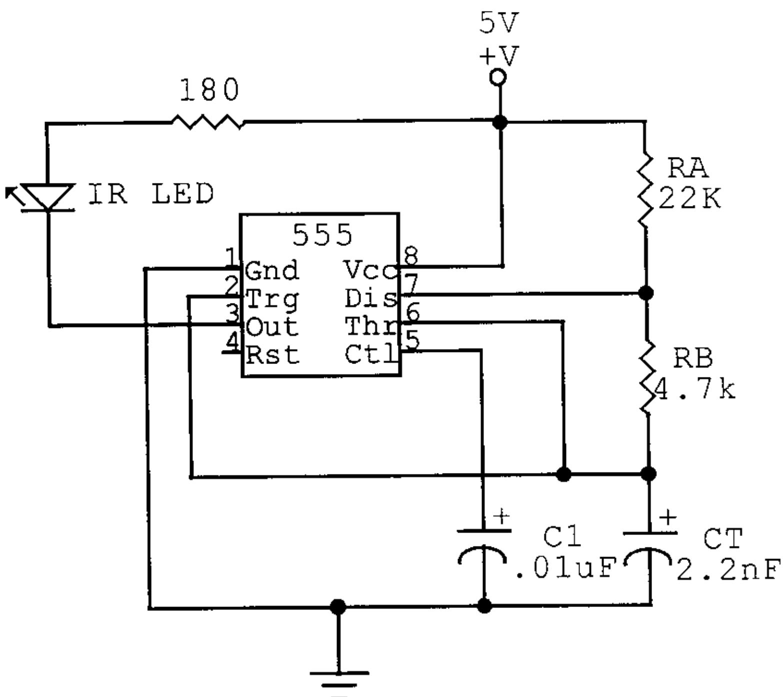


figure 5.3 Infrared Transmitter

f= 1 / T = 1.45 / (Ra+ 2 Rb) C

It is with respect to the hardware circuit shown in the figure .The pin configuration is shown in figure 5.2. The square wave output is used to intensity modulate an infra red source at a frequency of frequency 20 kHz. The infrared source has to be modulated to increase the transmission power of the transmitter.

5.3 Infrared Receiver

5.3.1 Infrared detector

A photodiode is used to detect the infrared pulse from the transmitter. The photodiode is placed at base of a transistor voltage follower circuit fig 5.4. The base-emitter junction of the transistor is forward biased when the photodiode conducts according to the intensity of the infrared pulse. This in turn produces a base current that drives the transistor. Output voltage is obtained across the emitter resistance that varies according to the intensity of the light those incidents on the photodiode.

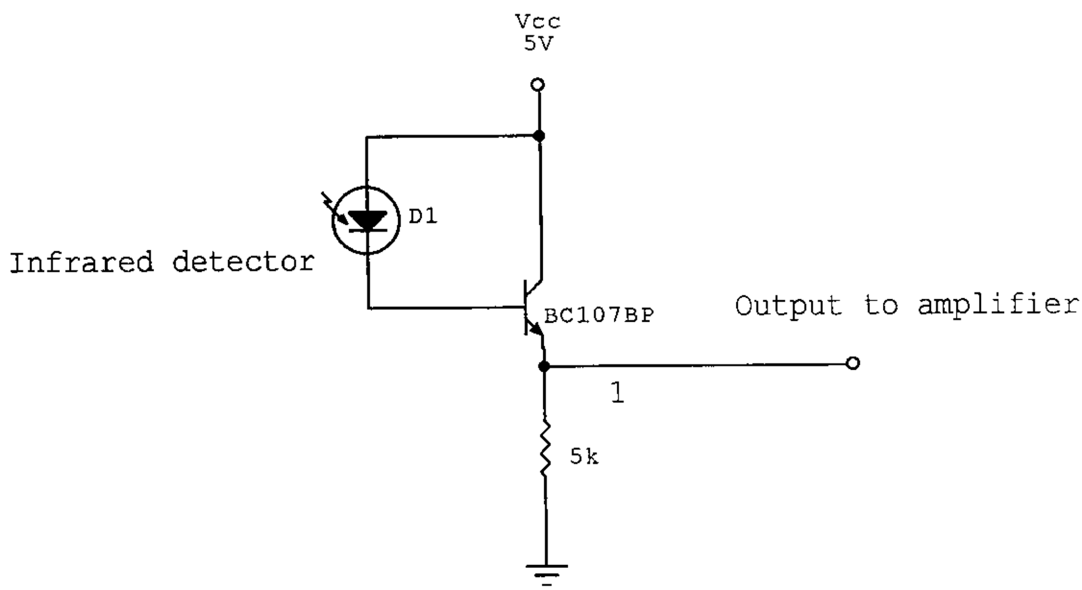


figure 5.4 Infrared detector

5.3.2 Voltage Amplifier

The voltage signal from the IR detector is amplified by a non-inverting amplifier constructed by an OP-AMP IC741 fig 5.5.The signal is applied to the non inverting terminal and feedback is given as shown in the circuit .The circuit amplifies without inverting the input signal .It is a negative feedback system as output is being fed back to the inverting terminal.

The Rf and R1 shown in the circuit forms a potential divider on which the gain of the amplifier depends.

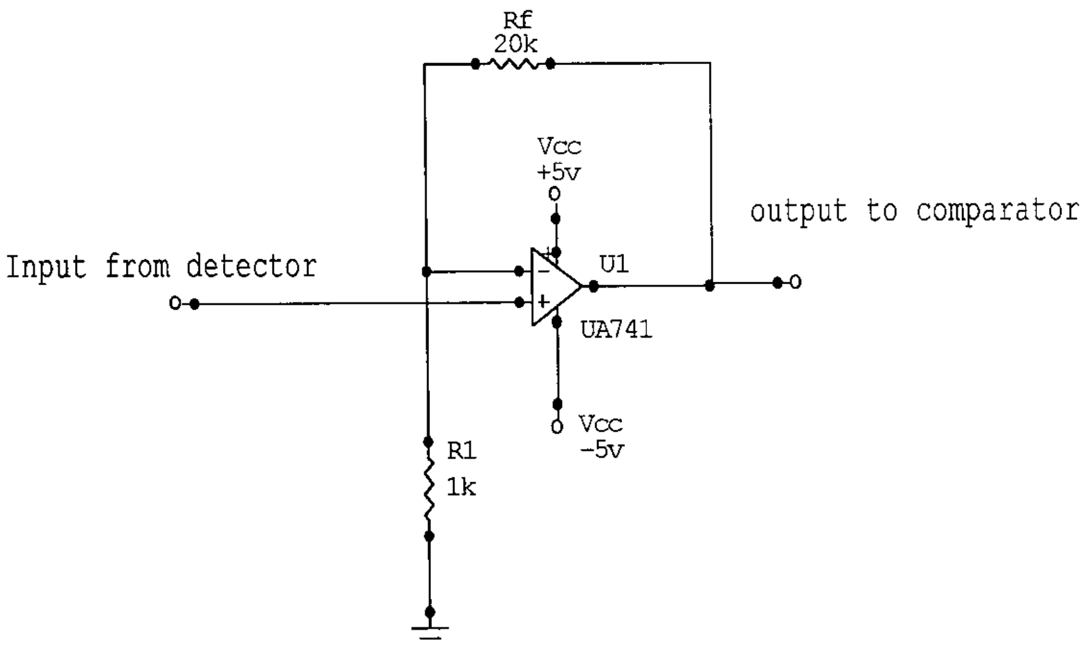


figure 5.5 Voltage amplifier

Gain of the non-inverting amplifier = 1 + Rf / R1

Theoretically a gain of 21 is expected from the amplifier for the Rf and Ri values of 20kohms and 1knohms respectively.

5.3.3 Comparator

The output from the amplifier is given to a non-inverting comparator. This comparator circuit fig 5.6 performs the evaluation. Circuit is constructed in the open loop configuration using an OP-AMP IC741. Comparator is used to implement the go or no go logic to detect the level of the condensate. The comparator is a circuit that compares the input signal voltage at the positive input with a known reference voltage at the negative input.

Output voltage = - Vsat for vi< Vref

Output voltage = + Vsat for vi> Vref

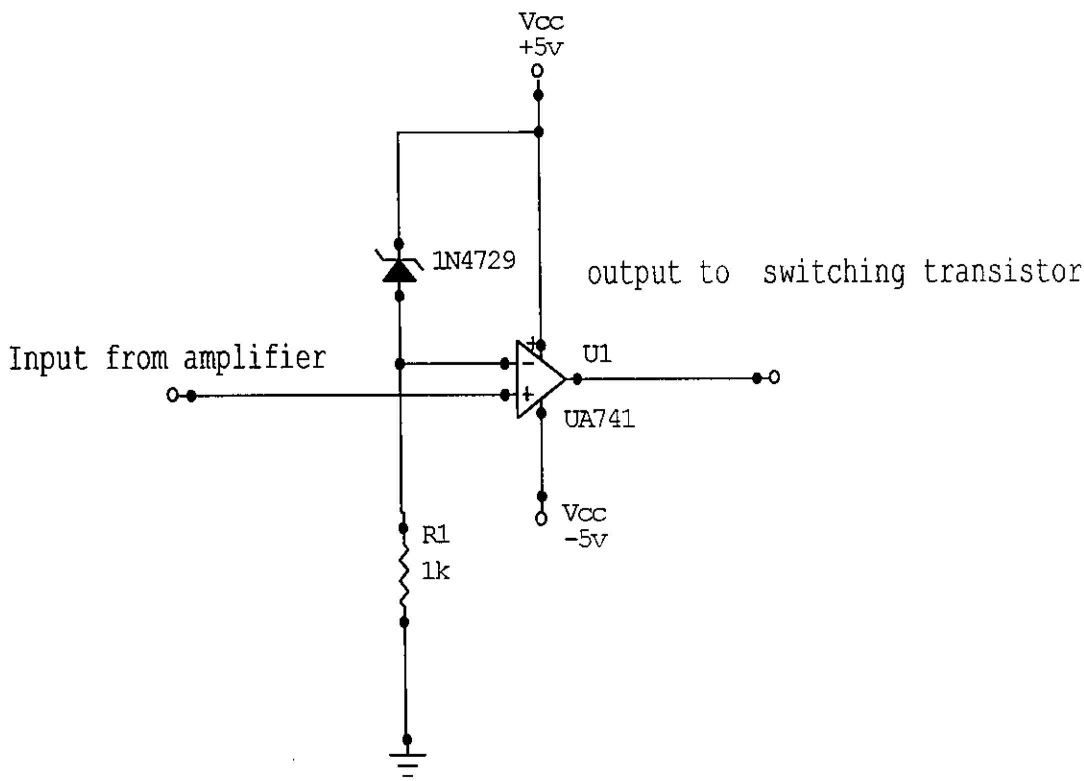


figure 5.6 Comparator

Hence the reference voltage is set such that it is just greater than the voltage at the amplifier for pure water. Thus from the two levels of the comparator output it is possible to sense whether the condensate has reached the upper or lower level respectively. A positive Vref is obtained at the (-) input terminal using a zener diode and a resistance that forms a potential divider across the supply and ground.

5.3.4 Switching transistor

The output of the comparator cannot be directly given to a TTL input, as the signal is a pulse of +Vsat and –Vsat. A transistor switching stage removes the negative component of the pulse. A BC158 transistor in common emitter configuration acts as a switch (fig 5.7) i.e. the output of +Vcc is obtained when the base emitter junction is reverse biased and output is 0 volts when the it is forward biased. Thus a pulse of +Vcc and 0 volts is obtained at the transistor output.

5.3.5 NOT gate

The output of the transistor is given to the NOT gate to obtain a perfect TTL output which is in turn given to the TTL input of the PIC microcontroller. An IC 74LS04 is used to get the required NOT output. The outputs from the upper level receiver and lower level receiver are the two separate inputs that are given to the NOT gate and respective outputs are taken to the microcontroller inputs.

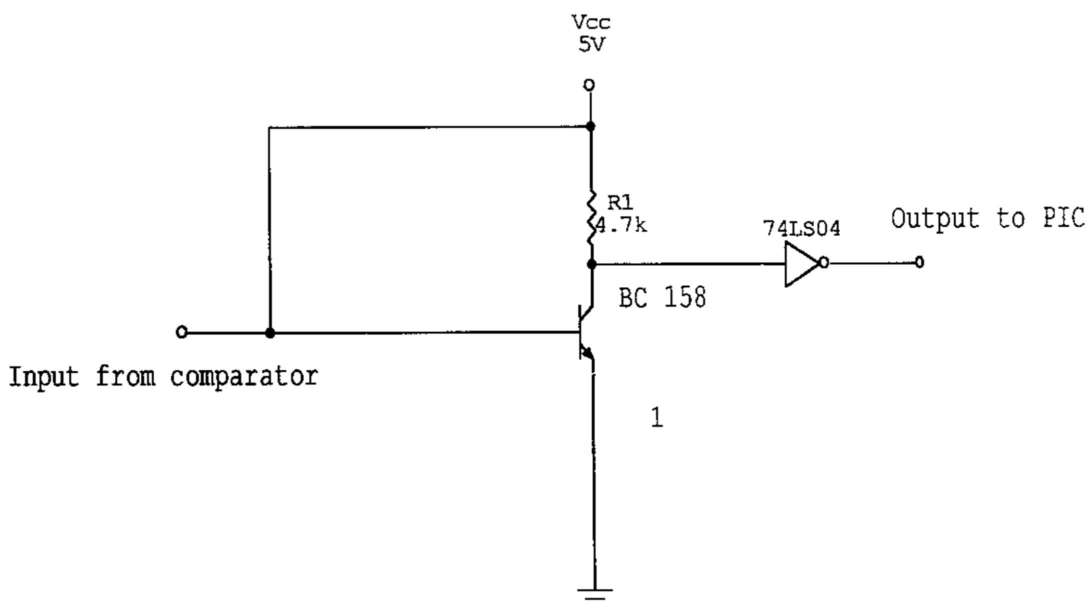


figure 5.7 Switching transistor and NOT gate circuit

5.4 Microcontroller

The PIC12C5XX from microchip technology is a family of low cost, high performance, 8 bit, fully static, EPROM/ROM –based CMOS microcontrollers. It employs RISC architecture with only 33 single cycles (1us) except for program branches, which take two cycles. The PIC12C5XXX delivers performance an order of magnitude higher than its competitors in the same price category. The 12 bit wide instructions are highly symmetrical resulting in 2:1 code compression over other 8-bit microcontrollers of its class. The easy to use and easy to remember instruction set reduces development time significantly.

The PIC12C5XX products are equipped with special features that reduce cost and power requirements. The Power-On reset (POR) and devices reset timer (DRT) eliminate the need for the external reset circuitry. There are four oscillator configurations to choose from, including

1. INTRC oscillator mode
2. The power saving LP (low power) oscillator
3. Power saving SLEEP mode, Watchdog timer and code protection features improve the system cost, power and reliability.

The PIC12C5xx are available in the cost efficient featured macro assembler, a software simulator, an in circuit emulator, a 'C' compiler, fuzzy logic support tools, a low cost development programmer and a full features programmer. All the tools are supported on IBM PC and compatible machines.

5.4.1 8-Pin, 8-bit CMOS Microcontroller (figure 5.8)

- High-performance RISC CPU:
- Only 33single word instruction to learn

- All instructions are single cycle (1us) except for program branches which are two-cycle
- Operating speed : DC- 4 Mhz clock input
  DC- 1us instruction cycle
- 12 bit wide instructions
- 8-bit wide data path
- Seven special function hardware signals
- Two level deep hardware stack
- Direct, indirect and relative addressing modes for data and instructions
- Internal 4Mhz RC oscillator with programmable calibration
- In circuit serial programming

Peripheral features

- 8-bit real time clock/counter (TMR0) with 8bit programmable prescaler
- Power-on reset (POR)
- Internal pull-up on MCLR (active low) pin

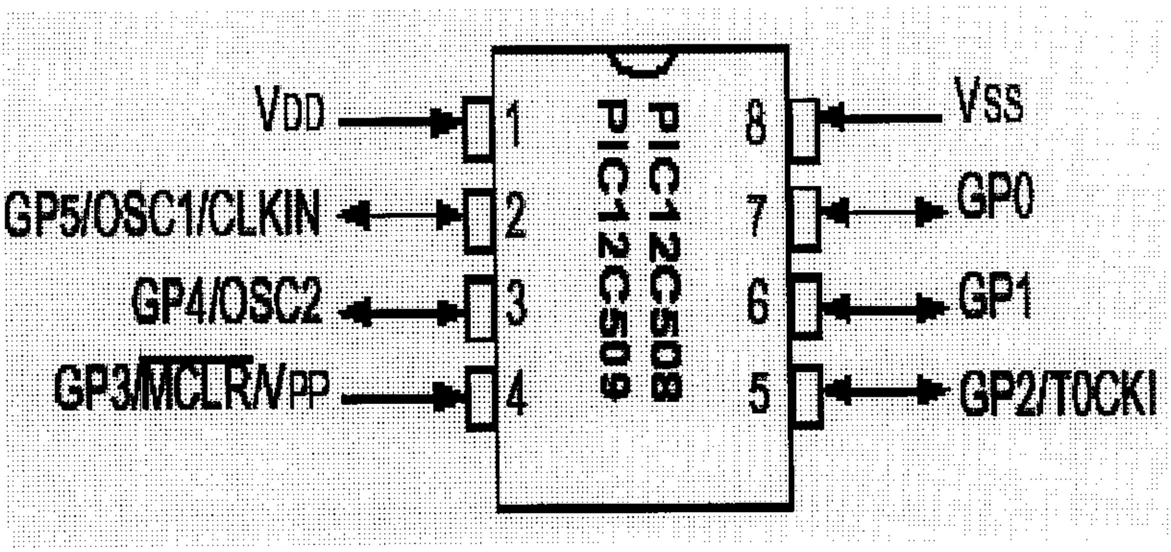


figure 5.8 PIC 12C5XX pin diagram

5.4.2 Applications

The PIC12C5XX series fits perfectly in applications ranging from personal care appliances and security systems to low – power remote transmitters / receivers. The EROM technology makes customizing application programs (transmitter codes, appliance settings, receiver's frequencies, etc.) extremely fast and convenient. The small footprint packages , for through hole or surface mounting, make space limitations .Low cost , low power, high performance ,ease of use and I/O flexibility make the PIC12C5xx series very versatile even in areas where no microcontroller use has been considered before(e.g., timer functions , coprocessor applications).

5.4.3 Implementation

The PIC12C508A is used in the circuit, which is programmed to operate in internal RC oscillator configuration. Based on the inputs from the upper level and lower level infrared receivers given to port pins GPIO.4 and GPIO.5 the controller is programmed to produce the output in GPIO.1 that in turn operates the drain valve switch. The upper level input triggers the Timer0 and the timer register is checked for the implementation of the logic to operate the drain valve.

Manual test switch is the input given to the controller in GPIO.3. The controller is programmed to check these inputs and operate the drain valve accordingly. The ports and the timer are initialized by the special function registers (OPTION, STATUS, and OSCCAL) in the software.

5.5 Conclusion

The hardware circuit met the design requirements that gave a dynamic range for the signal voltage. This circuit works with low operating voltage (5V). The TTL output of the circuit provided a compatible input to the PIC-microcontroller.

Software description

6.1 Introduction

The software was programmed in Microchip's version of 'C'.C was preferred because of its wide popularity, ease of use compared to assembly language, good programming constructs and rich reference sources. It ensures high performance and offers very good hardware integration due to its close relationship with assembly language programming and other high level language programming by providing raw programming power of assembly language and the understandable programming style of the other high level languages.

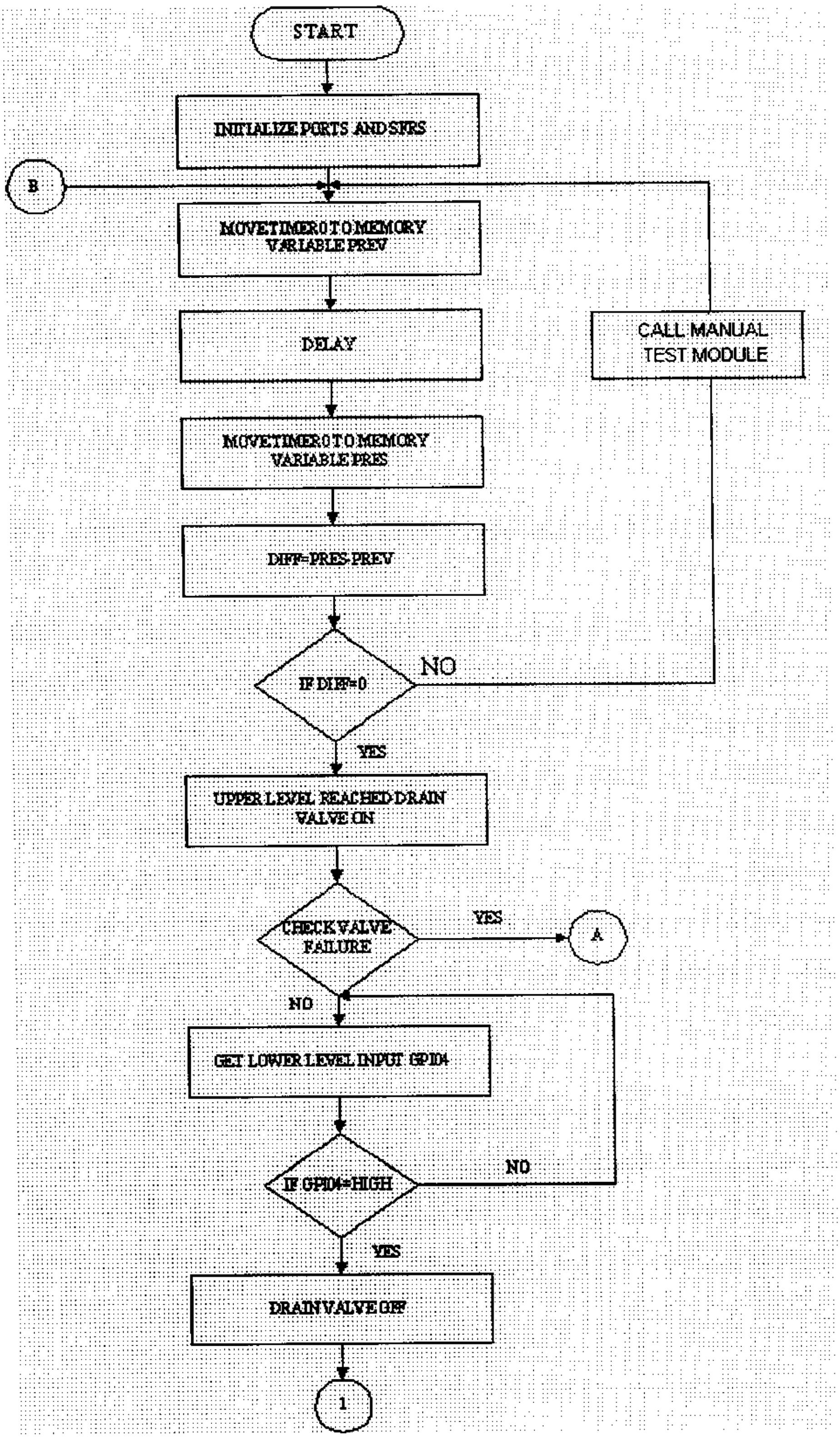
6.2 Development support

MPLAB-C is an ANSI based 'C' compiler for the Microchip technology incorporated PIC12/16/17 microcontroller families. Due to restrictions imposed by the microcontroller architecture, MPLAB-C does not support full ANSI-C standard. The MPLAB IDE also offers a full-featured macro assembler, a 'C' compiler and a simulator. In addition to this third party companies like Hi-Tech PIC C, CCS are also developing support tools in the form of various 'C' compilers and debugging tools for Microchip thereby giving us a wide rage of developing tools. A latest version of Hi-Tech PIC C v8.01PL3 compiler was also used to compile the source code written in 'C'.

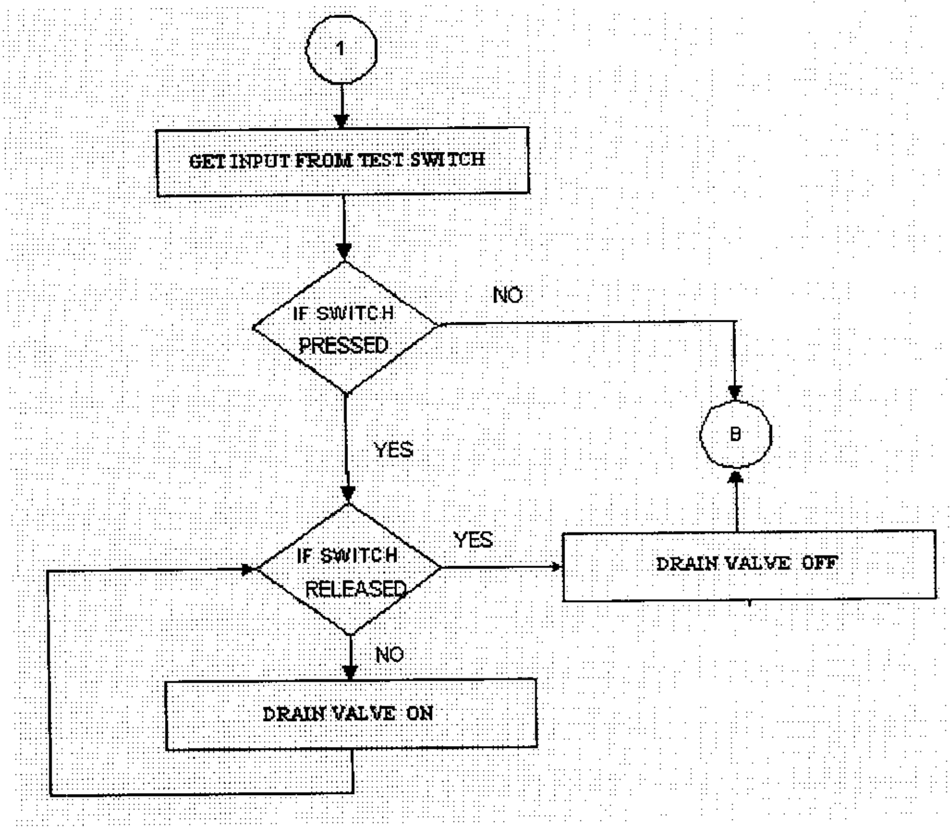
Program was initially done and tested in assembly language using MPLAB version 5.11 before converting to 'C' program. This gave a basic understanding of the initialization of the microcontroller ports and registers. MPLAB SIM was used to simulate and test the program for software inputs before uploading into the chip.

6.3 Flowchart

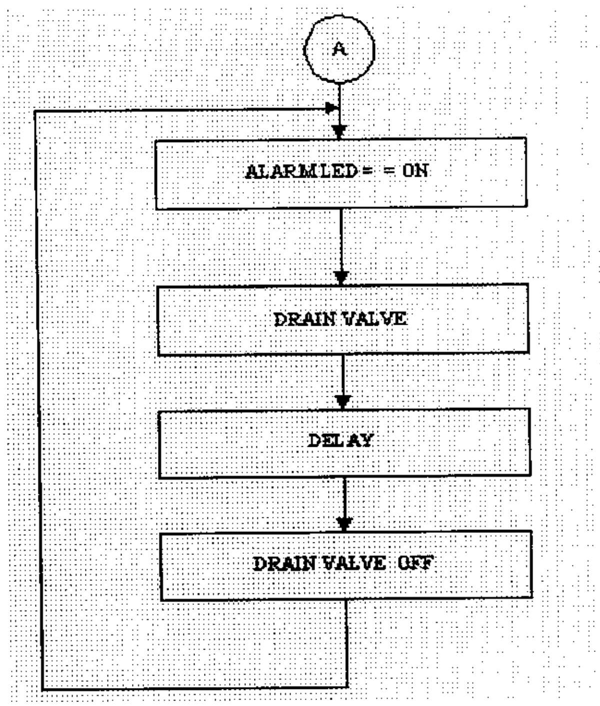
Sensor module



Manual test module



Alarm module



6.4 Program modules

Functionally the software can be divided into 3 modules. They are

- Sensor module
- Manual test drive module
- Timer module

6.4.1 Sensor Module

The sensor module detects the hardware outputs and operates the drain valve output accordingly. The microcontroller is programmed to detect the upper and lower levels of the condensate and operate the drain valve switch. The upper level input is given to the Timer0 pin TOCK1 (gpi0.5) operating in counter mode. Timer0 will increment on every rising edge of the pin TOCK1 that receives the pulse signal from the receiver. This pulse signal stops when the condensate reaches the upper level and hence the timer ceases to increment. Once this is detected by the microcontroller, the drain valve is switched on draining the condensate eventually by energizing the solenoid valve. As the condensate is drained the lower level input is checked which is always low when there is condensate in the tank. As soon as lower level input pin (GPIO.4) goes high it is evident that the lower level is reached. Now the drain valve output GPIO.0 goes low and hence de-energizing the solenoid valve.

6.4.2 Manual Test module

This module is provided to manually operate the system. This enables a functional test to be carried out at anytime by pressing the test switch .The input to the controller is given by a manual switch to the pin GPIO.3 that is always high and goes low when pressed. The microcontroller is programmed to check this test input regularly and detect the status of the switch. Once the pin GPIO.3 goes low the program control is transferred to the test module. In this module a loop routine checks the pin GPIO.3 and the drain valve is switched on energizing the solenoid valve and the condensate is drained continuously until the switch is released. Once the pin goes high the control comes out of the loop routine and drain valve output GPIO.0 goes low de-energizing the solenoid valve.

6.4.3 Alarm module

This is a backup module that is provided in case of failure of the sensor system. Sensor failure is detected when the sensor inputs does not change the drain valve output pin (gpi0.0) for a specified period of time (4 minutes). At this stage the controller is programmed to operate the drain valve in the timer mode. That is to switch on and off in a timed cycle. This mode is indicated by an alarm led. The solenoid valve will open every 10 minutes for a period of 7.5 seconds. The drain valve system continues working in this mode until problem is rectified and the system is reset.

6.4.4 Program description

Special function registers are registers used by the CPU and peripheral functions to control the operation of the device. These registers are configured in the initialization part of the program. Starting from the main menu, the main menu first initializes the port .To initialize the ports the TRIS register is to be configured. Three ports GPIO.1, 2, 3 are initialized as input ports and GPIO.0, 4 are initialized as output ports. Other unused ports are set as output ports.

TRIS register

Bit	7	6	5	4	3	2	1	0
	X	X	0	0	1	1	1	0

X - Unused
0 - output
1 - Input

Option register

The option register is an 8 bit wide; write only register that contains various control bits to configure the Timer0.

Bit	7	6	5	4	3	2	1	0
	1	1	1	1	0	0	0	0

Bits 7 and 6 are disabled .Bit 5(TOCS) sets the timer transition on TOCK1 pin. Bit 4(TOSE) sets the timer0 increment on high to low transition on the TOCL1 pin. Other are bits are prescalar assignment bits set to default condition. The oscillator mode is set to 4 MHz internal oscillator by configuring OSCAL register.

6.5 Source code

```
// the program has been developed to work for infrared sensor

//device = PIC12C508A

//osc= internal RC , watch dog timer = OFF. Code protect = ON

// master clear = internal , sum  = 3E01


#include<12C5XX.h>
#include<pic.h>

#define UPPERLEVEL 1
#define LOWERLEVEL 2
#define TESTIN    1
#define ON       1                    //active high output
#define OFF      0                    //active low output
#define LEDON    1
#define LEDOFF   0
#define PRESSED   0                   // manual test switch input status
#define RELEASE   1

#define DRAINVALVE GPIO.0             //output to MOC
#define TESTSW    GPIO.1              //input from test switch
#define INUPPER  GPIO.5               //input upperlevel pulse
```

```
#define INLOWER   GPIO.3          //input lowerlevel pulse
#define ALARMLED   GPIO.4         //output to alarm led indicator

//possible states

#define NORMAL     1
#define DRAIN      2
#define TEST       3
#define ALARM      4

unsigned int alarmtime;
unsigned int retrytime;
unsigned char retrycount,alarmledcount;
unsigned char drainontime;
unsigned long tenminscnt;
int prevcount,prescount,diffr;
int lowcount=1000,incount=0,alarmled=0;

// Initialise the GPIO registers , configure options

void initialise(void)
{
        _OPTION(0xc8);                    //Prescalar is 1:32 assigned to TI
        _TRIS(0xEE,GPIO);                 //1,3,5 ips 0,4 ops
        TMR0=0;
        #asm(BCF STATUS,5)
}

delay(void)
{
        int count=272;
        while(count!=0);
        count--;

}

// this function checks the input pulse at the upper input
// returns 1 if timer is stopped
// else the state is not changed

upperlevel()
{
        prevcount=TMR0;
        delay();
        prescount=TMR0;
        diff=prescount-prevcount;
        if(diff==0)
        {
```

```
                state=DRAIN;alarmled++ ;
        }
if(state==DRAIN)   lowerlevel();
}

// this function checks the input pulse at the lower input
// returns input 0 if level reached
// else state is not changed

lowerlevel()
{
        while(lowcount--)
        {
                if(INLOWER==ON) incount++;
        }
                if(incount>1)
                {
                        state=normal;
                        incount=0;
                        alarmled=0;
                }
}

main()
{
//initialise ports and peripherals of MCU

        intitialise();

// status of the relays and LEDs at the startup

        state=NORMAL;
        DRAINVALVE=OFF;
        ALARMLED=OFF;
        alarmcount=0;

        while(1)
        {
                upperlevel();
                if(alarmled=1000) state=ALARM;

                switch(state)
                {
                        case NORMAL:


                        DRAINVALVE=OFF;
                        ALARMLED=OFF;
```

```
        if(TESTSW==PRESSED)
        {
                state=TEST;break;
        }
        break;

// the drain state is reached by three conditions
// 1.upper level reached
// 2.two minutes elapsed in retry count
// 3.four minutes elapsed in alarm state

        case DRAIN:

                DRAINVALVE=ON;
                if (alarmtime==0)
                {
                DRAINVALVE=ON;
                ALARMLED=ON;
                state=TIMER;
                }
                if(TESTSW==PRESSED)
                {
                state=TEST;break;
                }
                break;

        case TEST:

                if(TESTSW==PRESSED)
                {
                        while(TESTSW==PRESSED)

                        DRAINVALVE=ON;

                }
                if(TESTSW==RELEASED)
                DRAINVALVE=OFF;
                break;


        case ALARM:

                while(ALARMLED)
                        {
                                DRAINVALVE=ON;
                                alarmcount=1282;
                                while(alramcount)
```

```
                        {
                            alarmcount--
                        }
                        DRAINVALVE=OFF;
                    }


        }
    }
}
```

6.6 Conclusion

The three software modules were implemented for a complete drain valve system and were tested successfully. Manual test mode and timer mode are entirely implemented by software; hence the system continues to work in an alternative mode even if there is any hardware failure until it is rectified. By suitably making changes in the compiler options the same 'C' code can be easily ported to different microcontrollers by making little or no changes to the source code is an added feature of using 'C'.

Conclusion

Conclusion

The infrared level detecting sensors for drain valve was designed and tested successfully to meet the requirements. This system can be used for all type of compressors with out any modification. This system was tested for all types of condensates and found reliable. It was able to overcome the shortcomings of all the previous type of sensors used in the drain valve.

The system is cost effective, it saves energy, air loss is minimum, less noise pollution and electrical power required is also very less. Since microcontroller is programmed to work in timer mode even if the sensor fails the drain valve is operated till service is available.

This system can further be used to indicate the level of lubricating oils in small lubricating tanks used in textile and mechanical industries with necessary modifications.

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- Liquid Drain Valve Catalogue.
- www.microchip.com
- www.tridentpneumatics.com

Appendix

PIC12C5XX

8-Pin, 8-Bit CMOS Microcontrollers

Devices Included in this Data Sheet:

- PIC12C508
- PIC12C508A
- PIC12CE518
- PIC12C509
- PIC12C509A
- PIC12CE519
- PIC12CR509A

Note: Throughout this data sheet PIC12C5XX refers to the PIC12C508, PIC12C509, PIC12C508A, PIC12C509A, PIC12CR509A, PIC12CE518 and PIC12CE519. PIC12CE5XX refers to PIC12CE518 and PIC12CE519.

High-Performance RISC CPU:

- Only 33 single word instructions to learn
- All instructions are single cycle (1 µs) except for program branches which are two-cycle
- Operating speed: DC - 4 MHz clock input
  DC - 1 µs instruction cycle

Device	Memory			
	EPROM Program	ROM Program	RAM Data	EEPROM Data
PIC12C508	512 x 12		25	
PIC12C508A	512 x 12		25	
PIC12C509	1024 x 12		41	
PIC12C509A	1024 x 12		41	
PIC12CE518	512 x 12		25	16
PIC12CE519	1024 x 12		41	16
PIC12CR509A		1024 x 12	41	

- 12-bit wide instructions
- 8-bit wide data path
- Seven special function hardware registers
- Two-level deep hardware stack
- Direct, indirect and relative addressing modes for data and instructions
- Internal 4 MHz RC oscillator with programmable calibration
- In-circuit serial programming

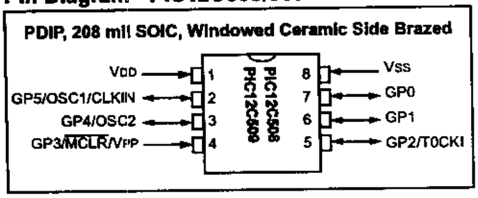
Peripheral Features:

- 8-bit real time clock/counter (TMR0) with 8-bit programmable prescaler
- Power-On Reset (POR)
- Device Reset Timer (DRT)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- 1,000,000 erase/write cycle EEPROM data memory
- EEPROM data retention > 40 years
- Power saving SLEEP mode
- Wake-up from SLEEP on pin change
- Internal weak pull-ups on I/O pins
- Internal pull-up on $\overline{MCLR}$ pin
- Selectable oscillator options:
  - INTRC: Internal 4 MHz RC oscillator
  - EXTRC: External low-cost RC oscillator
  - XT: Standard crystal/resonator
  - LP: Power saving, low frequency crystal

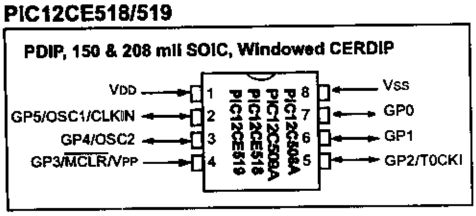
CMOS Technology:

- Low power, high speed CMOS EPROM/ROM technology
- Fully static design
- Wide operating voltage range
- Wide temperature range:
  - Commercial: 0°C to +70°C
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C
- Low power consumption
  - < 2 mA @ 5V, 4 MHz
  - 15 µA typical @ 3V, 32 KHz
  - < 1 µA typical standby current

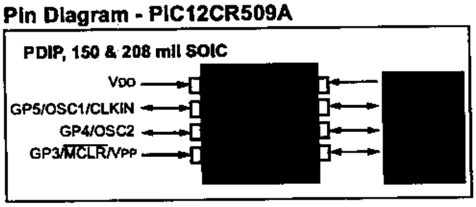
Pin Diagram - PIC12C508/509



Pin Diagram - PIC12C508A/509A, PIC12CE518/519



Pin Diagram - PIC12CR509A



Device Differences

Device	Voltage Range	Oscillator	Oscillator Calibration[2] (Bits)	Process Technology (Microns)
PIC12C508A	3.0-5.5	See Note 1	6	0.7
PIC12LC508A	2.5-5.5	See Note 1	6	0.7
PIC12C508	2.5-5.5	See Note 1	4	0.9
PIC12C509A	3.0-5.5	See Note 1	6	0.7
PIC12LC509A	2.5-5.5	See Note 1	6	0.7
PIC12C509	2.5-5.5	See Note 1	4	0.9
PIC12CR509A	2.5-5.5	See Note 1	6	0.7
PIC12CE518	3.0-5.5	-	6	0.7
PIC12LCE518	2.5-5.5	-	6	0.7
PIC12CE519	3.0-5.5	-	6	0.7
PIC12LCE519	2.5-5.5	-	6	0.7

Note 1: If you change from the PIC12C50X to the PIC12C50XA or to the PIC12CR50XA, please verify oscillator characteristics in your application.

Note 2: See Section 7.2.5 for OSCCAL implementation differences.

1.0 GENERAL DESCRIPTION

The PIC12C5XX from Microchip Technology is a family of low-cost, high performance, 8-bit, fully static, EEPROM/EPROM/ROM-based CMOS microcontrollers. It employs a RISC architecture with only 33 single word/single cycle instructions. All instructions are single cycle (1 µs) except for program branches which take two cycles. The PIC12C5XX delivers performance an order of magnitude higher than its competitors in the same price category. The 12-bit wide instructions are highly symmetrical resulting in 2:1 code compression over other 8-bit microcontrollers in its class. The easy to use and easy to remember instruction set reduces development time significantly.

The PIC12C5XX products are equipped with special features that reduce system cost and power requirements. The Power-On Reset (POR) and Device Reset Timer (DRT) eliminate the need for external reset circuitry. There are four oscillator configurations to choose from, including INTRC internal oscillator mode and the power-saving LP (Low Power) oscillator mode. Power saving SLEEP mode, Watchdog Timer and code protection features also improve system cost, power and reliability.

The PIC12C5XX are available in the cost-effective One-Time-Programmable (OTP) versions which are suitable for production in any volume. The customer can take full advantage of Microchip's price leadership in OTP microcontrollers while benefiting from the OTP's flexibility.

The PIC12C5XX products are supported by a full-featured macro assembler, a software simulator, an in-circuit emulator, a 'C' compiler, fuzzy logic support tools, a low-cost development programmer, and a full featured programmer. All the tools are supported on IBM® PC and compatible machines.

1.1 Applications

The PIC12C5XX series fits perfectly in applications ranging from personal care appliances and security systems to low-power remote transmitters/receivers. The EPROM technology makes customizing application programs (transmitter codes, appliance settings, receiver frequencies, etc.) extremely fast and convenient, while the EEPROM data memory technology allows for the changing of calibration factors and security codes. The small footprint packages, for through hole or surface mounting, make this microcontroller series perfect for applications with space limitations. Low-cost, low-power, high performance, ease of use and I/O flexibility make the PIC12C5XX series very versatile even in areas where no microcontroller use has been considered before (e.g., timer functions, replacement of "glue" logic and PLD's in larger systems, coprocessor applications).

TABLE 1-1: PIC12CXXX & PIC12CEXXX FAMILY OF DEVICES

		PIC12C508(A)	PIC12C509(A)	PIC12CR509A	PIC12CE518	PIC12CE519	PIC12C671	PIC12C672	PIC12CE673	PIC12CE674
Clock	Maximum Frequency of Operation (MHz)	4	4	4	4	4	10	10	10	10
Memory	EPROM Program Memory	512 x 12	1024 x 12	1024 x 12 (ROM)	512 x 12	1024 x 12	1024 x 14	2048 x 14	1024 x 14	2048 x 14
	RAM Data Memory (bytes)	25	41	41	25	41	128	128	128	128
Peripherals	EEPROM Data Memory (bytes)	—	—	—	16	16	—	—	16	16
	Timer Module(s)	TMR0	TMR0	TMR0	TMR0	TMR0	TMR0	TMR0	TMR0	TMR0
	A/D Converter (8-bit) Channels	—	—	—	—	—	4	4	4	4
Features	Wake-up from SLEEP on pin change	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Interrupt Sources	—	—	—			4	4	4	4
	I/O Pins	5	5	5	5	5	5	5	5	5
	Input Pins	1	1	1	1	1	1	1	1	1
	Internal Pull-ups	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	In-Circuit Serial Programming	Yes	Yes	—	Yes	Yes	Yes	Yes	Yes	Yes
	Number of Instructions	33	33	33	33	33	35	35	35	35
	Packages	8-pin DIP, JW, SOIC	8-pin DIP, JW, SOIC	8-pin DIP, SOIC	8-pin DIP, JW, SOIC	8-pin DIP, JW, SOIC	8-pin DIP, JW, SOIC	8-pin DIP, JW, SOIC	8-pin DIP, JW	8-pin DIP, JW

All PIC12CXXX & PIC12CEXXX devices have Power-on Reset, selectable Watchdog Timer, selectable code protect and high I/O current capability.
All PIC12CXXX & PIC12CEXXX devices use serial programming with data pin GP0 and clock pin GP1.

3.0 ARCHITECTURAL OVERVIEW

The high performance of the PIC12C5XX family can be attributed to a number of architectural features commonly found in RISC microprocessors. To begin with, the PIC12C5XX uses a Harvard architecture in which program and data are accessed on separate buses. This improves bandwidth over traditional von Neumann architecture where program and data are fetched on the same bus. Separating program and data memory further allows instructions to be sized differently than the 8-bit wide data word. Instruction opcodes are 12-bits wide making it possible to have all single word instructions. A 12-bit wide program memory access bus fetches a 12-bit instruction in a single cycle. A two-stage pipeline overlaps fetch and execution of instructions. Consequently, all instructions (33) execute in a single cycle (1µs @ 4MHz) except for program branches.

The table below lists program memory (EPROM), data memory (RAM), ROM memory, and non-volatile (EEPROM) for each device.

Device	Memory			
	EPROM Program	ROM Program	RAM Data	EEPROM Data
PIC12C508	512 x 12		25	
PIC12C509	1024 x 12		41	
PIC12C508A	512 x 12		25	
PIC12C509A	1024 x 12		41	
PIC12CR509A		1024 x 12	41	
PIC12CE518	512 x 12		25 x 8	16 x 8
PIC12CE519	1024 x 12		41 x 8	16 x 8

The PIC12C5XX can directly or indirectly address its register files and data memory. All special function registers including the program counter are mapped in the data memory. The PIC12C5XX has a highly orthogonal (symmetrical) instruction set that makes it possible to carry out any operation on any register using any addressing mode. This symmetrical nature and lack of 'special optimal situations' make programming with the PIC12C5XX simple yet efficient. In addition, the learning curve is reduced significantly.

The PIC12C5XX device contains an 8-bit ALU and working register. The ALU is a general purpose arithmetic unit. It performs arithmetic and Boolean functions between data in the working register and any register file.

The ALU is 8-bits wide and capable of addition, subtraction, shift and logical operations. Unless otherwise mentioned, arithmetic operations are two's complement in nature. In two-operand instructions, typically one operand is the W (working) register. The other operand is either a file register or an immediate constant. In single operand instructions, the operand is either the W register or a file register.

The W register is an 8-bit working register used for ALU operations. It is not an addressable register.

Depending on the instruction executed, the ALU may affect the values of the Carry (C), Digit Carry (DC), and Zero (Z) bits in the STATUS register. The C and DC bits operate as a $\overline{\text{borrow}}$ and $\overline{\text{digit borrow}}$ out bit, respectively, in subtraction. See the SUBWF and ADDWF instructions for examples.

A simplified block diagram is shown in Figure 3-1, with the corresponding device pins described in Table 3-1.

FIGURE 3-1: PIC12C5XX BLOCK DIAGRAM

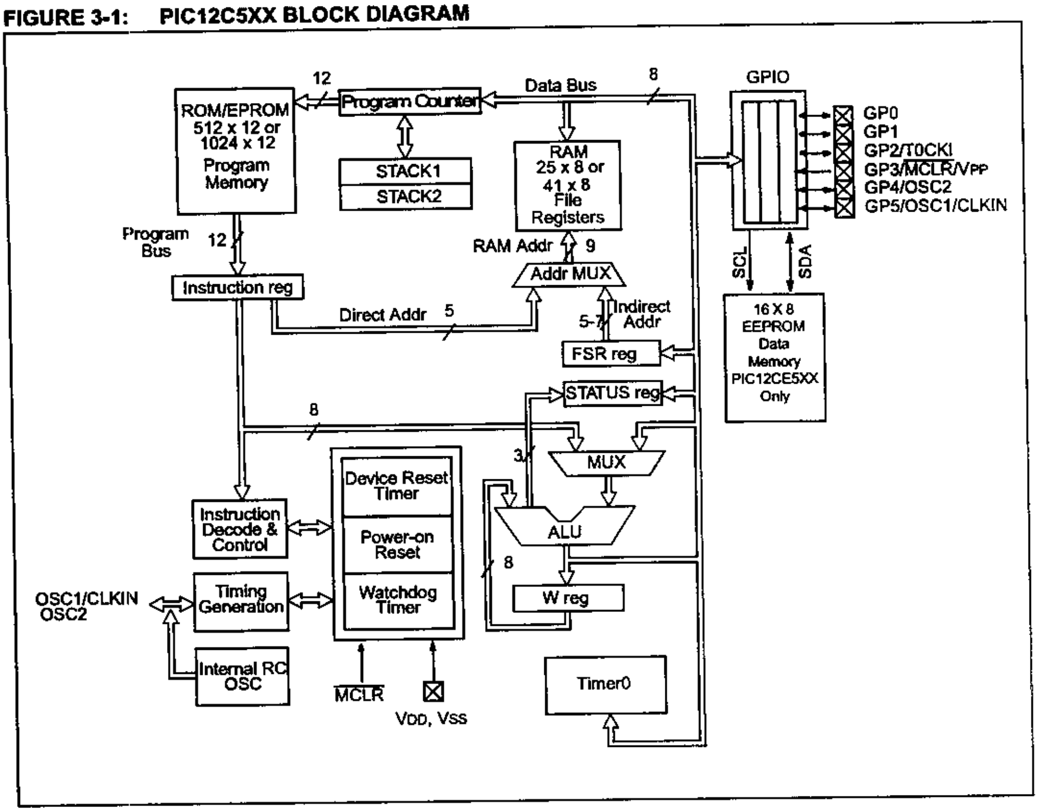


TABLE 3-1: PIC12C5XX PINOUT DESCRIPTION

Name	DIP Pin #	SOIC Pin #	I/O/P Type	Buffer Type	Description
GP0	7	7	I/O	TTL/ST	Bi-directional I/O port/ serial programming data. Can be software programmed for internal weak pull-up and wake-up from SLEEP on pin change. This buffer is a Schmitt Trigger input when used in serial programming mode.
GP1	6	6	I/O	TTL/ST	Bi-directional I/O port/ serial programming clock. Can be software programmed for internal weak pull-up and wake-up from SLEEP on pin change. This buffer is a Schmitt Trigger input when used in serial programming mode.
GP2/T0CKI	5	5	I/O	ST	Bi-directional I/O port. Can be configured as T0CKI.
GP3/$\overline{MCLR}$/VPP	4	4	I	TTL/ST	Input port/master clear (reset) input/programming voltage input. When configured as $\overline{MCLR}$, this pin is an active low reset to the device. Voltage on $\overline{MCLR}$/VPP must not exceed VDD during normal device operation or the device will enter programming mode. Can be software programmed for internal weak pull-up and wake-up from SLEEP on pin change. Weak pull-up always on if configured as $\overline{MCLR}$. ST when in $\overline{MCLR}$ mode.
GP4/OSC2	3	3	I/O	TTL	Bi-directional I/O port/oscillator crystal output. Connections to crystal or resonator in crystal oscillator mode (XT and LP modes only, GPIO in other modes).
GP5/OSC1/CLKIN	2	2	I/O	TTL/ST	Bidirectional IO port/oscillator crystal input/external clock source input (GPIO in Internal RC mode only, OSC1 in all other oscillator modes). TTL input when GPIO, ST input in external RC oscillator mode.
VDD	1	1	P	—	Positive supply for logic and I/O pins
VSS	8	8	P	—	Ground reference 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

4.3 STATUS Register

This register contains the arithmetic status of the ALU, the RESET status, and the page preselect bit for program memories larger than 512 words.

The STATUS register can be the destination for any instruction, as with any other register. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the $\overline{TO}$ and $\overline{PD}$ bits are not writable. Therefore, the result of an instruction with the STATUS register as destination may be different than intended.

For example, `CLRF STATUS` will clear the upper three bits and set the Z bit. This leaves the STATUS register as `000u u1uu` (where `u` = unchanged).

It is recommended, therefore, that only `BCF`, `BSF` and `MOVWF` instructions be used to alter the STATUS register because these instructions do not affect the Z, DC or C bits from the STATUS register. For other instructions, which do affect STATUS bits, see Instruction Set Summary.

FIGURE 4-4: STATUS REGISTER (ADDRESS:03h)

R/W-0	R/W-0	R/W-0	R-1	R-1	R/W-x	R/W-x	R/W-x
GPWUF	—	PA0	$\overline{TO}$	$\overline{PD}$	Z	DC	C
bit7	6	5	4	3	2	1	bit0

R = Readable bit
W = Writable bit
- n = Value at POR reset

bit 7: **GPWUF**: GPIO reset bit
1 = Reset due to wake-up from SLEEP on pin change
0 = After power up or other reset

bit 6: **Unimplemented**

bit 5: **PA0**: Program page preselect bits
1 = Page 1 (200h - 3FFh) - PIC12C509, PIC12C509A, PIC12CR509A and PIC12CE519
0 = Page 0 (000h - 1FFh) - PIC12C5XX
Each page is 512 bytes.
Using the PA0 bit as a general purpose read/write bit in devices which do not use it for program page preselect is not recommended since this may affect upward compatibility with future products.

bit 4: **$\overline{TO}$**: Time-out bit
1 = After power-up, `CLRWDT` instruction, or `SLEEP` instruction
0 = A WDT time-out occurred

bit 3: **$\overline{PD}$**: Power-down bit
1 = After power-up or by the `CLRWDT` instruction
0 = By execution of the `SLEEP` instruction

bit 2: **Z**: Zero bit
1 = The result of an arithmetic or logic operation is zero
0 = The result of an arithmetic or logic operation is not zero

bit 1: **DC**: Digit carry/$\overline{borrow}$ bit (for `ADDWF` and `SUBWF` instructions)
ADDWF
1 = A carry from the 4th low order bit of the result occurred
0 = A carry from the 4th low order bit of the result did not occur
SUBWF
1 = A borrow from the 4th low order bit of the result did not occur
0 = A borrow from the 4th low order bit of the result occurred

bit 0: **C**: Carry/$\overline{borrow}$ bit (for `ADDWF`, `SUBWF` and `RRF`, `RLF` instructions)

ADDWF	SUBWF	RRF or RLF
1 = A carry occurred	1 = A borrow did not occur	Load bit with LSB or MSB, respectively
0 = A carry did not occur	0 = A borrow occurred	

4.4 OPTION Register

The OPTION register is a 8-bit wide, write-only register which contains various control bits to configure the Timer0/WDT prescaler and Timer0.

By executing the `OPTION` instruction, the contents of the W register will be transferred to the OPTION register. A RESET sets the OPTION<7:0> bits.

> **Note:** If TRIS bit is set to '0', the wake-up on change and pull-up functions are disabled for that pin; i.e., note that TRIS overrides OPTION control of $\overline{GPPU}$ and $\overline{GPWU}$.
>
> **Note:** If the T0CS bit is set to '1', GP2 is forced to be an input even if TRIS GP2 = '0'.

FIGURE 4-5: OPTION REGISTER

W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1
$\overline{GPWU}$	$\overline{GPPU}$	T0CS	T0SE	PSA	PS2	PS1	PS0
bit7	6	5	4	3	2	1	bit0

W = Writable bit
U = Unimplemented bit
- n = Value at POR reset
Reference Table 4-1 for other resets.

bit 7: $\overline{GPWU}$: Enable wake-up on pin change (GP0, GP1, GP3)
1 = Disabled
0 = Enabled

bit 6: $\overline{GPPU}$: Enable weak pull-ups (GP0, GP1, GP3)
1 = Disabled
0 = Enabled

bit 5: **T0CS**: Timer0 clock source select bit
1 = Transition on T0CKI pin
0 = Transition on internal instruction cycle clock, Fosc/4

bit 4: **T0SE**: Timer0 source edge select bit
1 = Increment on high to low transition on the T0CKI pin
0 = Increment on low to high transition on the T0CKI pin

bit 3: **PSA**: Prescaler assignment bit
1 = Prescaler assigned to the WDT
0 = Prescaler assigned to Timer0

bit 2-0: **PS2:PS0**: Prescaler rate select bits

Bit Value	Timer0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

4.5 OSCCAL Register

The Oscillator Calibration (OSCCAL) register is used to calibrate the internal 4 MHz oscillator. It contains four to six bits for calibration. Increasing the cal value increases the frequency. See Section 7.2.5 for more information on the internal oscillator.

FIGURE 4-6: OSCCAL REGISTER (ADDRESS 05h) FOR PIC12C508 AND PIC12C509

R/W-0	R/W-1	R/W-1	R/W-1	R/W-0	R/W-0	U-0	U-0
CAL3	CAL2	CAL1	CAL0	—	—	—	—
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7-4: **CAL<3:0>:** Calibration

bit 3-0: **Unimplemented:** Read as '0'

FIGURE 4-7: OSCCAL REGISTER (ADDRESS 05h) FOR PIC12C508A/C509A/CR509A/12CE518/ 12CE519

R/W-1	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	U-0
CAL5	CAL4	CAL3	CAL2	CAL1	CAL0	—	—
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7-2: **CAL<5:0>:** Calibration

bit 1-0: **Unimplemented:** Read as '0'

5.0 I/O PORT

As with any other register, the I/O register can be written and read under program control. However, read instructions (e.g., `MOVF GPIO,W`) always read the I/O pins independent of the pin's input/output modes. On RESET, all I/O ports are defined as input (inputs are at hi-impedance) since the I/O control registers are all set. See Section 7.0 for SCL and SDA description for PIC12CE5XX.

5.1 GPIO

GPIO is an 8-bit I/O register. Only the low order 6 bits are used (GP5:GP0). Bits 7 and 6 are unimplemented and read as '0's. Please note that GP3 is an input only pin. The configuration word can set several I/O's to alternate functions. When acting as alternate functions the pins will read as '0' during port read. Pins GP0, GP1, and GP3 can be configured with weak pull-ups and also with wake-up on change. The wake-up on change and weak pull-up functions are not pin selectable. If pin 4 is configured as $\overline{MCLR}$, weak pull-up is always on and wake-up on change for this pin is not enabled.

5.2 TRIS Register

The output driver control register is loaded with the contents of the W register by executing the `TRIS f` instruction. A '1' from a TRIS register bit puts the corresponding output driver in a hi-impedance mode. A '0' puts the contents of the output data latch on the selected pins, enabling the output buffer. The exceptions are GP3 which is input only and GP2 which may be controlled by the option register, see Figure 4-5.

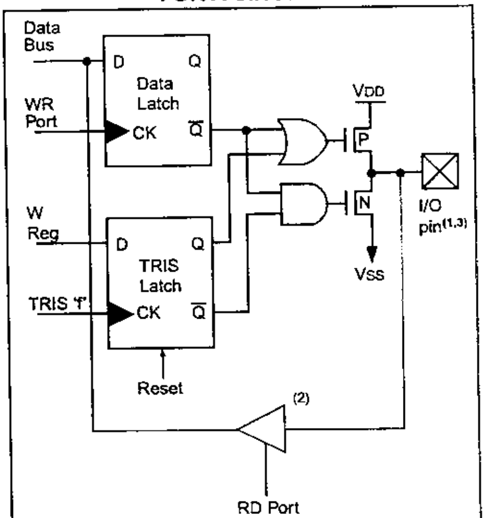
> **Note:** A read of the ports reads the pins, not the output data latches. That is, if an output driver on a pin is enabled and driven high, but the external system is holding it low, a read of the port will indicate that the pin is low.

The TRIS registers are "write-only" and are set (output drivers disabled) upon RESET.

5.3 I/O Interfacing

The equivalent circuit for an I/O port pin is shown in Figure 5-1. All port pins, except GP3 which is input only, may be used for both input and output operations. For input operations these ports are non-latching. Any input must be present until read by an input instruction (e.g., `MOVF GPIO,W`). The outputs are latched and remain unchanged until the output latch is rewritten. To use a port pin as output, the corresponding direction control bit in TRIS must be cleared (= 0). For use as an input, the corresponding TRIS bit must be set. Any I/O pin (except GP3) can be programmed individually as input or output.

FIGURE 5-1: EQUIVALENT CIRCUIT FOR A SINGLE I/O PIN



Note 1: I/O pins have protection diodes to VDD and VSS.

Note 2: See Table 3-1 for buffer type.

Note 3: See Section 7.0 for SCL and SDA description for PIC12CE5XX

6.0 TIMER0 MODULE AND TMR0 REGISTER

The Timer0 module has the following features:

- 8-bit timer/counter register, TMR0
  - Readable and writable
- 8-bit software programmable prescaler
- Internal or external clock select
  - Edge select for external clock

Figure 6-1 is a simplified block diagram of the Timer0 module.

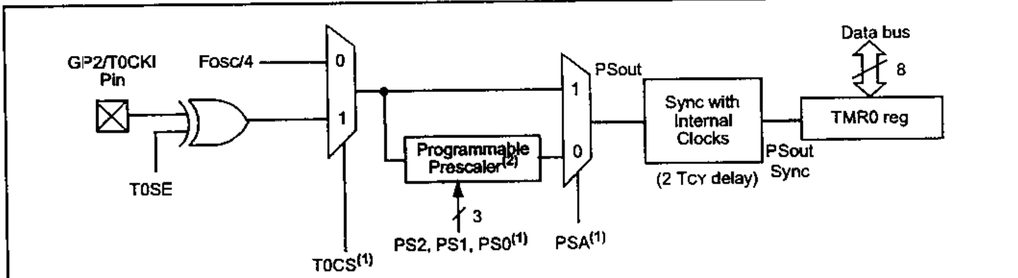
Timer mode is selected by clearing the T0CS bit (OPTION<5>). In timer mode, the Timer0 module will increment every instruction cycle (without prescaler). If TMR0 register is written, the increment is inhibited for the following two instruction cycles (Figure 6-2 and Figure 6-3). The user can work around this by writing an adjusted value to the TMR0 register.

Counter mode is selected by setting the T0CS bit (OPTION<5>). In this mode, Timer0 will increment either on every rising or falling edge of pin T0CKI. The T0SE bit (OPTION<4>) determines the source edge. Clearing the T0SE bit selects the rising edge. Restrictions on the external clock input are discussed in detail in Section 6.1.

The prescaler may be used by either the Timer0 module or the Watchdog Timer, but not both. The prescaler assignment is controlled in software by the control bit PSA (OPTION<3>). Clearing the PSA bit will assign the prescaler to Timer0. The prescaler is not readable or writable. When the prescaler is assigned to the Timer0 module, prescale values of 1:2, 1:4,..., 1:256 are selectable. Section 6.2 details the operation of the prescaler.

A summary of registers associated with the Timer0 module is found in Table 6-1.

FIGURE 6-1: TIMER0 BLOCK DIAGRAM



Note 1: Bits T0CS, T0SE, PSA, PS2, PS1 and PS0 are located in the OPTION register.
2: The prescaler is shared with the Watchdog Timer (Figure 6-5).

8.0 SPECIAL FEATURES OF THE CPU

What sets a microcontroller apart from other processors are special circuits to deal with the needs of real-time applications. The PIC12C5XX family of microcontrollers has a host of such features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection. These features are:

- Oscillator selection
- Reset
  - Power-On Reset (POR)
  - Device Reset Timer (DRT)
  - Wake-up from SLEEP on pin change
- Watchdog Timer (WDT)
- SLEEP
- Code protection
- ID locations
- In-circuit Serial Programming

The PIC12C5XX has a Watchdog Timer which can be shut off only through configuration bit WDTE. It runs off of its own RC oscillator for added reliability. If using XT or LP selectable oscillator options, there is always an 18 ms (nominal) delay provided by the Device Reset Timer (DRT), intended to keep the chip in reset until the crystal oscillator is stable. If using INTRC or EXTRC there is an 18 ms delay only on V_{DD} power-up. With this timer on-chip, most applications need no external reset circuitry.

The SLEEP mode is designed to offer a very low current power-down mode. The user can wake-up from SLEEP through a change on input pins or through a Watchdog Timer time-out. Several oscillator options are also made available to allow the part to fit the application, including an internal 4 MHz oscillator. The EXTRC oscillator option saves system cost while the LP crystal option saves power. A set of configuration bits are used to select various options.

8.1 Configuration Bits

The PIC12C5XX configuration word consists of 12 bits. Configuration bits can be programmed to select various device configurations. Two bits are for the selection of the oscillator type, one bit is the Watchdog Timer enable bit, and one bit is the $\overline{MCLR}$ enable bit.

FIGURE 8-1: CONFIGURATION WORD FOR PIC12C5XX

—	—	—	—	—	—	—	MCLRE	CP	WDTE	FOSC1	FOSC0
bit11	10	9	8	7	6	5	4	3	2	1	bit0

Register: CONFIG
Address(1): FFFh

bit 11-5: **Unimplemented**

bit 4: **MCLRE**: $\overline{MCLR}$ enable bit.
1 = $\overline{MCLR}$ pin enabled
0 = $\overline{MCLR}$ tied to V_{DD}, (Internally)

bit 3: **CP**: Code protection bit.
1 = Code protection off
0 = Code protection on

bit 2: **WDTE**: Watchdog timer enable bit
1 = WDT enabled
0 = WDT disabled

bit 1-0: **FOSC1:FOSC0**: Oscillator selection bits
11 = EXTRC - external RC oscillator
10 = INTRC - internal RC oscillator
01 = XT oscillator
00 = LP oscillator

Note 1: Refer to the PIC12C5XX Programming Specifications to determine how to access the configuration word. This register is not user addressable during device operation.

8.2 Oscillator Configurations

8.2.1 OSCILLATOR TYPES

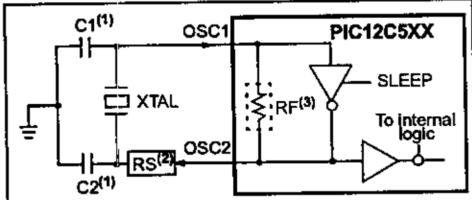
The PIC12C5XX can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1:FOSC0) to select one of these four modes:

- LP: Low Power Crystal
- XT: Crystal/Resonator
- INTRC: Internal 4 MHz Oscillator
- EXTRC: External Resistor/Capacitor

8.2.2 CRYSTAL OSCILLATOR / CERAMIC RESONATORS

In XT or LP modes, a crystal or ceramic resonator is connected to the GP5/OSC1/CLKIN and GP4/OSC2 pins to establish oscillation (Figure 8-2). The PIC12C5XX oscillator design requires the use of a parallel cut crystal. Use of a series cut crystal may give a frequency out of the crystal manufacturers specifications. When in XT or LP modes, the device can have an external clock source drive the GP5/OSC1/CLKIN pin (Figure 8-3).

FIGURE 8-2: CRYSTAL OPERATION (OR CERAMIC RESONATOR) (XT OR LP OSC CONFIGURATION)



Note 1: See Capacitor Selection tables for recommended values of C1 and C2.
2: A series resistor (RS) may be required for AT strip cut crystals.
3: RF approximate value = 10 MΩ.

FIGURE 8-3: EXTERNAL CLOCK INPUT OPERATION (XT OR LP OSC CONFIGURATION)

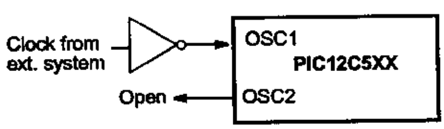


TABLE 8-1: CAPACITOR SELECTION FOR CERAMIC RESONATORS - PIC12C5XX

Osc Type	Resonator Freq	Cap. Range C1	Cap. Range C2
XT	4.0 MHz	30 pF	30 pF

These values are for design guidance only. Since each resonator has its own characteristics, the user should consult the resonator manufacturer for appropriate values of external components.

TABLE 8-2: CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR - PIC12C5XX

Osc Type	Resonator Freq	Cap.Range C1	Cap. Range C2
LP	32 kHz(1)	15 pF	15 pF
XT	200 kHz 1 MHz 4 MHz	47-68 pF 15 pF 15 pF	47-68 pF 15 pF 15 pF

Note 1: For $V_{DD} > 4.5V$, $C1 = C2 \approx 30$ pF is recommended.

These values are for design guidance only. Rs may be required to avoid overdriving crystals with low drive level specification. Since each crystal has its own characteristics, the user should consult the crystal manufacturer for appropriate values of external components.

8.2.5 INTERNAL 4 MHz RC OSCILLATOR

The internal RC oscillator provides a fixed 4 MHz (nominal) system clock at VDD = 5V and 25°C, see "Electrical Specifications" section for information on variation over voltage and temperature.

In addition, a calibration instruction is programmed into the top of memory which contains the calibration value for the internal RC oscillator. This location is never code protected regardless of the code protect settings. This value is programmed as a `MOVLW XX` instruction where XX is the calibration value, and is placed at the reset vector. This will load the W register with the calibration value upon reset and the PC will then roll over to the users program at address 0x000. The user then has the option of writing the value to the OSCCAL Register (05h) or ignoring it.

OSCCAL, when written to with the calibration value, will "trim" the internal oscillator to remove process variation from the oscillator frequency. .

> **Note:** Please note that erasing the device will also erase the pre-programmed internal calibration value for the internal oscillator. The calibration value must be read prior to erasing the part so it can be reprogrammed correctly later.

For the PIC12C508A, PIC12C509A, PIC12CE518, PIC12CE519, and PIC12CR509A, bits <7:2>, CAL5-CAL0 are used for calibration. Adjusting CAL5-0 from 000000 to 111111 yields a higher clock speed. Note that bits 1 and 0 of OSCCAL are unimplemented and should be written as 0 when modifying OSCCAL for compatibility with future devices.

For the PIC12C508 and PIC12C509, the upper 4 bits of the register are used. Writing a larger value in this location yields a higher clock speed.

8.3 RESET

The device differentiates between various kinds of reset:

a) Power on reset (POR)

b) $\overline{\text{MCLR}}$ reset during normal operation

c) $\overline{\text{MCLR}}$ reset during SLEEP

d) WDT time-out reset during normal operation

e) WDT time-out reset during SLEEP

f) Wake-up from SLEEP on pin change

Some registers are not reset in any way; they are unknown on POR and unchanged in any other reset. Most other registers are reset to "reset state" on power-on reset (POR), $\overline{\text{MCLR}}$, WDT or wake-up on pin change reset during normal operation. They are not affected by a WDT reset during SLEEP or $\overline{\text{MCLR}}$ reset during SLEEP, since these resets are viewed as resumption of normal operation. The exceptions to this are $\overline{\text{TO}}$, $\overline{\text{PD}}$, and GPWUF bits. They are set or cleared differently in different reset situations. These bits are used in software to determine the nature of reset. See Table 8-3 for a full description of reset states of all registers.

9.0 INSTRUCTION SET SUMMARY

Each PIC12C5XX instruction is a 12-bit word divided into an OPCODE, which specifies the instruction type, and one or more operands which further specify the operation of the instruction. The PIC12C5XX instruction set summary in Table 9-2 groups the instructions into byte-oriented, bit-oriented, and literal and control operations. Table 9-1 shows the opcode field descriptions.

For **byte-oriented** instructions, 'f' represents a file register designator and 'd' represents a destination designator. The file register designator is used to specify which one of the 32 file registers is to be used by the instruction.

The destination designator specifies where the result of the operation is to be placed. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed in the file register specified in the instruction.

For **bit-oriented** instructions, 'b' represents a bit field designator which selects the number of the bit affected by the operation, while 'f' represents the number of the file in which the bit is located.

For **literal and control** operations, 'k' represents an 8 or 9-bit constant or literal value.

TABLE 9-1: OPCODE FIELD DESCRIPTIONS

Field	Description
`f`	Register file address (0x00 to 0x7F)
`W`	Working register (accumulator)
`b`	Bit address within an 8-bit file register
`k`	Literal field, constant data or label
`x`	Don't care location (= 0 or 1) The assembler will generate code with x = 0. It is the recommended form of use for compatibility with all Microchip software tools.
`d`	Destination select; d = 0 (store result in W) d = 1 (store result in file register 'f') Default is d = 1
`label`	Label name
`TOS`	Top of Stack
`PC`	Program Counter
`WDT`	Watchdog Timer Counter
$\overline{\text{TO}}$	Time-Out bit
$\overline{\text{PD}}$	Power-Down bit
`dest`	Destination, either the W register or the specified register file location
[ ]	Options
( )	Contents
→	Assigned to
< >	Register bit field
∈	In the set of
italics	User defined term (font is courier)

All instructions are executed within a single instruction cycle, unless a conditional test is true or the program counter is changed as a result of an instruction. In this case, the execution takes two instruction cycles. One instruction cycle consists of four oscillator periods. Thus, for an oscillator frequency of 4 MHz, the normal instruction execution time is 1 µs. If a conditional test is true or the program counter is changed as a result of an instruction, the instruction execution time is 2 µs.

Figure 9-1 shows the three general formats that the instructions can have. All examples in the figure use the following format to represent a hexadecimal number:

0xhhh

where 'h' signifies a hexadecimal digit.

FIGURE 9-1: GENERAL FORMAT FOR INSTRUCTIONS

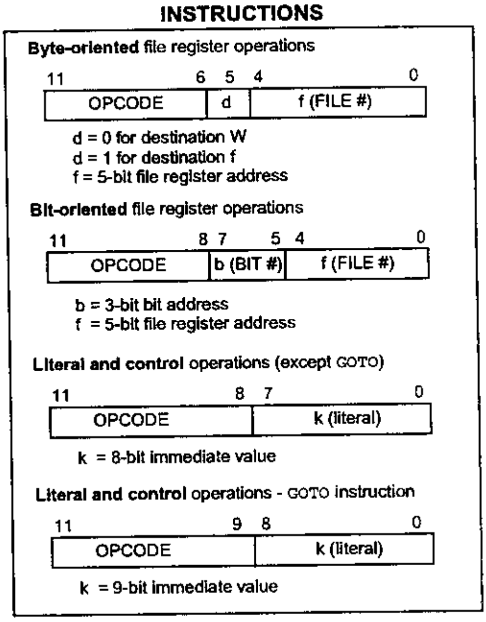


TABLE 9-2: INSTRUCTION SET SUMMARY

Mnemonic,	Operands	Description	Cycles	12-Bit Opcode MSb		LSb	Status Affected	Notes
ADDWF	f,d	Add W and f	1	0001	11df	ffff	C,DC,Z	1,2,4
ANDWF	f,d	AND W with f	1	0001	01df	ffff	Z	2,4
CLRF	f	Clear f	1	0000	011f	ffff	Z	4
CLRW	–	Clear W	1	0000	0100	0000	Z	
COMF	f, d	Complement f	1	0010	01df	ffff	Z	
DECF	f, d	Decrement f	1	0000	11df	ffff	Z	2,4
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	0010	11df	ffff	None	2,4
INCF	f, d	Increment f	1	0010	10df	ffff	Z	2,4
INCFSZ	f, d	Increment f, Skip if 0	1(2)	0011	11df	ffff	None	2,4
IORWF	f, d	Inclusive OR W with f	1	0001	00df	ffff	Z	2,4
MOVF	f, d	Move f	1	0010	00df	ffff	Z	2,4
MOVWF	f	Move W to f	1	0000	001f	ffff	None	1,4
NOP	–	No Operation	1	0000	0000	0000	None	
RLF	f, d	Rotate left f through Carry	1	0011	01df	ffff	C	2,4
RRF	f, d	Rotate right f through Carry	1	0011	00df	ffff	C	2,4
SUBWF	f, d	Subtract W from f	1	0000	10df	ffff	C,DC,Z	1,2,4
SWAPF	f, d	Swap f	1	0011	10df	ffff	None	2,4
XORWF	f, d	Exclusive OR W with f	1	0001	10df	ffff	Z	2,4
BIT-ORIENTED FILE REGISTER OPERATIONS								
BCF	f, b	Bit Clear f	1	0100	bbbf	ffff	None	2,4
BSF	f, b	Bit Set f	1	0101	bbbf	ffff	None	2,4
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	0110	bbbf	ffff	None	
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	0111	bbbf	ffff	None	
LITERAL AND CONTROL OPERATIONS								
ANDLW	k	AND literal with W	1	1110	kkkk	kkkk	Z	
CALL	k	Call subroutine	2	1001	kkkk	kkkk	None	1
CLRWDT	k	Clear Watchdog Timer	1	0000	0000	0100	$\overline{TO}$, $\overline{PD}$	
GOTO	k	Unconditional branch	2	101k	kkkk	kkkk	None	
IORLW	k	Inclusive OR Literal with W	1	1101	kkkk	kkkk	Z	
MOVLW	k	Move Literal to W	1	1100	kkkk	kkkk	None	
OPTION	–	Load OPTION register	1	0000	0000	0010	None	
RETLW	k	Return, place Literal in W	2	1000	kkkk	kkkk	None	
SLEEP	–	Go into standby mode	1	0000	0000	0011	$\overline{TO}$, $\overline{PD}$	
TRIS	f	Load TRIS register	1	0000	0000	0fff	None	3
XORLW	k	Exclusive OR Literal to W	1	1111	kkkk	kkkk	Z	

Note 1: The 9th bit of the program counter will be forced to a '0' by any instruction that writes to the PC except for `GOTO`. (Section 4.6)

2: When an I/O register is modified as a function of itself (e.g. `MOVF GPIO, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

3: The instruction `TRIS f`, where f = 6 causes the contents of the W register to be written to the tristate latches of GPIO. A '1' forces the pin to a hi-impedance state and disables the output buffers.

4: If this instruction is executed on the TMR0 register (and, where applicable, d = 1), the prescaler will be cleared (if assigned to TMR0).

NPN general purpose transistors BC107; BC108; BC109

FEATURES

- Low current (max. 100 mA)
- Low voltage (max. 45 V).

APPLICATIONS

- General purpose switching and amplification.

DESCRIPTION

NPN transistor in a TO-18; SOT18 metal package.
PNP complement: BC177.

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector, connected to the case

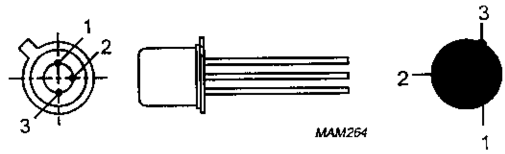


Fig.1 Simplified outline (TO-18; SOT18) and symbol.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	BC107		–	50	V
	BC108; BC109		–	30	V
V_{CEO}	collector-emitter voltage	open base			
	BC107		–	45	V
	BC108; BC109		–	20	V
I_{CM}	peak collector current		–	200	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	300	mW
h_{FE}	DC current gain	$I_C = 2$ mA; $V_{CE} = 5$ V			
	BC107		110	450	
	BC108		110	800	
	BC109		200	800	
f_T	transition frequency	$I_C = 10$ mA; $V_{CE} = 5$ V; f = 100 MHz	100	–	MHz

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	BC107		–	50	V
	BC108; BC109		–	30	V
V_{CEO}	collector-emitter voltage	open base			
	BC107		–	45	V
	BC108; BC109		–	20	V
V_{EBO}	emitter-base voltage	open collector			
	BC107		–	6	V
	BC108; BC109		–	5	V
I_C	collector current (DC)		–	100	mA
I_{CM}	peak collector current		–	200	mA
I_{BM}	peak base current		–	200	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	300	mW
T_{stg}	storage temperature		–65	+150	°C
T_j	junction temperature		–	175	°C
T_{amb}	operating ambient temperature		–65	+150	°C

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th\ j-a}$	thermal resistance from junction to ambient	note 1	0.5	K/mW
$R_{th\ j-c}$	thermal resistance from junction to case		0.2	K/mW

Note

1. Transistor mounted on an FR4 printed-circuit board.

National Semiconductor

February 1995

LM78XX Series Voltage Regulators

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX series of regulators easy to use and mininize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

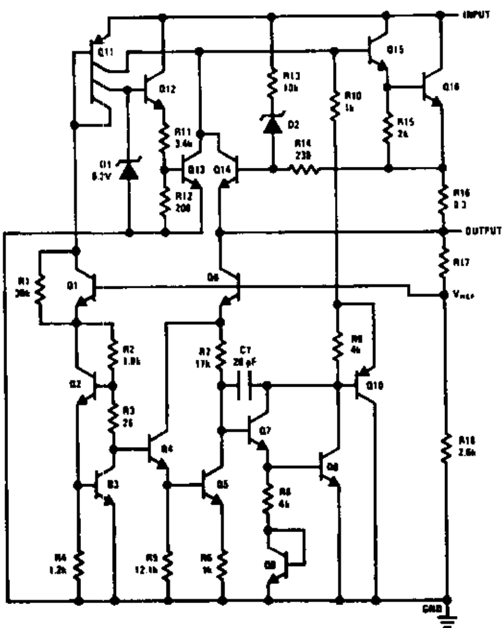
Features

- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

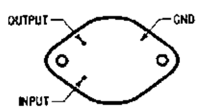
LM7805C	5V
LM7812C	12V
LM7815C	15V

Schematic and Connection Diagrams



TL/H/7746–1

Metal Can Package
TO-3 (K)
Aluminum

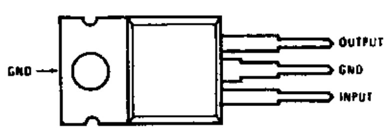


TL/H/7746–2

Bottom View

Order Number LM7805CK, LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package
TO-220 (T)



TL/H/7746–3

Top View

Order Number LM7805CT, LM7812CT or LM7815CT
See NS Package Number T03B

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Input Voltage (V_O = 5V, 12V and 15V)	35V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range (T_A)	0°C to +70°C
Maximum Junction Temperature	
(K Package)	150°C
(T Package)	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	
TO-3 Package K	300°C
TO-220 Package T	230°C

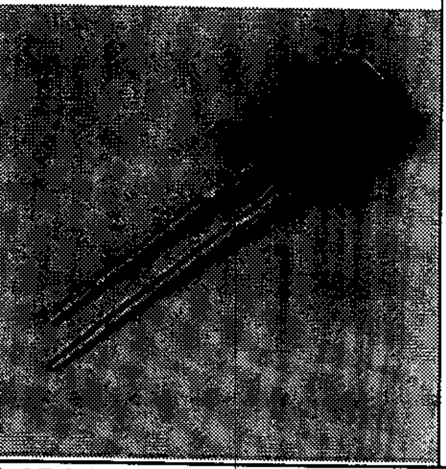
Electrical Characteristics LM78XXC (Note 2) 0°C ≤ Tj ≤ 125°C unless otherwise noted.

Symbol	Parameter	Conditions		5V Min	5V Typ	5V Max	12V Min	12V Typ	12V Max	15V Min	15V Typ	15V Max	Units
	Output Voltage			5V			12V			15V			
	Input Voltage (unless otherwise noted)			10V			19V			23V			
V_O	Output Voltage	T_j = 25°C, 5 mA ≤ I_O ≤ 1A		4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V
		P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A		4.75		5.25	11.4		12.6	14.25		15.75	V
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)		V
ΔV_O	Line Regulation	I_O = 500 mA	T_j = 25°C		3	50		4	120		4	150	mV
			ΔV_{IN}		(7 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)		V
			0°C ≤ T_j ≤ +125°C			50			120			150	mV
			ΔV_{IN}		(8 ≤ V_{IN} ≤ 20)			(15 ≤ V_{IN} ≤ 27)			(18.5 ≤ V_{IN} ≤ 30)		V
		I_O ≤ 1A	T_j = 25°C			50			120			150	mV
			ΔV_{IN}		(7.5 ≤ V_{IN} ≤ 20)			(14.6 ≤ V_{IN} ≤ 27)			(17.7 ≤ V_{IN} ≤ 30)		V
			0°C ≤ T_j ≤ +125°C			25			60			75	mV
			ΔV_{IN}		(8 ≤ V_{IN} ≤ 12)			(16 ≤ V_{IN} ≤ 22)			(20 ≤ V_{IN} ≤ 26)		V
ΔV_O	Load Regulation	T_j = 25°C	5 mA ≤ I_O ≤ 1.5A		10	50		12	120		12	150	mV
			250 mA ≤ I_O ≤ 750 mA			25			60			75	mV
		5 mA ≤ I_O ≤ 1A, 0°C ≤ T_j ≤ +125°C				50			120			150	mV
I_Q	Quiescent Current	I_O ≤ 1A	T_j = 25°C			8			8			8	mA
			0°C ≤ T_j ≤ +125°C			8.5			8.5			8.5	mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_O ≤ 1A				0.5			0.5			0.5	mA
		T_j = 25°C, I_O ≤ 1A				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN} ≤ 27)			(17.9 ≤ V_{IN} ≤ 30)		V
		I_O ≤ 500 mA, 0°C ≤ T_j ≤ +125°C				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)		V
V_N	Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40			75			90		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz	I_O ≤ 1A, T_j = 25°C or	62	80		55	72		54	70		dB
			I_O ≤ 500 mA, 0°C ≤ T_j ≤ +125°C	62			55			54			dB
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(8 ≤ V_{IN} ≤ 18)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)		V
R_O	Dropout Voltage	T_j = 25°C, I_{OUT} = 1A			2.0			2.0			2.0		V
	Output Resistance	f = 1 kHz			8			18			19		mΩ
	Short-Circuit Current	T_j = 25°C			2.1			1.5			1.2		A
	Peak Output Current	T_j = 25°C			2.4			2.4			2.4		A
	Average TC of V_{OUT}	0°C ≤ T_j ≤ +125°C, I_O = 5 mA			0.6			1.5			1.8		mV/°C
V_{IN}	Input Voltage Required to Maintain Line Regulation	T_j = 25°C, I_O ≤ 1A			7.5		14.6			17.7			V

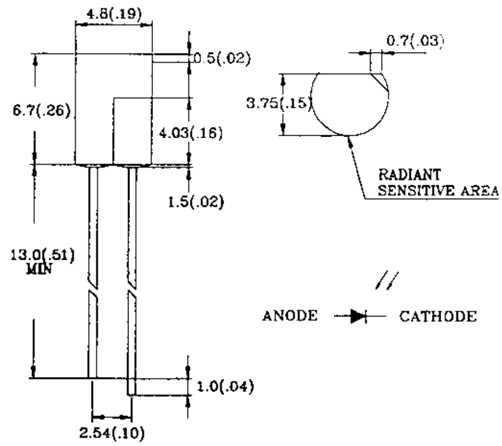
Note 1: Thermal resistance of the TO-3 package (K, KC) is typically 4°C/W junction to case and 35°C/W case to ambient. Thermal resistance of the TO-220 package (T) is typically 4°C/W junction to case and 50°C/W case to ambient.

Note 2: All characteristics are measured with capacitor across the input of 0.22 μF, and a capacitor across the output of 0.1μF. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account seperately.

PARA LIGHT **L-SC1R9PD1XX** PHOTODIODE



◆PACKAGE DIMENSIONS



◆ABSOLUTE MAXIMUN RATING: (Ta=25℃)

Part No.	P_D (mw)	$V_{(BR)R}$ (V)	Topr	Tstg
L-SC1R9PD1XX	0.1	30	-35℃ to 85℃	-35℃ to 85℃
PARAMETER	Power Dissipation	Reverse break down Voltage	Operating Temperature Range	Storage Temperature Range

ead Soldering Temperature { 1.6mm (0.063 inch) From Body } 250℃±5℃ For 3 Seconds

◆ELECTRO-OPTICAL CHARACTERISTICS: (Ta=25℃)

Part No.	I_D (nA)			$V_{(BR)R}$ (V)			Voc (mV)			I_L (uA)			t_{on}/t_{off} (nS)			C_T (pF)			λ (nm)		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Peak	Ma
SC1R9PD1C		5	30	33	170			390		30	40			45/45			18		400		105
C1R9PD1D1		5	30	33	170			390		30	40			45/45			18		900	940	
C1R9PD1D2		5	30	33	170			390		30	40			45/45			18		800	870	
TEST ONDITION	V_R=10V Ee=0mW/cm²			I_R=100uA Ee=0mW/cm²			λ=940nm Ee=0.5mW/cm²			V_R=5V Ee=0.1mW/cm²			V_R=10V RL=1000Ω			f=1MHZ V_R=5V Ee=0mW/cm²					
RAMETER	REVERSE DARK CURRENT			REVERSE BREAKDOWN VOLTAGE			OPEN CTRCUIT VOLTAGE			LIGHT CURRENT			TURN-ON TURN-OFF TIME			TOTAL CAPACTTANCE			SPECTRAL SENSITIVITY WAVELENGTH		

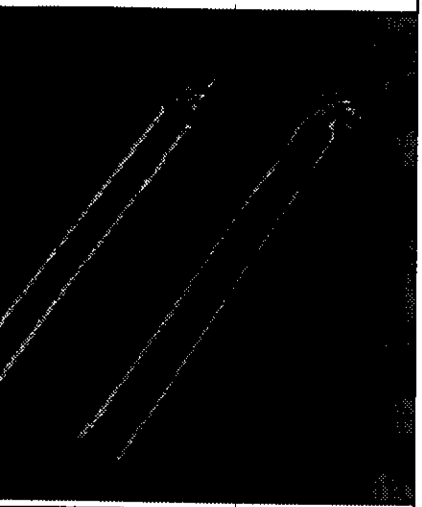
2=BLACK

ll dimension are in millimeter (inches).

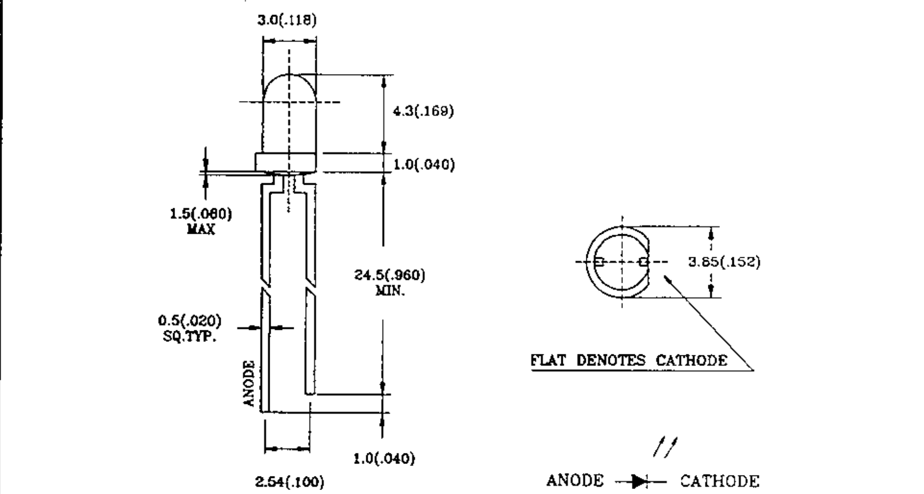
olerance is ±0.25mm(0.01")unless otherwise specified.

ARA

L-31XXIR1XX 3.0mm INFRARED EMITTING DIODE



◆PACKAGE DIMENSIONS



SOLUTE MAXIMUN RATING: (Ta=25℃)

t No.	P_D (mw)	V_R (V)	Topr	Tstg
XIR1XX	100	5	-35℃ to 85℃	-35℃ to 85℃
METER	Power Dissipation	Reverse Voltage	Operating Temperature Range	Storage Temperature Range
oldering Temperature { 1.6mm (0.063 inch) From Body } 250℃±5℃ For 3 Seconds				

ECTRO-OPTICAL CHARACTERISTICS: (Ta=25℃)

No.	VF (V)			IR (uA)			λP (nm)			2θ1/2 (Age)			Ie (mw/sr)		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
EIR1C		1.2 1.4	1.6			10		940			20		7	14	
EIR1C		1.2 1.4	1.6			10		940			25		6	12	
EIR1C		1.2 1.4	1.6			10		940			30		6	12	
EIR1C		1.2 1.4	1.6			10		940			40		6	10	
IR1BC		1.2 1.4	1.6			10		940			20		7	14	
IR1BC		1.2 1.4	1.6			10		940			25		6	12	
IR1BC		1.2 1.4	1.6			10		940			30		6	12	
IR1BC		1.2 1.4	1.6			10		940			40		6	10	
T TION	I_F=20mA IF=100mA			V_R= 5V			I_F= 20mA			I_F =20mA			I_F= 20mA		

E CLEAR