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Department of Electrical Engineering

EE-445
Industrial Electronics

Laboratory Manual

July 2003

PREFACE

This manual is designed to provide students of Electrical engineering courses with the insight of Industrial Electronics. This manual discusses implementation of various IC s for industrial utilities. By the end of the course students are expected to have understanding of the electronic devices and their usage.

LIST OF EXPERIMENTS

Experiment # 0

Printed Circuit Techniques

INTRODUCTION:

More than 40 years after they first appeared, the printed-circuit boards (PCBs) are still the most important means of connecting components into electronic systems. They have evolved from simple systems of etched copper strips connecting 30-50-component terminals on one side of a piece of phenolic board, to multiple layers of copper on polymer substrates connecting upwards of 10000 terminals in a three-dimensional pattern.

On early boards, the copper routes were laid out by hand, and the artwork delineating them photolithographically was hand-drawn; now, the entire process is computer-controlled. Then, conductor paths were 100 mils wide (0.1 inch or 2.5 mm); now they are as narrow as 3 mils. The main objectives of this experiments are:

1. To acquaint the student with printed circuit layout techniques.
2. To acquaint the student with the silk-screen process.
3. To understand and apply the correct procedures for conductor pattern masking.
4. To acquaint the student with etching techniques.
5. To acquaint the student with printed circuit component assembly and soldering.

PRELIMINARY DISCUSSION:

Printed circuit techniques are methods that can be employed in place of using hookup wire for the connection of electronic circuits. These methods allow conductor pattern to be reproduced into copper foil, which is initially bonded to an insulating base material, Fig. 1 a and b.

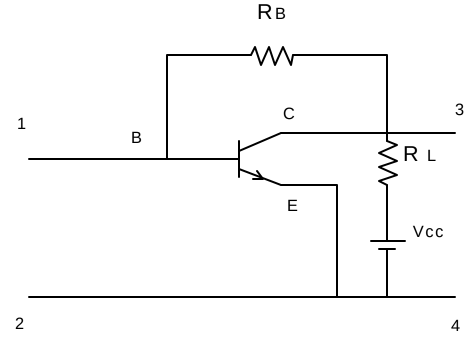


Fig. 1-a: Common Emitter

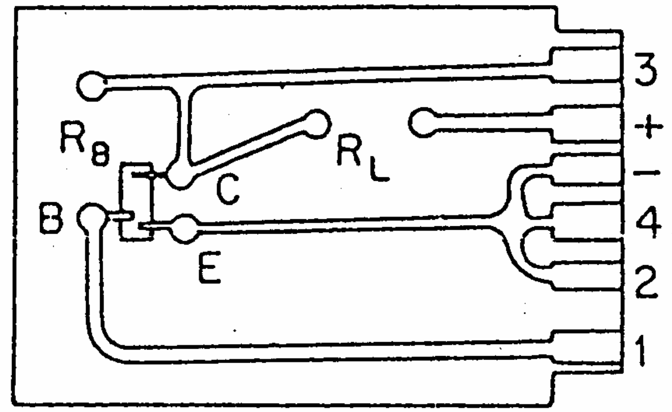


Fig. 1-b: Conductor Pattern

There are a number of procedures for producing conductive patterns. The most common are photoetching, stenciling, spraying, painting, die stamping, vaccum distillation, and chemical deposition. Some of the advantages of printed circuits are that they lend themselves to quantity production, dip soldering can be employed, component assembly size and weight can be reduced, and the probability of wiring errors is minimized.

The common materials that comprise PCBs are electrolytic copper foil bonded to a paperbase phenolic material. The foil may be bonded on one or on both sides of the base material forming single or double copper laminated board. For special purposes, nonstandard materials such as aluminum, steel, silver, and tinfoils are available. However, copper foil is used extensively because of its high conductivity, good soldering characteristics, availability in broad widths, and low cost. Copper foils are available in several thickness and weights. Depending on foil thickness and line width, the current-carrying capacity can range as high as 35 A.

The most important phase in the development of a final printed circuit assembly is the preliminary planning or design stage. There is no basic formula for selecting a PCB assembly. Attention to detail is essential and compromise in design will be experienced. Compromise is due to such considerations as one- or two-sided conductive pattern, pattern configuration, shielding, grounding requirements, component clearance, conductor separation and width, holes size and locations, board size and shape, and method of input and output connections. It is important to note that once the board is etched, the conductive pattern is permanent. Therefore, careful planning is necessary to make all corrections and modifications before the board is to undergo any stamping or chemical phases.

The two basic procedures that will be discussed in this section for producing PCBs are: 1. the silk-screen process and 2. masking with tape or etchant-resisting paint. The silk-screen process is intended for mass production of a common printed circuit pattern. Although this method gives fast and high-quality results, the tape or paint resist method of masking is quite suitable for producing small quantities of printed circuit having uncomplicated patterns.

The masking process using tape, paint resist, transfers, or ball-point tube resist is less involved than the silk-screen process. It can be done without special facilities or equipment to produce a complete masked conductor pattern. Before masking with either paint or tape resist, the copper should be completely cleaned to remove all grease and containmants. Two basic reasons for cleaning the copper surface before masking are to allow the resist to completely adhere to give optimum protection to the underlying conductor pattern and to allow the etchant to attack and remove the undesired portions of the copper. Avoid grease-base cleaners or abrasives since they leave a film. Fine steelwool may be used when appropriate cleaners are not available. After the cleaning process, the conductor pattern must be transferred to the copper. This may be done by use of carbon paper. Only thin lines are necessary to show the centers of the conductors making up the conductor pattern. Care must be taken to secure the conductor pattern artwork so that it does not slip during the transfer process. When the paint or tape resist is applied, the correct conductor spacing and location will be obtained by centering the paint or tape width on the transfer lines. There is a wide choice of tape resist widths. The selection primarily depends on required current-carrying and conductor spacing. When applying tape resist and dots over the transfer lines and terminal points on the copper, each piece must be firmly pressed into place to ensure that no etchant can creep under the tape. This is particularly true at the joints between the tape and the dots, Fig. 2-a. When conductor direction changes, the tape does not have to be butted or overlapped. It is preferable to arch the tape to form the desired curves as the resist is being applied. Overlapping is required when the tape joins dots, but this can be avoided when teardrop resist is used at terminal points. The ends of the teardrops are squared off, thereby allowing for butt joints, Fig 2-b. There is less chance for etchant to creep into a butt joint than under a lap joint.

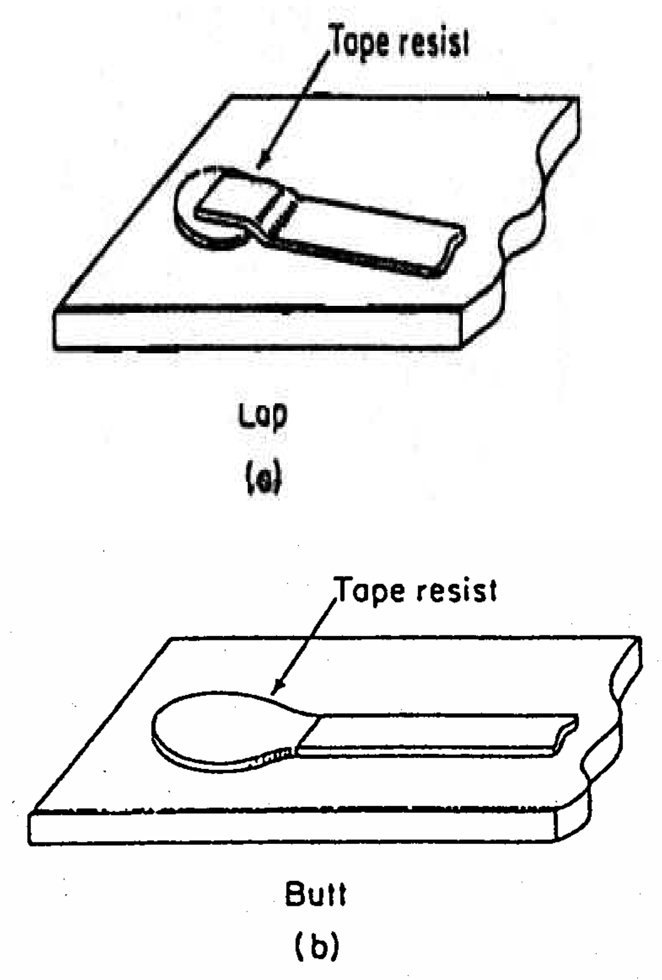


Fig.2:

If paint resist is used, a small, soft brush or an inking pen may be employed. An inking pen will give a more uniform line width. The dots of paint or tape resist placed at terminal points should always be at least 1/8 in. in diameter. This will provide enough copper to allow a complete ring of solder to be formed around each of the conductor leads passing through the terminal pads. It should be emphasized that the appearance of the tape or paint resist pattern will be duplicated in the etched conductor pattern. If the resist extends beyond intended limits or falls short of them, the copper remaining after the etching process will follow suit. In the case of unintentional gaps in the tape resist, open circuits result in the conductor pattern. If the resist extends beyond set limits, there is an excellent possibility of short circuits being produced. In either case, the conductor pattern would have to be modified. Jumper wires would have to be used to bridge gaps and filing would have to be done to remove short circuits caused by excess copper. Therefore, the masked pattern must be checked before the etching process to avoid unnecessary modifications.

Alternatively, with a special sheet of plastic film-TEC200-a plain paper copier, and an iron, you can produce a professional looking printed-circuit board using what is probably the easiest and cheapest method of producing single or multiple printed-circuit boards. Making PCBs using TEC200 plastic film can be broken down into three easy steps:

1. Photocopy the printed-circuit pattern on to the plastic film.
2. Transfer the copied pattern on to the copper-clad blank (unetched printed-circuit material) by ironing.
3. Let the board cool and then peel off the plastic film.

The toner from the copy machine fuses to the blank, leaving a very tough etch-resist pattern that is also very precise.

It is important to use a "plain paper" type copy machine that uses dry toner. Lower-cost machines are often incapable of recognizing the film sheets (transparent medium) as paper, and as such will not copy to them.

Before handling the fil sheets, make sure that your hands are thoroughly clean, and then handle the sheets only by the edges. Body oils deposited on the plastic film will interface with the toner resist just as it does with other resists.

If you are copying the pattern from a printed page (magazine article, electronics-hobbyist construction book, etc.), the pattern shown is most-likely of the copper side of the board, therefore the image must be reversed. To reverse the pattern, simply copy the pattern to a sheet of TEC200, then copy the image from the first film sheet on to a second sheet of TEC200. The first sheet of film must be placed in the scanner up-side down (i.e. pattern side up), and covered with a clean sheet of paper to prevent a dirty machine-lid background from adding to your pattern.

The image produced on the second sheet of film is then placed toner-side down on a copperclad blank and backed up by a sheet of plain paper. A hot iron is then used to transfer the toner resist pattern on to the copper-clad blank.

The film sheet you used to get a mirror image may now be cleaned and reused, using nail polish remover, acetone, paint thinners, or other solvents that you may already have around.

You can design your own printed-circuit layout on a sheet of white paper using dry-transfer patterns (inserting component labels as you progress). Then when the layout pattern is complete, it can be transferred to TEC200 film. The pattern is then ready to be transferred to the printed-circuit blank, and your original layout (the one on paper) can be used as a parts-placement guide.

If you find minor deficiencies in the transferred pattern, touch them up with a fine-poiint permanent-ink marking pen. The blank is now ready for etching.

The etching solution will not undercut the pattern unless the etching rate is excessively slow, a condition usually caused by weak or cool solution, and/or the lack of agitation. Weak (overly used) solutions should be discarded. The temperature of the etching solution can be raised by subjecting it to a blast of hot air from a hair dryer or similar hot-air blower. Agitating the solution can be handled in several ways, for example by hand agitation (shaking the etching tank).

The silk-screen process is more complicated than the above mentioned masking techniques. A positive of the conductor pattern is first drawn or marked on Myler or drafting vellum. A photosensitive gelatin must be exposed under this positive of the conductor pattern. After the gelatin has been exposed, it is developed, inspected, and rinsed in hot water, producing a negative of the conductor pattern. While the gelatin is soft, it is pressed on to a silk screen and allowed to dry. The result is a stencil of the conductor pattern on the silk screen. When a printed circuit is to be masked, the copper-clad board is placed under the silk screen. Ink resist is forced through the screen with a squeegee on to the copper. The result is a very neat and completely masked printed circuit.

Once the entire blank is etched, clean the resist off with scouring powder, warm water (the warmer the better), and a plastic scouring pad. You can also use solvents to remove resist from the board.

Before components are mounted on to the PCB, the conductor pattern should be dip-soldered when several boards are to be made. When only a few boards are needed and the facilities for dip soldering are not available, the conductor pattern can be hand soldered. It is desirable to tin the conductor pattern for greater reliability and to facilitate soldering wires or component leads to the conductor pads. Excessive heat must be avoided in the tinning process and also when soldering leads to the conductor pattern. Overheating can upset the bond between the copper foil and the board. Once the conductor pattern begins to lift from the board, little can be done to repair it.

Wires and component leads must be carefully soldered to the conductor pattern. Before attempting to mount the parts and components on the printed circuit card, the terminal holes must be drilled. Holes must be at least 0.008-0.012 in. in diameter larger than the lead diameter. This will ensure that the solder will readily fill the gap between the component lead and the conductor pad. It is necessary to secure all components and parts mechanically to the board before soldering. To xsecure components, such as resistors, insert the leads through the opposite side of the board from the copper foil and bend approximately 60 degrees in the direction of the conductor. This will ensure that leads will not move when soldered, Fig. 3.

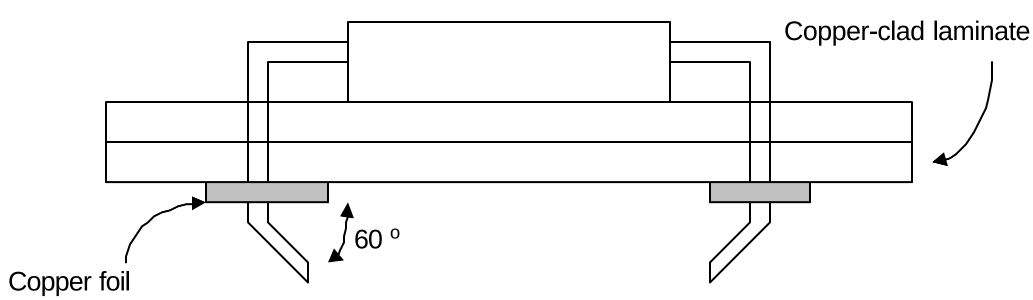


Fig. 3: Components mounting

PROJECT:

The following project is not intended to completely familiarize one in the printed circuit process or to teach all phases of this art. However, the general knowledge gained will allow one to succdessfully mask and etch a conductor pattern to establish electrical connections.

1. Lay out a conductor pattern for the circuit shown in Fig. 1(a) as shown in Fig. 1(b).
2. Cut the copper-clad laminate to the required size.
3. Thoroughly clean the surface of the copper.
4. Print the conductor pattern onto the copper-clad blank.
5. Allow the ink resist to dry.
6. Etch the printed circuit.
7. Place the etched card on to a hard supporting surface. Scribe and drill all terminal pads.
8. Remove the ink resist and tin the conductor pattern.
9. Mount the components on to the PCB.
10. Solder all wires and component leads to specified terminal pads. Cut ecess lead length protruding through the terminal pads per specifications.
11. Mount the components.
12. Clean all soldered terminal connections and conductive strips.

BY THE END OF THIS PROJECT WE HOPE THAT YOU WILL BE FAMILIAR WITH THE MOST IMPORTANT TECHNIQUES AND PROCEDURES USED IN PRODUCING PCBs. HOPEFULLY YOU WILL FIND IT USEFUL IN DESIGNING YOUR FUTURE PROJECTS.

Experiment # 1

555 TIMER IN INDUSTRIAL APPLICATIONS

INTRODUCTION:

The 555 Timer is a universally accepted device for the generation of clock waveforms, single pulses, PWM, FM and in a wide range of applications ranging from simple hobbyist games to computer timing control. Our major interest in the present experiment is to investigate the use industrial applications of the 555 timer. In this regard usually two transducers are combined with the 555 timer to provide us with a useful application. Usually a transducer is used to convert a nonelectrical quantity into an electrical quantity is used to control the frequency of operation of the 555 timer. As you know the frequency of oscillation of a 555 timer configures as a square wave generator is a function of the externally connected resistances. Thus by making one of these resistances a function of a nonelectrical quantity it is possible to change the frequency of oscillation according to the variations of this nonelectrical quantity. The output square wave of the 555 timer can be used to give the user a sensible measure of the variations in the nonelectrical quantity. This can be achieved through flashing, ringing or any other measuring system. In all cases the change in the frequency of the square wave output of the 555 timer is used to activate another transducer at the output of the system.

EXPERIMENTAL WORK:

In this experiment we will examine the operation of a number of interesting industrial applications of the 555 timer.

(a) Skin Resistance (lie Detector)

Fig 1 shows the circuit of a lie detector. In this application, the body resistance is used to control the frequency of oscillation of the 555 timer. The output is obtained via a loudspeaker. The theory behind this lie detector is very simple. It is well known that when the subject tells the truth he remains relatively relaxed, but he becomes exposed to increased stress when he lies. Stress causes increased perspiration, which in turn results in increased resistance between the two electrodes positioned on the subject's skin.

(b) Electric Fuel Pump Driver

Fig 2 shows the circuit of an adjustable-speed pump driver. In this application the 555 timer and a transistor provide a system for driving a high-speed electric fuel pump. This arrangement allows the pumping rate to be adjusted and can be used with any pump of the solenoid-plunger type. The output of the 555 timer drives the transistor on and off and so operates the solenoid-driven plunger of the pump. Commutating diode D protects the transistor from surges at the turnoff. The speed can be adjusted by changing R_2. The components shown are selected to drive a pump requiring less than 1 ampere. If a different pump is used that requires a current of more than 1 ampere, a different transistor must be chosen.

(c) Flasher

Fig. 3 shows the circuit of a flasher. It can be used in a darkroom situation to indicate whether it is safe to enter or not. Other applications are also possible. Explain the circuit operation.

<u>Note that the transistor must supply the necessary current for operating the lamp.</u>

YOU ARE REQUESTED TO CONSTRUCT THESE THREE EXAMPLES. VERIFY THEIR OPERATION. WRITE A REPORT INCLUDING YOUR OBSERVATIONS.

WHY NOT TRY TO MODIFY THESE CIRCUITS TO PRODUCE OTHER USEFUL INDUSTRIAL APPLICATIONS?

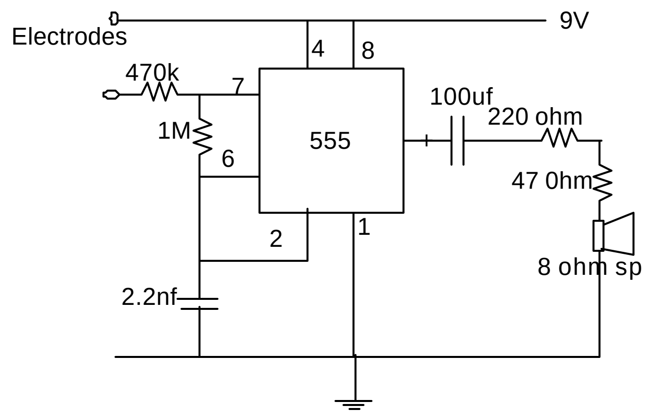


Fig. 1: Lie Detector

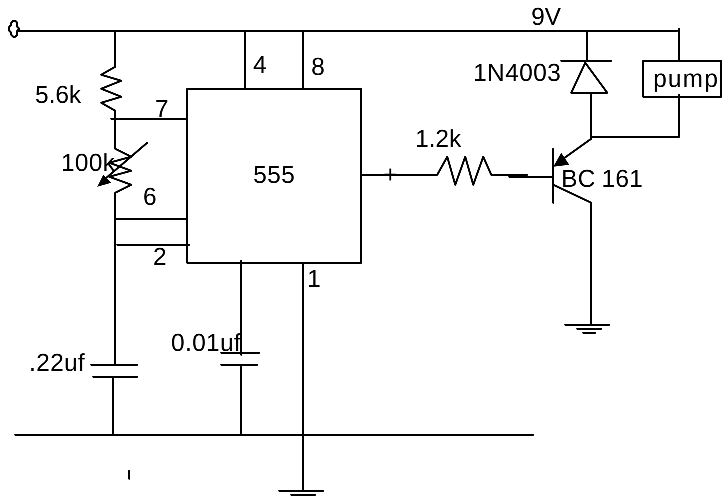


Fig.2: Adjustable speed Pump Deiver

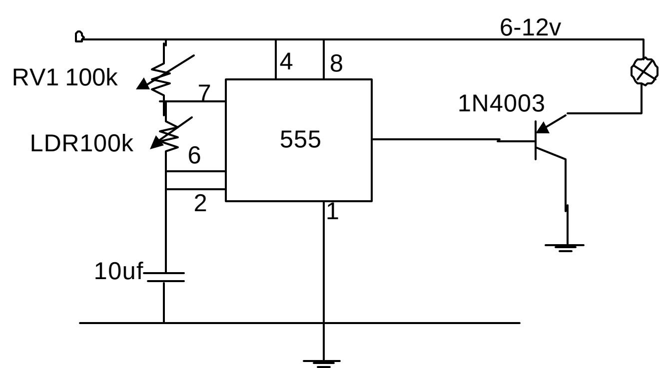


Fig.3: Flasher Circuit

Experiment # 2

555 TIMER ADDITIONAL INDUSTRIAL APPLICATIONS

INTRODUCTION:

From your lecture note you know that the 555 timer can be used in two modes: the stable mode and the monostable (one shot) mode. In the astable mode once you switch on the dc supply you will get a train of pulses. The frequency of these pulses is dependent on the externally connected resistors and capacitor. However, its mark/space ratio is not equal to 1. Over the years designers were trying to obtain a mark/space ratio equal to 1 using different approaches. Fig. 1 shows one approach. In this circuit the output will be Hi for a time t_1=0.693R_AC as usual.
However, the output will be low for a time

$$t_2 = \frac{R_A R_B}{R_A + R_B} C \ln\left[\frac{R_B - 2R_A}{2R_B - R_A}\right] \tag{1}$$

Try to prove equation (1). Thus, by proper selection of R_A and R_B one can obtain $t_1 = t_2$. That is a mark/space ration equal to 1.

NOTE THAT THIS CIRCUIT WILL NOT OSCILLATE IF RB IS GREATER THAN R_A/2 BECAUSE THE JUNCTION OF R_A and R_B CANNOT BRING PIN 2 DOWN TO V_{CC}/3 AND TRIGGER THE LOWER COMPARATOR OF THE 555 TIMER.

On the other hand the 555 timer can be used to generate linear ramp (sawtooth) signals. As you know these signals are very important in many applications. Give examples. A possible circuit for generating ramp signals using the 555 timer is shown in Fig. 2. First try to understand what the transistor is doing in this circuit. Then show that the circuit can produce a ramp voltage at the output every time a trigger pulse is applied to pin 2. Show that the duration of the ramp can be expressed by

$$T = 2/3 \frac{V_{CC} R_E (R_1 + R_2)}{R_1 V_{CC} - V_{BE}(R_1 + R_2)} C \tag{2}$$

Finally, the 555 timer configured as an astable circuit has many useful applications. In experiment (1) we have considered some of these applications. Here is another more sophisticated one. Fig. 3 shows a

Monotone alarm circuit activated by (a) dark, (b) light, (c) under-temperature, (d) over-temperature. Here we exploit the fact that pin 4 must be at a hi potential to enable the 555 timer. If it is at a Lo potential then the 555 timer will be disabled and can perform its function as an astable. Try to understand the role played by the transistor. In short the transistor will switch pin 4 between Hi and Lo potentials depending on the temperature or the light intensity. Accordingly, the 555 timer astable will be enabled or disabled.

EXPERIMENTAL WORK:

In the laboratory you are expected to construct the three circuits of Figs. 1-3 using the recommended values of components shown. Verify their operation. Write a report including your observations. BY THE END OF THIS EXPERIMENT WE EXPECT THAT YOU WILL BE FAMILIAR WITH THE VARIETY OF APPLICATIONS OF THE 555 TIMER. CAN YOU THINK OF OTHER APPLICATIONS? PLEASE TRY.

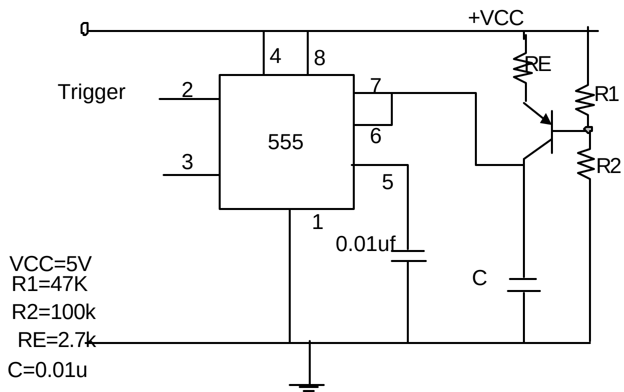


Fig.1: Square Wave Oscillator

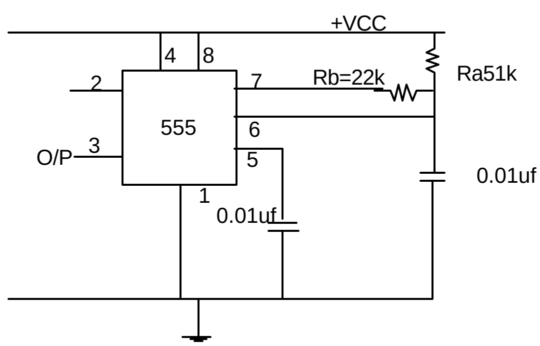
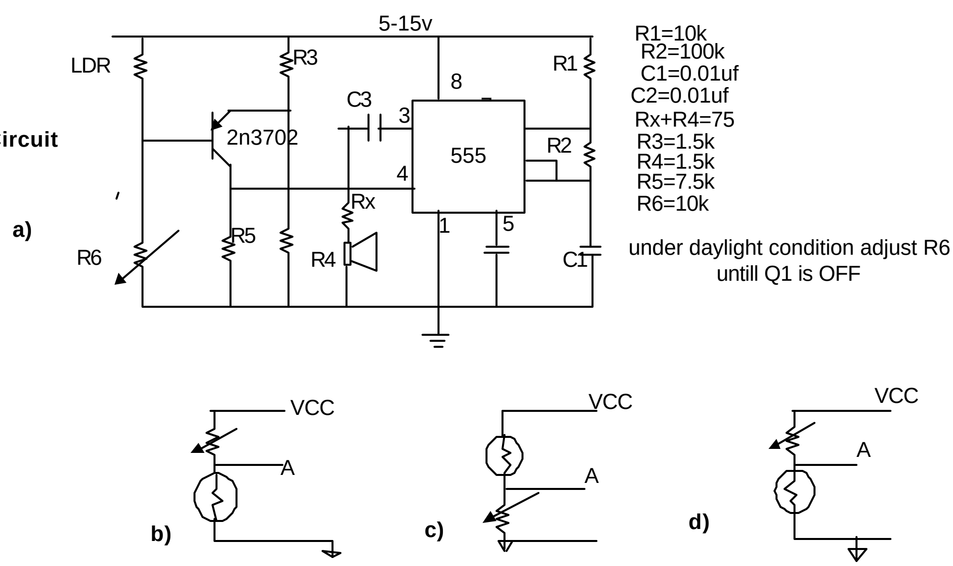


Fig.2: Ramp Signal Circuit

Fig.3: Monotone Alarm Circuit



Experiment # 3

HEART MEASUREMENT
(BIOFEEDBACK MEASUREMENT CIRCUIT)

INTRODUCTION:

Perhaps heart rate monitors are the most interesting type of biofeedback circuit for experimenting. There are numerous ways for detecting the heartbeat, but there are two normal electronic approaches to the problem. One of them is to use a photoelectric system. Because we use a light sensor of the type shown in Fig. 1, this method is known as photo-plethysmography.

The theory is very simple. With a light emitting diode (LED) shining a light beam through the finger tip, and a photocell on the opposite side of the finger then detecting the amount of light passing through, the heart rate can be measured. The blood-flow in the capillary bed of the finger causes variations in the amount of light received by the photocell, and these result in small changes in the resistance of the photocell. With suitable circuitry these resistance changes can be converted to small voltage pulses and then amplified to give a usable signal level.

In practice things are not quite as straightforward as this, and there are problems with such a simple set up. The first problem is getting a strong enough light source to transmit a significant amount of light through the finger-tip. Ultra-bright LEDs are now available and seem to give good results if they are operated at a reasonably high current. The main problem is that of getting consistent results, that is to produce a sensor that will operate reliably for a reasonable period of time. The first requirement is some form of finger rest to help keep the user's finger perfectly still, as any slight movement here can produce signals that are far stronger than those generated by the hearbeat. It is also important to have the smallest possible gap between the LED and the photocell, and this means a separation of only about 15 millimeters. The gap must not be so small that the finger-tip is wedged in place, as this would almost certainly prevent the unit from work at all. It is also important that the LED, photocell, and finger rest are all firmly fixed together so that these do not move significantly relative to one another. Finally, the light level received by the photocell is not likely to be very high, and as far as possible should be shielded from any ambient light.

As far as the circuit is concerned, basically all that is needed is an amplifier and a Schmitt Trigger circuit. Fig. 2 shows a suitable circuit diagram. PCC1 is the photocell and this is a CdS type. This is almost certainly the best type of cell for this application where a fast response time is not needed, but good sensitivity is a decided asset. D1 is the light source, and this must be an ultra-bright type if the unit is to operate well. IN FACT THE CIRCUITS IS UNLIKELY TO WORK AT ALL SUING AN ORDINARY LED IN THE D1 POSITION. The amplifier is a two stage type which has IC1 as an inverting amplifier and IC2 as a non-inverting type. The bandwidth is limited to only few Hz by the inclusion of C5 and C6, and this helps to give a low noise level while not attenuating any signal frequencies. BEAR IN MIND THAT THE HEART-RATE IS AT A FREQUENCY THAT WILL NORMALLY BE LITTLE MORE THAN 1 Hz. IC2b operates as a Schmitt Trigger which provides output pulses at the monitored heart rate. D2 flashes in sympathy with the user's heartbeat, but obviously the output pulses at pin 7 of IC2b can be fed to a pulse counter of some kind if preferred.

EXPERIMENTAL WORK:

Perform the experiment. Write a brief report including your observations. Comment, on the results obtained. Show how the performance of the circuit can be improved.

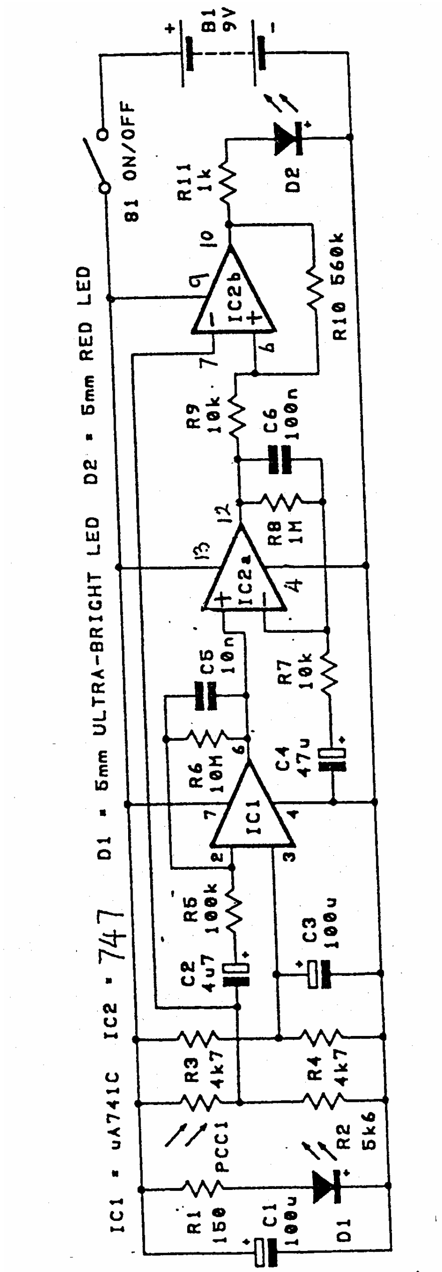


Fig.1: Heart Measurement Circuit

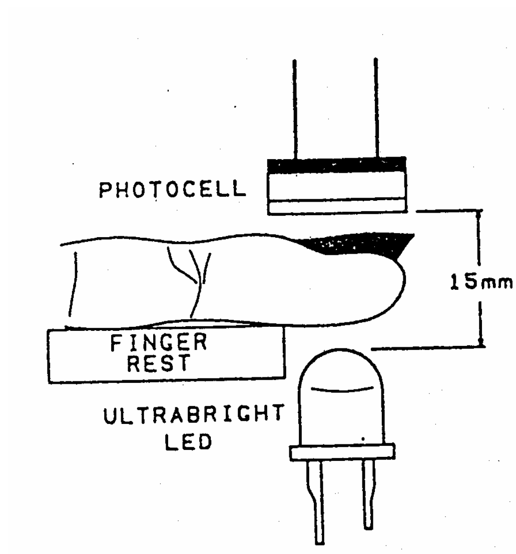


Fig.2: Schematic Diagram

Experiment # 4

OPTICAL LINK

INTRODUCTION:

From your lecture notes you know that optoelectronic devices are widely used in many industrial applications. One of these application is information transmission between distant points. This information can be in a digital or analog form. The major intention of this experiment is to investigate the design and operation of a simple optical link. It is assumed that the data to be transmitted is in an analog form, for example the output of a transducer, say a microphone. The output voltage of the microphone will be converted into current which, in turn, will be converted into light. This light can be visible or infrared. This depends on the type of LED used. The light will be transmitted via the link which can be a fiber cable or simply the air. At the receiving end the light will be converted into current which, in turn, will be converted into voltage. This voltage will be used to derive a trans ducer, say a loudspeaker. The complete circuit which have been discussed in the lecture is shown in Fig. 1.

THE TRANSMITTER:

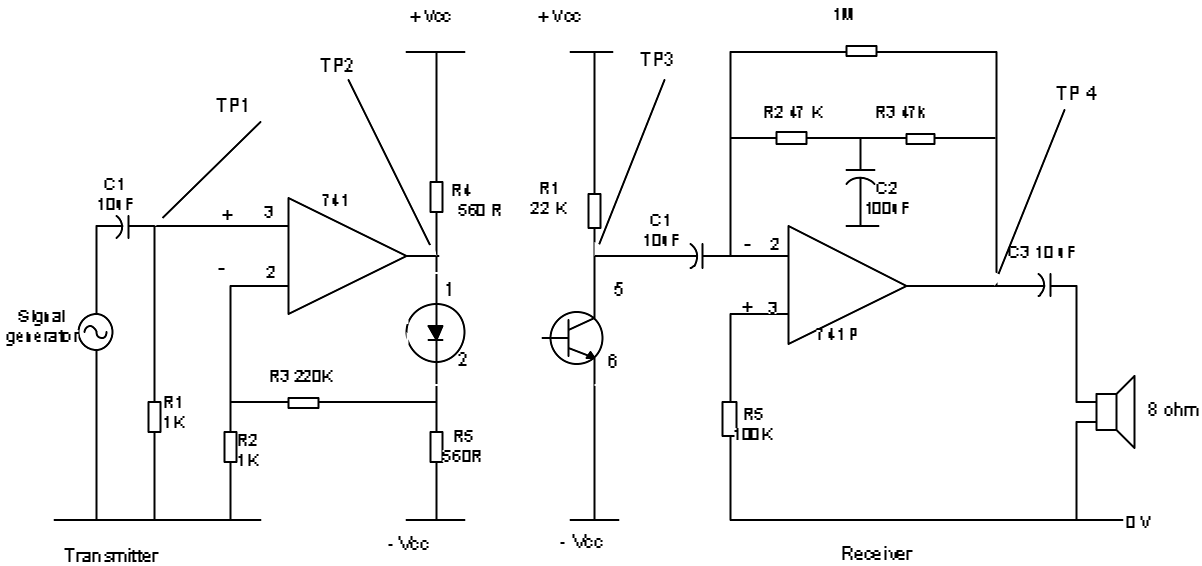
This is essentially a voltage-to-current transducer, changing the voltage changes at the input to current changes through the infrared LED. The LED is the sender of an optical coupler.

THE RECEIVER:

This is essentially a current to voltage converter. The capacitor C_1 blocks DC, so only AC changes are amplified by the amplifier built around the 741. The resistor R_4 sets the gain, with the resistors R_2,R_3 and the capacitor C_3 maintaining DC bias (the high value of R_4 would lead to unacceptably large offsets due to leakage currents on its own). C_2 ensures that the AC gain is unaffected. Obtain an expression for transfer function of the transmitter circuit between the collector of the phototransistor and the output of the operational amplifier. What is the function performed by this circuit? Do you know why the resistor R_5?

In the laboratory an optical coupler will be used. Thus there is no possible interference from the surrounding light. But if the light is transmitted through the air then it is necessary to place the LED and the phototransistor at the focus of parabolic mirrors. A hand torch can be a useful case for building the circuit in as a parabolic mirror is already available. Glass lenses should be discarded as glass blocks infrared. For maximum sensitivity, a Wrattan 88A filter should be used in front of the phototransistor. This blocks visible light, but passes infrared without attenuation.

YOU ARE REQUESTED TO CONSTRUCT THE CIRCUIT SHOWN IN AND TO TEST IT AT THE DIFFERENT TEST POINTS SHOWN. MAKE SURE THAT THE CIRCUIT WORKS PROPERLY AND TRY TO FIND THE MAXIMUM WORKING FREQUENCY OF THE CIRCUIT. WHAT MEASURES CAN BE TAKEN IN ORDER TO EXTEND THE WORKING FREQUENCY RANGE OF THIS OPTICAL LINK!


+Vcc
+Vcc
1M
TP2
TP3
TP1
R2 47 K
R3 47k
TP 4
C1
741
R4
560 R
R1
22 K
C2
C1
C3
Signal
generator
R3 220K
R1
1K
R2
1K
R5
560R
R5
100K
741 P
8 ohm
0 V
Transmitter
- Vcc
- Vcc
Receiver

Experiment #5

ULTRASONIC REMOTE CONTROL SYSTEM

INTRODUCTION:

Low frequencies in the range 20-100 KHz can not be heard by human being. Therefore, they are described as ultrasonic. They propagate in the air at a much lower speed than light. This property can be used to advantage in many industrial applications. For example the measurements of the change of the propagation time of an ultrasonic wave in a solid or liquid medium can help it detecting variations in the thickness or the density of the medium. Ultrasonic systems are, therefore, widely used in industry for monitoring and/or measuring thickness and density. By the same principle, they can be used in detecting cavities and inclusions in castings, abrupt variations in composition of alkloys and many other similar applications. Ultrasonic systems can be also used in constructing home security systems as well as in remote control of TV sets or toys.

TRANSMITTER CIRCUIT:

From your lecture notes you know that an ultrasonic transmitting unit is no more than a crystal of a piezoelectric material sandwiched between two metal plates; see Fig. 1. The same crystal can be used for receiving ultrasonic transmissions. This is attributed to the characteristics of the crystal which converts mechanical vibrations into electrical voltages and vice versa. In an electronic transmitting circuit the crystal electrical equivalent circuit is a parallel resonance circuit. Thus in an LC sinusoidal oscillator circuit rather than using discrete capacitors and inductors a crystal can be used. The frequency of oscillation will be decided by the crystal resonance frequency. If oscillations are successfully generated an alternating voltage will appear across the terminals of the crystal. This, in turn, will result in crystal vibrations and consequently air vibrations. This establishes an ultrasonic wave. This is the idea of an ultrasonic transmitter. Note that the crystal is used to generate the alternating voltage and also to initiate air vibrations. Fig. 2 shows a possible ultrasonic transmitter circuit based on this idea. Other possible ways of thinking are also possible. Try to develop an alternative ultrasonic transmitter circuit.

RECEIVER CIRCUIT:

If the path between the transmitter and the receiver is clear, the ultrasonic emission from the sending end is received and detected by the receiver which converts the air vibrations hitting the crystal into electrical signal. Otherwise, if the path between the transmitter and the receiver is not clear, the ultrasonic wave is blocked and the receiver detects nothing. Usually a detected signal is too small and, thus, required voltage amplification. This can be achieved using a voltage amplifier. The output of the amplifier is expected to operate a transducer which may convert the electrical signal into sound, light, or any appropriate output for further processing. A possible ultrasonic receiver is shown in Fig. 3. The circuit is very similar to the one discussed in the lecture except that a LED now replaces the relay coil.

EXPERIMENTAL WORK:

During the experiment you are requested to construct the circuits shown in Figs. 2 and 3. Check the operation of the transistors under DC conditions. Make sure that this agrees with your theoretical hand calculations. Then check the waveforms at the testing points given. Verify the operation of the circuit and find the useful range of its operation. Try to think what measures can be taken to increase its useful operating range. Submit a report including your findings.

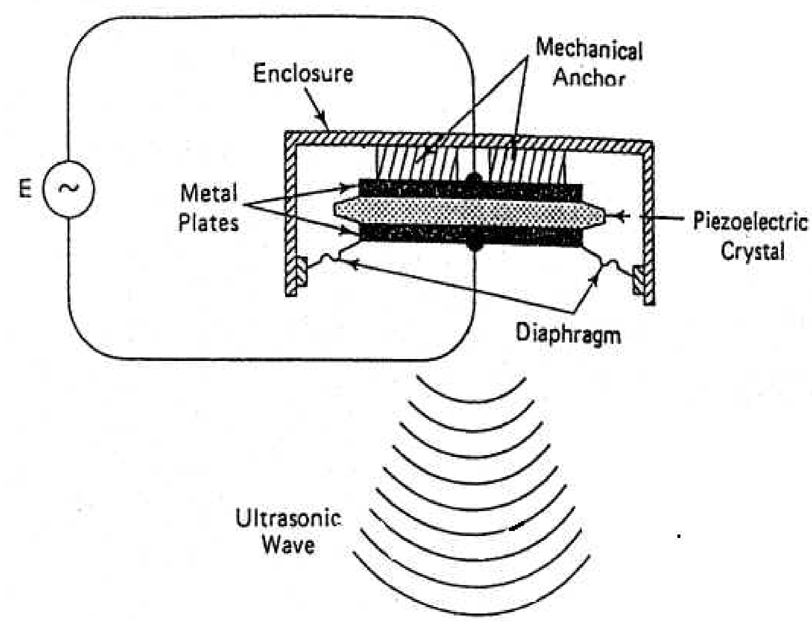


Fig.1: Ultrasound Transmission (Schematic Diagram)

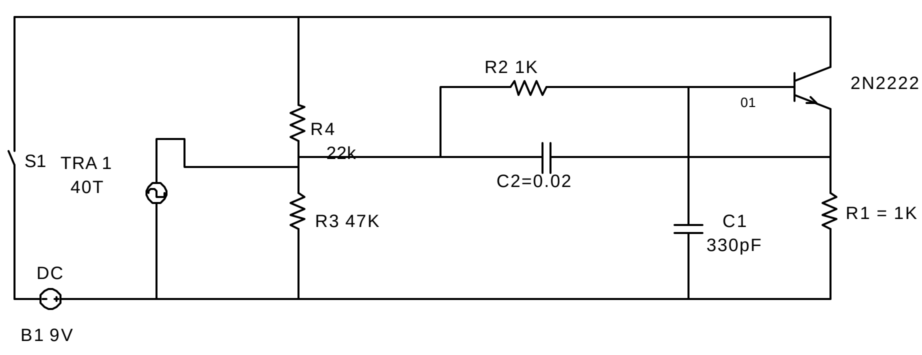


Fig 2: Ultrasound Transmission (Circuit Diagram)

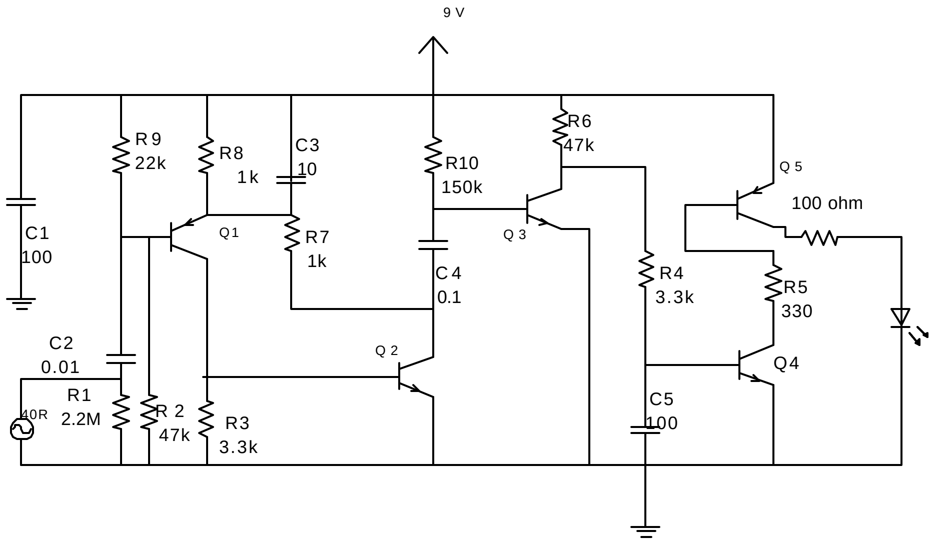


Fig 3: Ultrasound Receiver Circuit

Experiment # 6

FERROUS MOTION SENSORS

INTRODUCTION:

Ferrous motion sensors have many important industrial applications. As the title reveals only ferrous metal items that actually move can be sensed. A large metal object of the size of an automobile can be sensed several meters from the sensor and could be used with an electronic counter to find the total number of vehicles passing a given point. This may be used by traffic authorities to estimate how busy is a junction or a roundabout. The sensor can be placed near a conveyor to count the number of ferrous items passing by, or to initiate a relay operation to stop the conveyor or to flash a warning light. The sensor can be used to detect nails, wire, and other ferrous metal objects that could damage an expensive saw blade moving through the sensor. A special version of the sensor large enough to encircle a doorway could be used as a weapon detector. This can be used by security authorities in airports. Obviously there is a wide range of applications for this sensor.

CIRCUIT OPERATION:

Fig. 1 shows the circuit of a ferrous motion sensor. The idea is very simple. A ferrous object moving near a coil carrying a DC current (do you know how the coil gets its DC current? Think about it) will disturb the magnetic field produced by the coil. This will result in an induced voltage in the coil windings. This small voltage signal is fed to a high gain amplifier. The signal is boosted over 200 times with the first amplifier, and its output is connected to the circuit gain control, R_5. The second amplifier boosts the signal over 400 times and the output is connected to the input of the third amplifier where the signal is increased even more by a gain factor of 100 times. The theoretical gain of the three amplifiers is a staggering 8000000 times.

If the amplifiers were connected in a standard audio amplifier configuration, the circuit would go into oscillation due to the high gain and would not be useful, but with the addition of capacitors C_2, C_3 and C_5 the frequency response of the three-stage amplifier is **reduced to near DC** (try to obtain an expression for this frequency response and see how low is the high frequency poles). The ultra-low frequency response also helps reduce the possibility of interference from the 60 Hz line frequency.

When a ferrous object passes by the ferrite pickup loop a small magnetic signal is detected and boosted by the three-stage amplifier as a low frequency **pulse**. The 0-1 milliammeter reads about one-half scale without any input signal (do you know why is this?), but can drop nearly to zero or rise to full scale as an object passes the pickup loop. Also, the LED will flicker off and on as the object passes the loop. Power for the circuit is supplied by a 9-volt transistor battery

BUILDING THE MOTION SENSOR:

If the pickup loop is to be located at a distance from the main circuit, use a shielded lead in connecting the loop to the circuit (why?). In the laboratory we will use a readymade ferrite core loop. For your interest a procedure to construct a loop is given here. Remember that the loop can be so big to allow a person to pass through it. To construct you own loop, place two rubber grommets on a ferrite rod as shown in Fig. 2, spaced 2 ¼ inches apart (about 5 cm). Approximately 120 meters of number 37 enameled copper wire is wound on the ferrite rod between the two grommets. This is about 3000 turns, but the actual number is not very important. A coil would with only one half the number of turns, or one with twice the turns would work out all right, so do not waste too much time trying to determine the actual number of turns when winding the pickup coil.

A fast way to wind the coil is to place the ferrite rod material in the chuck of a variable-speed hand drill and mount the wire spool where it can turn freely. Start the drill at slow speed condition and slowly increase the speed while winding the coil. Even though the coil is jumble-wound try to keep it neat and as evenly spaced on the rod as possible.

EXPERIMENTAL WORK:

Any twisted two-wire cable can be used to connect the pickup to the circuit, but if a long run is needed use a shielded two-wire cable and connect the shield to the battery negative of the circuit.

Place the pickup in a fixed position and turn S_1 on. The meter should read about one-half scale after the circuit becomes stable. The stabilizing time should be no more than a few seconds for the three amplifiers, even with the gain set to its maximum. A good test for the ferrous motion sensor is to take a small, permanent magnet and wave it back and forth in front of either end of pickup loop. Any other ferrous material can do the job. The meter and LED should respond in a “bang-bang” action. Keep moving the magnet back and forth while slowly moving away from the pickup. The motion sensor should still see the magnet’s field one or more meter away from the pickup coil (in our laboratory this will be about few centimeters because of the pickup coil used). All other ferrous metals will cause a similar effect, but any item that is **magnetic** will produce the greatest effect on the detector.

If the detector fails to operate, check the DC voltage at the output pins of the three operational amplifiers. All three pins should read about the same voltage, and will be closed to ½ the battery voltage (why?). Another item to check is the resistance of the pickup coil. The resistance should be between 150 and 250 ohms. The coil is the most likely place for a broken or poorly soldered wire, so check it out carefully. Also, do not let the coil drop or hit a hard surface, as the ferrite rod material will break if mishandled.

QUESTION:

The motion sensor described and tested can sense only moving ferrous materials. Can you think of a motion sensor for moving nonferrous materials? Please report your idea directly to me.

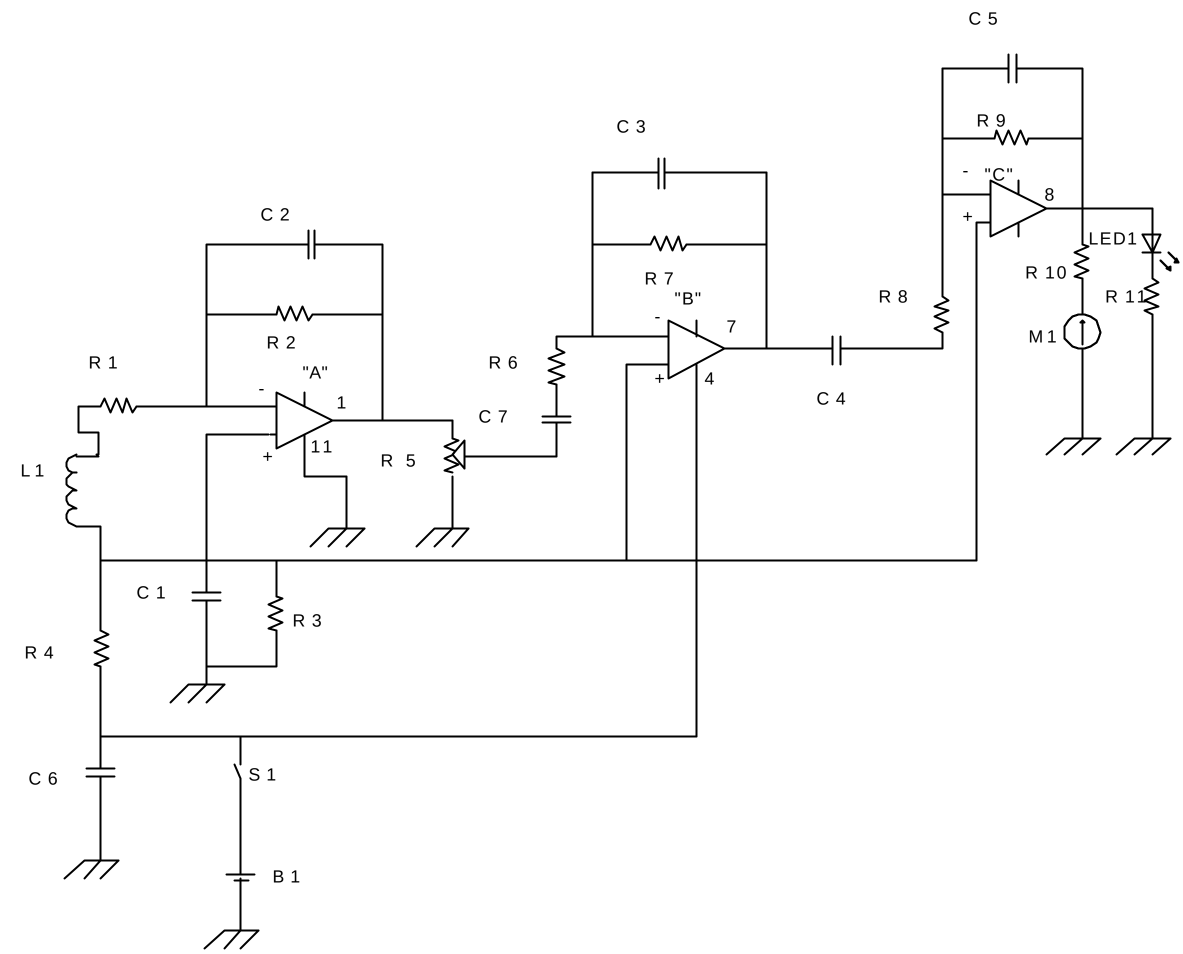


Fig.1: Ferrous Motion Sensor Circuit Diagram (A,B,C : 741 OA)

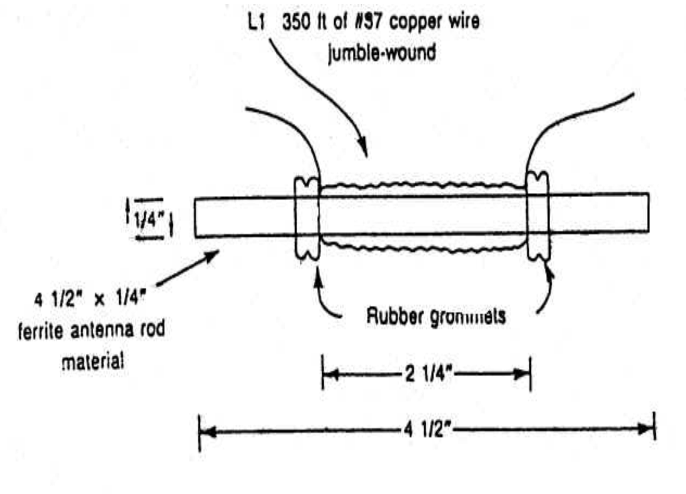


Fig.2: Motion Sensor Schematic Diagram

Experiment # 7

INSTRUMENTATION AMPLIFIERS

INTRODUCTION:

Instrumentation amplifiers are the correct choice for a large number of industrial problems where a very small signal (differential input) must be amplified in the presence of large amounts of noise or background (common-mode input) voltage.

Upon completion of this experiment you will be able to:

1. measure the differential gain for a basic differential amplifier.
2. measure the common-mode gain and calculate the CMRR for a basic differential amplifier.
3. build and test a discrete three op amp instrumentation amplifier.
4. add an offset voltage to the reference terminal of the instrumentation amplifier.

EXPERIMENTAL WORK:

Part 1: Construct the circuit of Fig. 1. Measure V_1 and V_2 with respect to the ground and calculate the differential input voltage to the amplifier. Is there any common mode in this case? If the answer is yes, what is the value of the common mode voltage? Calculate the differential gain of this differential amplifier and use it to estimate the output voltage, V_0, of the amplifier. Measure the output voltage. Does the measured and the calculated values of the output voltage compare favorably? If the answer is no, what may be the sources of error? What changes must be made to change the gain of this amplifier to 100 and then to 1?

Part 2: Modify the circuit of fig. 1 to include a common mode adjustment as shown in Fig. 2. Connect both inputs together to the common mode voltage V_2. Measure V_2. Now monitor the output voltage, V_0, of the differential amplifier using a voltmeter. Adjust the potentiometer until use measure the **smallest** output voltage possible. This output voltage is the common mode output voltage V_{OCM}. This voltage should be approximately 1 mV. Calculate the common-mode voltage gain. Note that the common mode voltage gain is ideally **zero**. The common-mode voltage gain should be a very small quantity. Using the results of part 1, calculate the CMRR. What change can be made in Fig. 2 to improve (increase) the CMRR?

Part 3: The circuit shown in Fig. 3 is a three op amp instrumentation amplifier, with buffered input (A_1 and A_2) added to increase the input impedance. Differential gain is adjusted by the ***m*R** resistor. The output voltage is a single ended voltage V_o and responds only to the differential voltage $V_{diff} = V_1 - V_2$. Now select an ***m*R** resistor equal to 20 $k\Omega$. Calculate the differential gain. Measure V1, V_2 and V_0. Calculate the measured value of differential gain. Do the calculated values of the differential gain compare favorably? If time allows repeat the same procedure for ***m*R** equal to 100 $k\Omega$. If the measured and calculated values of the differential gain do not compare favorably, what measures can be taken to improve the accuracy?

Part 4: Normally the output voltage of a differential amplifier is the product of the differential input voltage times the differential gain. It may be desirable to offset the output voltage V_o by a DC voltage level. For example, when the output of an instrumentation amplifier drives the pen of a chart recorder, it is often convenient to be able to position the pen at a point other than its mechanical zero. Output offsetting can be accomplished as shown in Fig. 4 by applying a DC voltage to reference voltage pin 6. Construct this circuit using a fourth operational amplifier. Adjust the $1\,k\Omega$ potentiometer until V_{ref} equal 0 V. Now measure the output voltage of the differential amplifier. It must be the same value Vo measured in part 4. Adjust V_{ref}, using the potentiometer, to be 3 V. Measure V_o of the differential amplifier. It must be shifted by 3 V from the previous value. Try to give some applications of adding V_{ref} to the output of a differential amplifier.

BY THE END OF THIS EXPERIMENT WE HOPE THAT YOU WILL BE FAMILIAR WITH THE PHYSICAL MEANING OF THE COMMON MODE VOLTAGE, THE CMRR, THREE OP AMP DIFFERENTIAL AMPLIFIER AND OUTPUT OFFSETTING.

Write a report including your measurements and comments.

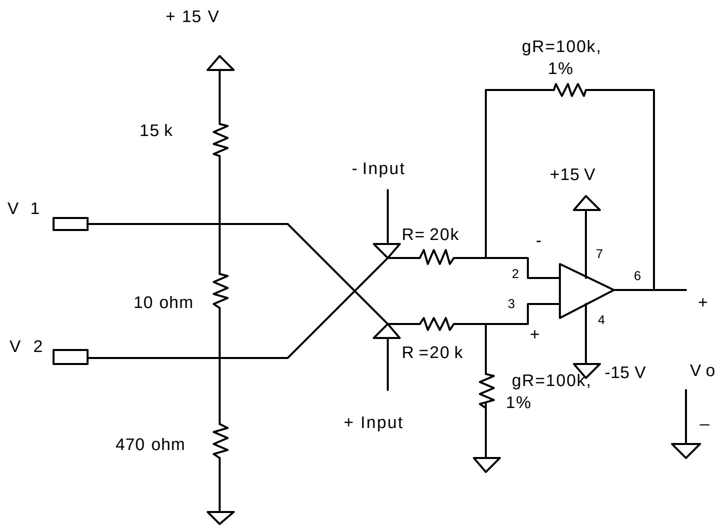


Fig.1: Instrumentation Amplifier with Differential Input

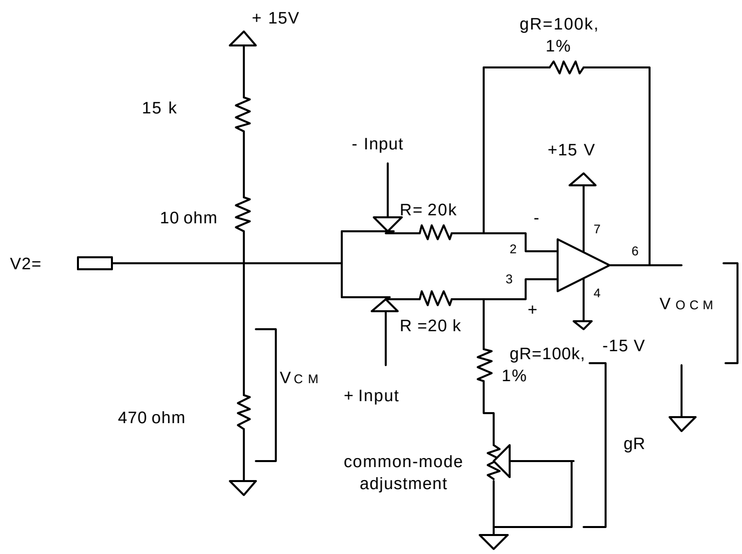


Fig.2: Instrumentation Amplifier with Common Mode Adjustment

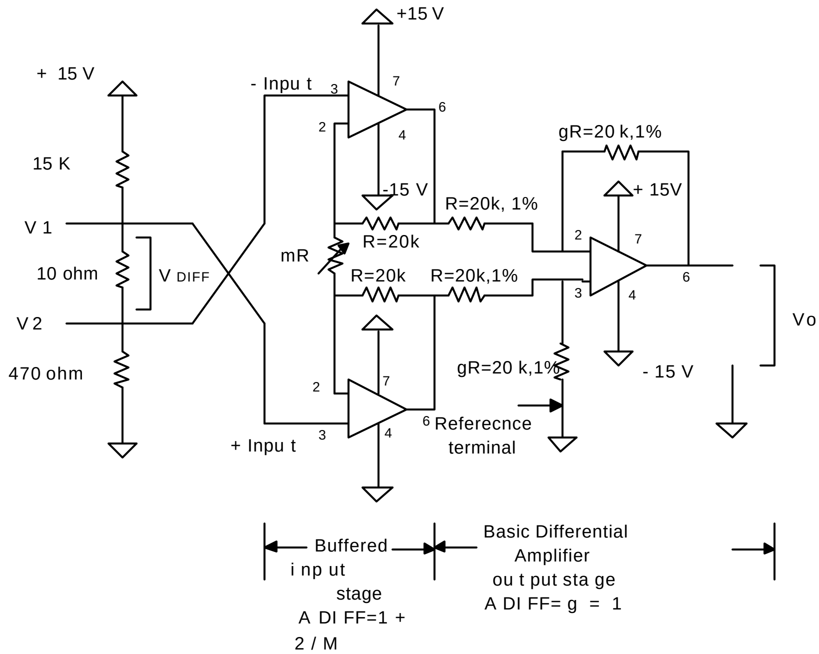


Fig.3: Three Op-Amp Instrumentation Amplifier

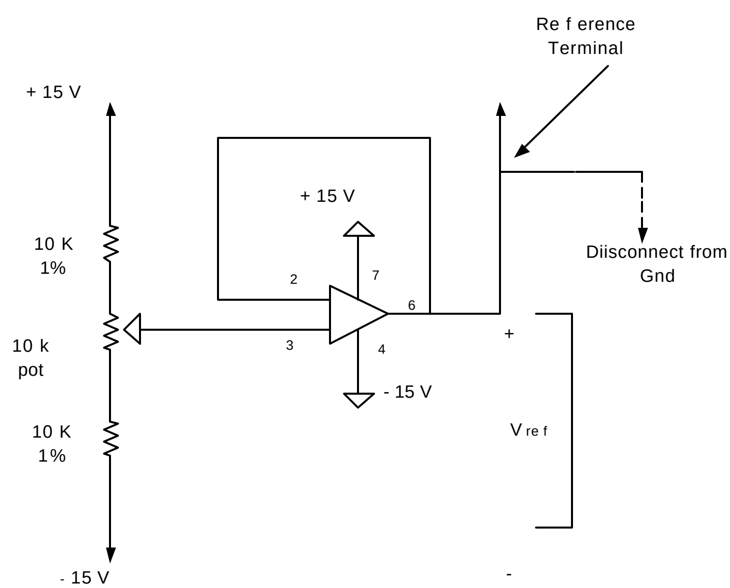


Fig.4: DC Offset Circuit

Experiment # 8

WATER ALERT SYSTEM

INTRODUCTION:

A water alert system is no more than a water-level alarm system, which will prevent expensive water damage at home. Also it relieves you from having to mop up the floor when a bathtub overflows. Moreover, if you have problems with water getting into your basement, you can set up the system to notify you the instant that water seeps in. In general, the system can be used to monitor the water level wherever you like to do so.

THE CIRCUIT:

The circuit is shown in Fig. 1. The circuit can be divided into two parts: an annunciator and a water detector. The water detector shown has both a normal-sensitivity input, which is good for most applications, and a high-gain input. The high gain input can be useful for testing fluids with a very high resistivity, such as very pure water. Furthermore, it may be necessary to use the high-gain input if the 2N3904 NPN transistors have a low gain (below 100). The high-gain input overcomes the problems caused by weak transistors by combining Q1 and Q2 to form a Darlington pair. It is always a good idea to test the effectiveness of both inputs to determine what is needed for a particular application. It is always recommended to use separate probe leads when you decide to use the high gain input; do not use twisted leads. If the gap between the input terminals that you use is bridged by fluid, the slight amount of current that flows through it will be greatly amplified. So Q1 will allow plenty of current to flow to the gate of the SCR to turn it on.

When the SCR turns on, it grounds the annunciator circuit, turning it on. Resistor R6 provides enough current to latch the SCR on when it is triggered. The rest of the circuit is the annunciator which is built around the 555 timer. The 555 timer drives the piezoelectric crystal (BZ) at around 2 KHz to produce an alarming sound that can be easily heard from another room.

EXPERIMENT

Fig. 2 shows a possible construction for the probe which will sense the presence of water. It is made from two metal strips to be mounted to the floor or any surface. In the laboratory we will try to simulate a practical situation say by using a cup of water and immersing the two leads in water to check the operation of the circuit.

YOU ARE REQUESTED TO BUILD THE CIRCUIT, TO CHECK ITS OPERATION AND TO COMMENT ON YOUR OBSERVATIONS.

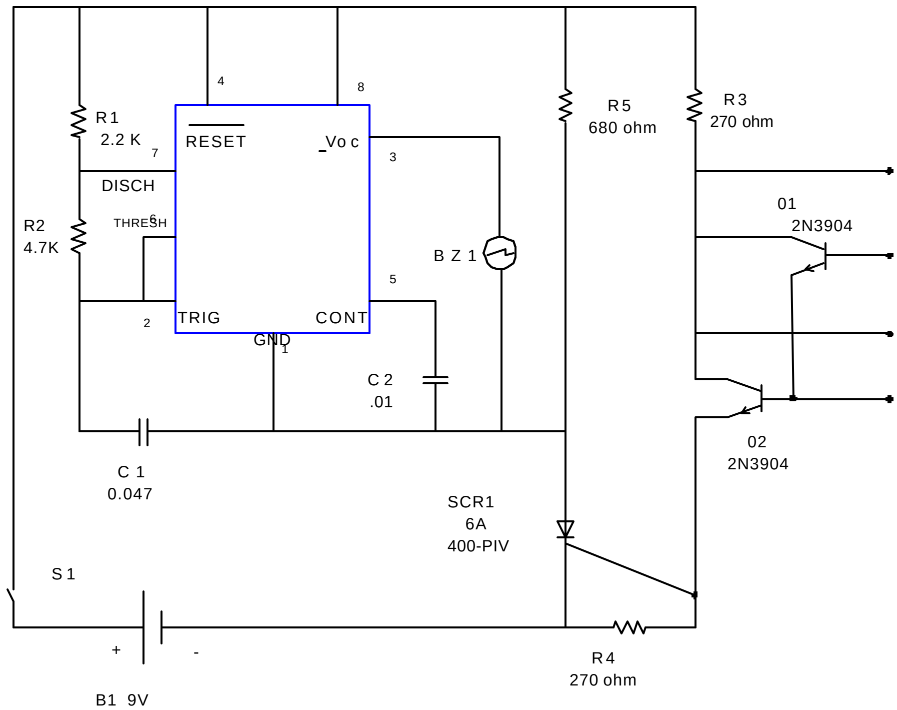


Fig 1: Water Alert System

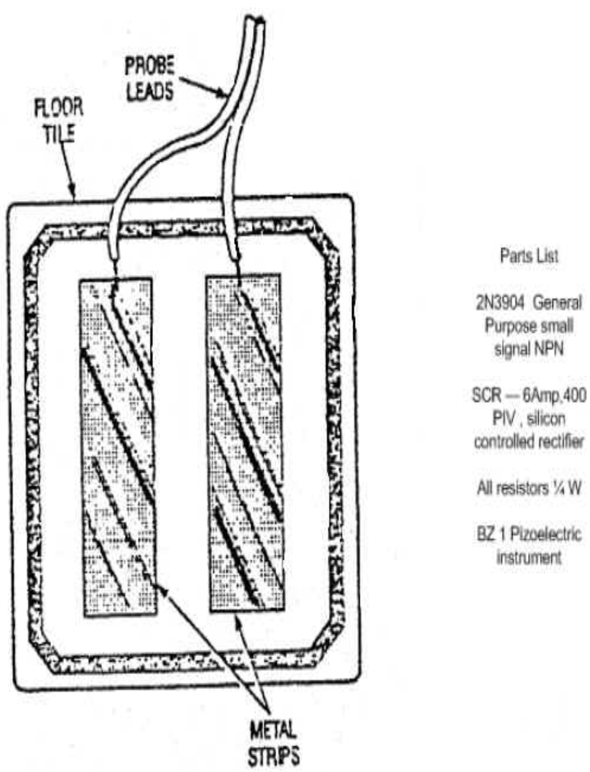


Fig.2: Probe to Sense the Presence of Water

Experiment # 9

LIGHT DIMMERS AND MOTOR SPEED CONTROL

INTRODUCTION:

As their name implies, SCR devices can often be used as controlled rectifiers. For example, the SCR is widely used in a light-dimmer control or for the speed control of simple series motors (such as electric saws and drills). A simple control of this type is shown in Fig. 1. To visualize the effect of this circuit, an analysis of the RC circuit must be considered. If the current of the gate of the SCR is assumed to be quite small, the current through the capacitor is

$$I_c = \frac{V_i}{R_1 + R_2 + 1/jwC} \qquad 1$$

where V_i is the input voltage. The voltage across the capacitor is

$$V_c = \frac{V_i}{1 + jwC(R_1 + R_2)} \qquad 2$$

Note that if $wC(R_1 + R_2) << 1$ then V_c is essentially equal to V_i. In contrast, if $wC(R_1 + R_2) << 1$ then V_c becomes approximately equal to $V_i / jwC(R_1 + R_2)$. This later value of V_c will lag V_i by approximately 90^o and will have a magnitude much less than V_i. Thus, for a given value of ωC, the magnitude and the phase angle of the gate voltage V_c in this analysis can both be adjusted by changing R_1+R_2 (or really just R1) in Fig. 1.

By adjusting the magnitude and the phase angle of the gate voltage, the time when the SCR fires can be controlled. This effect is illustrated in Fig. 2. In Fig. 2(a), the value of $wC(R_1 + R_2) << 1$, so the gate voltage has almost the same magnitude and the same phase as the applied voltage. Since the gate potential exceeds the firing potential very early in the cycle, current flows as if the SCR were a conventional diode. Near the end of the positive half cycle, the anode voltage is reduced to a value less than the hold-voltage of the SCR. The SCR becomes off and the load current drops to zero. However, since the hold voltage is usually much smaller than the amplitude of the input voltage, one can, approximately, assume that the SCR current will drop to zero when the anode voltage drops to zero. During the negative half cycle the voltages then reverse on the anode and gate. (The diode in Fig. 1 protects the gate against the large reverse-bias voltages). With the reverse potentials, almost no current flows through the SCR. As the gate and anode voltages again become positive, the cycle repeats.

In Fig. 2(b), the value of $wC(R + R_2) \cong 1$. Then from equation (2), the gate voltage lags the applied voltage by 45^o. In the case, the gate will not permit the SCR to fire until the voltage across the load and the SCR has progressed 45o through the positive half-cycle. Thus, the current waveform has the shape shown in Fig. 2(b). Notice that the average value of this current waveform is less than the average value of the current waveform shown in Fig. 2(a). Since the power delivered to the load is $I_{rms}^2 R$, the power to the load is reduced as the conduction angle is increased (or as the firing angle is decreased).

In Fig. 2c, the value of $wC(R_1 + R_2) >> 1$. The gate voltage now lags the applied voltage by almost 90^o. In addition, the amplitude of the gate voltage is reduced to such a small magnitude that the gate will not fire until the gate voltage is almost at its peak value. (Note that there is a possibility that the gate will not fire at all if the peak value of the gate voltage is less than the firing voltage). Thus the gate fires when the applied voltage to the load and the SCR has almost reached the end of its positive half cycle. A short pulse of current flows and then ceases as the applied voltage to the load and SCR drops to approximately zero.

DESIGN EXAMPLE:

Let us design a light-dimmer circuit to handle a 100 W light globe. We shall use the circuit shown in Fig. 1. The SCR must be able to handle about 1A (current of the 100 W light) and block at least 185 V (the 120 V line may increase to 130 V with 185 V peak). Since the 2N3562 has a blocking voltage of 200 V and an average anode current of 1A (these data are available in the data sheet), it will be used. Curves of gate-cathode voltage versus gate current (available from manufacturer's data sheet) indicate typical 2N3562 devices have 1.3 V from the gate to cathode when the gate current is 150 mA. If the rms value of 1.3 V and 0.15 A are used, the average power dissipation would seem to be 195 mW. However, since this circuit is a half-wave circuit, the actual average dissipated power is really only 98 mW, which is below the allowable gate dissipation (100 mW as given in the data sheet). Maximum gate current flows when R1 is zero. Then the value of R_2 should limit the gate current to 0.15 A rms. The value of R_2 is 120 V/0.15 A = 800 Ω. To allow an extra safety margin, let us choose R_2=1kΩ.

To provide wide range of control, let us choose $wCR_2 << 1$ when $R_1 = 0$. with R_2=1kΩ, then C<<2.66μ F (notice that $\omega = 2\pi x6$rad/sec). Let us take C = 0.5 μF. Finally we require $wC(R_1 + R_2) >> 1$ when R_1 is fully in the circuit. Simple calculations shows that R_1 25kΩ is a reasonable choice.

The maximum reverse voltage permitted on the gate is 5 V , so the diode shown in Fig. 1 will be required. This diode must be able to withstand the total reverse voltage applied to the circuit as noted by Fig. 2. Thus the diode must have a reverse voltage rating greater than 185 V and must be able to pass a current equal to the maximum gate current (150 mA in this case) when forward biased.

The circuit shown in Fig.1 has one serious limitation. As you know the current will pass through the load only during the positive half cycle. Obviously a possible solution for this problem is to use the triac-based circuit shown in Fig. 3. Since the triac can switch from a blocking to a conducting state for either polarity of applied anode voltage and with either positive or negative gate triggering, the current through the load will have the waveform shown in Fig. 4. In this circuit, the current is controlled from zero to a full conduction value by adjusting R_1 through the proper range.

Most commercial circuits include a diac in the control circuit as shown in Fig. 5. Its function is to provide a sharp trigger pulse to the triac. As the voltage v_c across the capacitor increase from zero, as shown in Fig. 6, the diac will prevent trigger current from flowing to the triac until the voltage on C exceeds the trigger voltage, V_{trg} which is the sum of the diac's trigger voltage V_T, plus the triac's gate voltage, V_{GT}, or

$$V_{trg} = V_T + V_{GT} \qquad (3)$$

The diac will then trigger, dumping almost all the charge on C into the gate of the triac. This sharp pulse reduces the triac's switching time. Thus it runs cooler than would otherwise be the case.

In order to do an exact analysis of the circuit of Fig. 5 the above very nonlinear components require the solution of a rather awkward differential equation. However, since the error introduced is not large, we can assume that steady state impedance relationships apply. Then if we ignore the load placed on the capacitor when the diac fires, the waveform of the voltage across the unloaded capacitor in Fig. 5 would be that of V_{Copen} of Fig 6(a). The actual voltage across the capacitor will be that shown in Fig. 6(b). With these approximations the analysis of the circuit of Fig. 5 will be similar to that of Fig. 1 except that the firing voltage here is equal to the sum of the firing voltage of the diac plus the gate voltage of the triac while for the circuit of Fig. 1 it is equal to the sum of one diode voltage plus the gate voltage of the SCR. A typical turn-on voltage for the 1N5758 diac is 19.6 V and a typical gate trigger voltage for the 2N6152 triac is 3V. Usually manufacturer data sheets gives maximum and minimum values of the diac turn-on voltage. For example for the 1N5758 diac the maximum turn-on voltage is 24 V and the minimum turn-on voltage is 16 V. The typical turn-on voltage can be calculated as the square root of the multiplication of these two limit values. Typical values for gate trigger voltages for SCR ranges from 2.5 V – 3.5 V for the triacs ranges from 3V-3.4 V.

EXPERIMENTAL WORK:

In the laboratory you will construct the circuits shown in Figs. 1 and 5. Check the waveforms at different points in the circuit and make sure that the firing angle is controllable by means of the variable resistor. Subject to availability, replace the load in Fig. 1 and 5 by a 100 W light globe. Check the operation of your light dimmers by means of the variable resistor.

BE CAREFUL YOU ARE DEALING WITH 120 V. BE CAREFUL

WRITE A REPORT SHOWING YOUR RESULTS. COMMENT ON THE PERFORMANCE OF THESE LIGHT DIMMERS.COMMENT ON ANY DISCREPANCIES BETWEEN THEORTETICAL AND PRACTICAL RESULTS

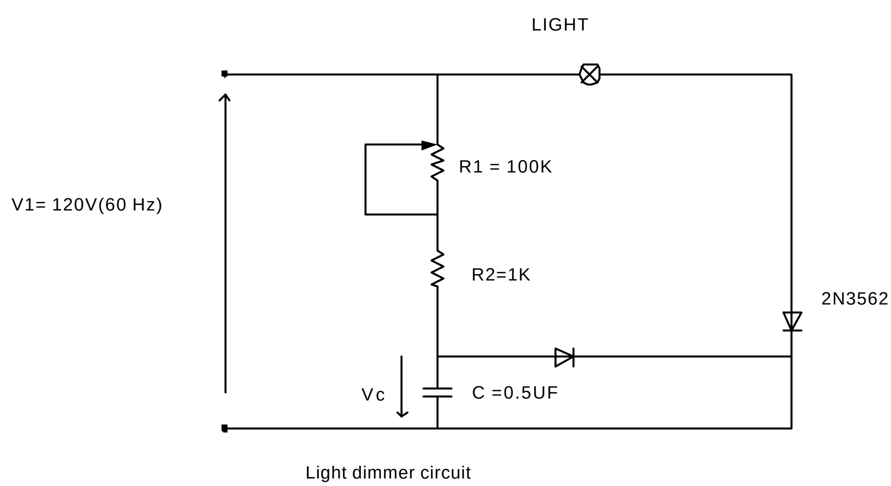


Fig.1: Light Dimmer (or Motor Speed Control) Circuit

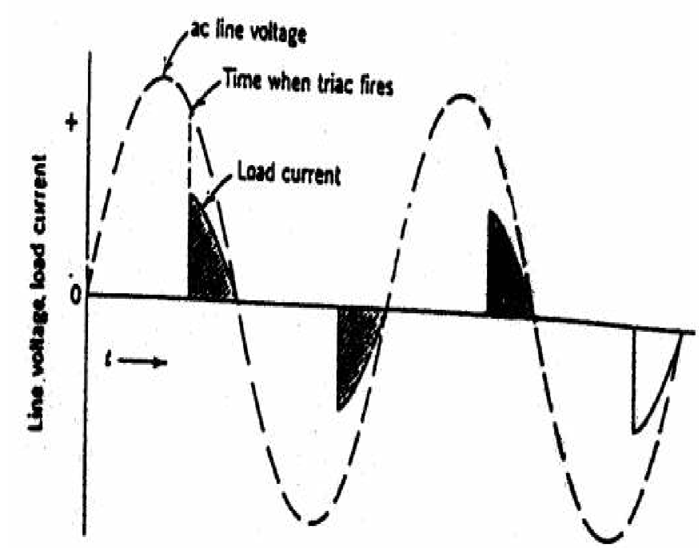


Fig. 4: Voltage and Current Waveform for the Circuit in Fig.3.

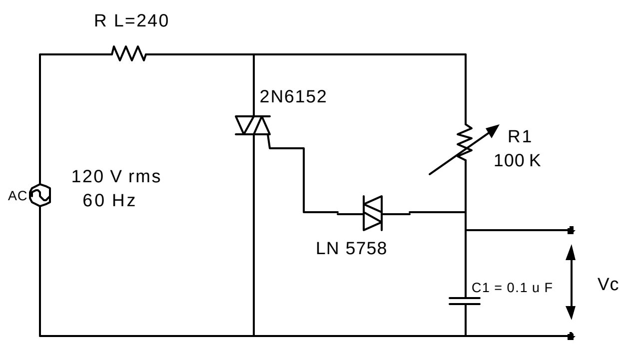


Fig.5: Commercial Dimmer Circuit

(a)

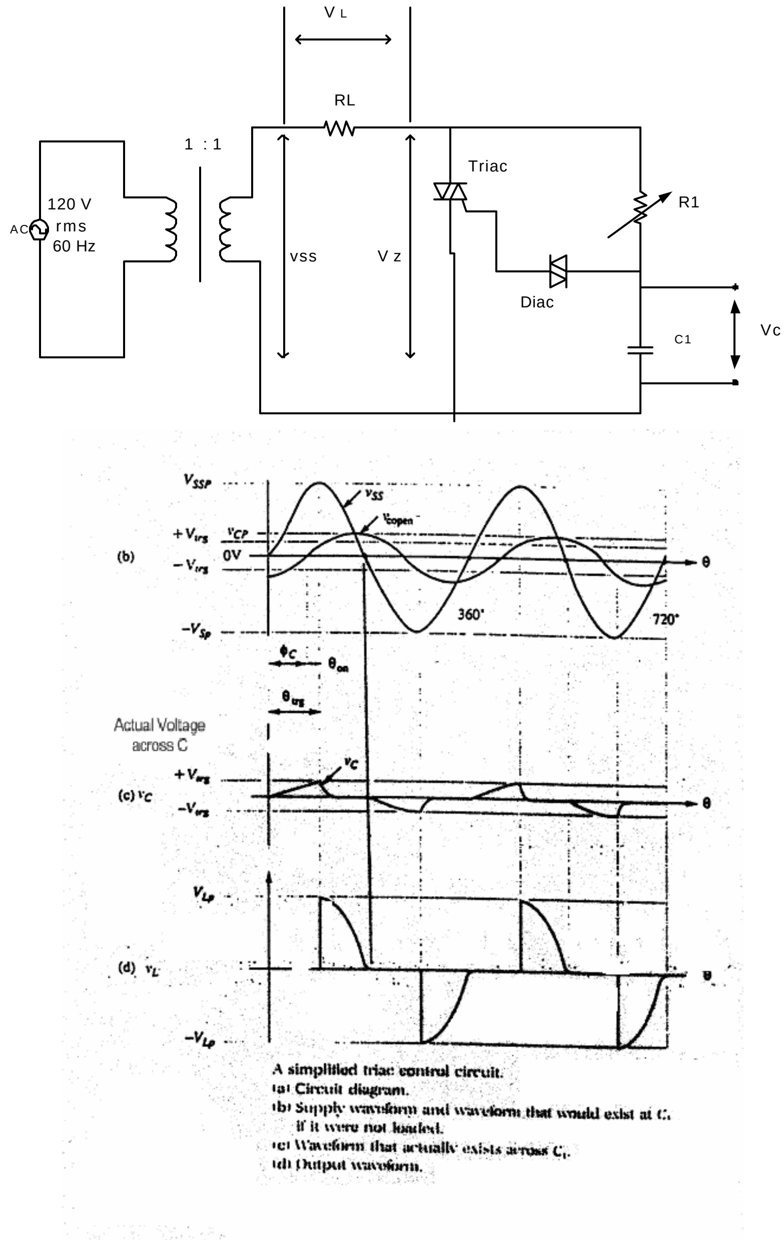


Fig.6: A Simplified Triac Control Circuit and the Corresponding Input and Output Waveforms

Experiment # 10

UJT and SCR RELAXATION and SINUSOIDAL OSCILLATORS

INTRODUCTION:

Though the unijunction transistor (UJT) and the silicon-controlled rectifier (SCR) are commonly used in power control circuits, they can also be advantageously employed in designing simple relaxation (nonsinusoidal) and sinusoidal oscillators using a minimum parts count for a discrete oscillator circuit. Such designs are particularly useful in telephone tone-generator applications, where multiple-sine-wave audio signals are needed for simulating touch-tone frequencies.

Proposed Circuits:

Consider the circuit shown in Fig. 1. Initially the UJT is off and $\mathbf{V}_{BB}$ begins charging C through R. When V_o exceeds V_p as determined by equation (1), the UJT fires very quickly discharging C down to its "on" or saturated value, $V_{EB(sat)}$, where it stays until the emitter current I_E drops below the holding, or "valley" current I_V. Provided the current then flowing through resistor R is less than the valley current I_V for the UJT, it then switches back to its high impedance state and the process repeats.

$$V_P \cong 0.6V + hV_{BB} \qquad (1)$$

The requirement that after C has discharged, the emitter current must be less than I_V if the UJT is to switch back to its high impedance state, places a lower limit on the allowable value of R. Assuming that C is discharged down to $V_E = V_{EB1(sat)}$, then

$$V_{BB} - I_V R = V_{EB1(sat)} \qquad (2)$$

or

$$R_{\min} = \frac{V_{BB} - V_{EB1(sat)}}{I_V} \qquad (3)$$

Since the discharge time is usually negligible, the period of the above oscillation is given by

$$T = -RC * \ln\left(\frac{VBB - VP}{V_{BB} - V_{EB1(sat)}}\right) \qquad (4)$$

As an example, consider the design of a saw-tooth generator using the 2N4948 UJT with the parameters:

$R_{BB} = 12k\Omega \max, h = 0.82 \max, V_{EB1(sat)} = 3.0V \max, I_v = 4.0mA \min$

The minimum voltage to which the capacitor will charge is given by

$$V_P \approx -.6 + hV_{BB}$$

With V_{BB}=15V, then V_P=12.9V

The minimum value to which the capacitor should discharge is given by $V_{EB1(sat)} = 3.0V$. Thus the amplitude of the output waveform should be

$$V_o = V_P - V_{EB1(sat)} = 12.9 - 3 = 9.9V$$

The period of the waveform is given by

$$T = -RC * \ln \frac{V_{BB} - V_P}{V_{BB} - V_{EB1(sat)}}$$

or

$$T = -10k\Omega * 0.1mF * \ln \frac{15V - 12V}{15V - 3V} = 1.64 m\sec$$

It is obvious from this last equation that the smaller R is, the smaller T will be, or the higher the frequency will be. Its minimum value is determined by

$$R_{\min} = \left(V_{BB} - V_{EB1(sat)}\right) / I_v$$

or

$$R_{\min} = \frac{15V - V}{4mA} = 3k\Omega$$

A slight modification in the circuit of Fig. 1 results in the circuit of fig. 2 with R_1 and R_2 added to provide a take-off for the output voltages. Usually, these resistances are of the order of few tens of Ohms and are much smaller than R_{BB}. This will not affect the analysis performed above. Typical output waveforms of the circuit of Fig. 2 are shown in Fig. 3.

By utilizing the current pulses flowing between B_2 and B_1 and modifying the circuit as shown in Fig. 4 a sinusoidal output can be obtained. In fact the current pulse contains a large amount of harmonics. If the tuned circuit is tuned at one of them, then sinusoidal output will be obtained. With adjustments to resistor R (shown as $2k\Omega$ for this example), the current pulses can be controlled so that relatively undistorted sine wave is available at B_2.

Alternatively, a sinusoidal oscillation can be obtained from a UJT by exploiting its negative resistance to advantage. As you know oscillations can not build up in physical LC circuits unless an external source continuously supply energy to compensate for the losses in the internal resistances of physical elements. To help maintain oscillation we have to cancel-out the effect of these internal resistances. Obviously, this requires a negative resistance. Negative resistances are not physically available. However, we can obtain them using devices exhibiting negative-resistance performance in part of their characteristics; for example the UJT. Fig. 5 shows such a circuit in which the UJT negative resistance is used to cancel-out the physical resistances of the coil. The potentiometer sets the peak point of the emitter and should be adjusted for maximum output consistent with a good sine wave. The output is output 200 mV and the circuit operates from 1 kHz to 500 kHz by using suitable values for L and C.

SCRs also can be used for generating oscillations. Consider the circuit shown in Fig. 6. The voltage across the SCR rises until there is sufficient gate current to switch it on. Not that the capacitor will charge from the 15 V supply via the resistor 47 K. The anode resistor is selected so that when the SCR conducts, the current through the SCR will drop below the minimum hold current and thus the SCR will switch off. Note that when the SCR conducts the capacitor will start discharging via the low resistance of the conducting SCR. Eventually the voltage across the SCR will drop to the minimum hold voltage. When this happens the 47 K resistor will ensure that the current through the SCR is less than the hold current. That is

$$\frac{15 - V_{hold\min}}{47K} < I_{holdmin}$$

Once the SCR switched off, a new cycle will start.
<u>Supply voltage and temperature are critical and not every SCR will oscillate.</u>

Alternatively, an improved performance can be obtained by including an inductor, such as a speaker coil, as shown in Fig. 1. The improvement here is achieved because the back e.m.f. of the inductor helps to switch off the SCR. The components in this circuit are not critical and the circuit can work satisfactorily over a wide range of DC supply voltages. Frequencies of oscillation from 100Hz to 10 kHz can be easily obtained.

EXPERIMENTAL WORK:

In the laboratory you will construct the circuits of Figs. 1-7, check their proper operation by checking the waveforms at different points in the circuit. Also check the controllability of the frequency of oscillation and the waveshapes obtainable.

You may like to design your own oscillator. We encourage this. Please do check your own designs during the laboratory hours.

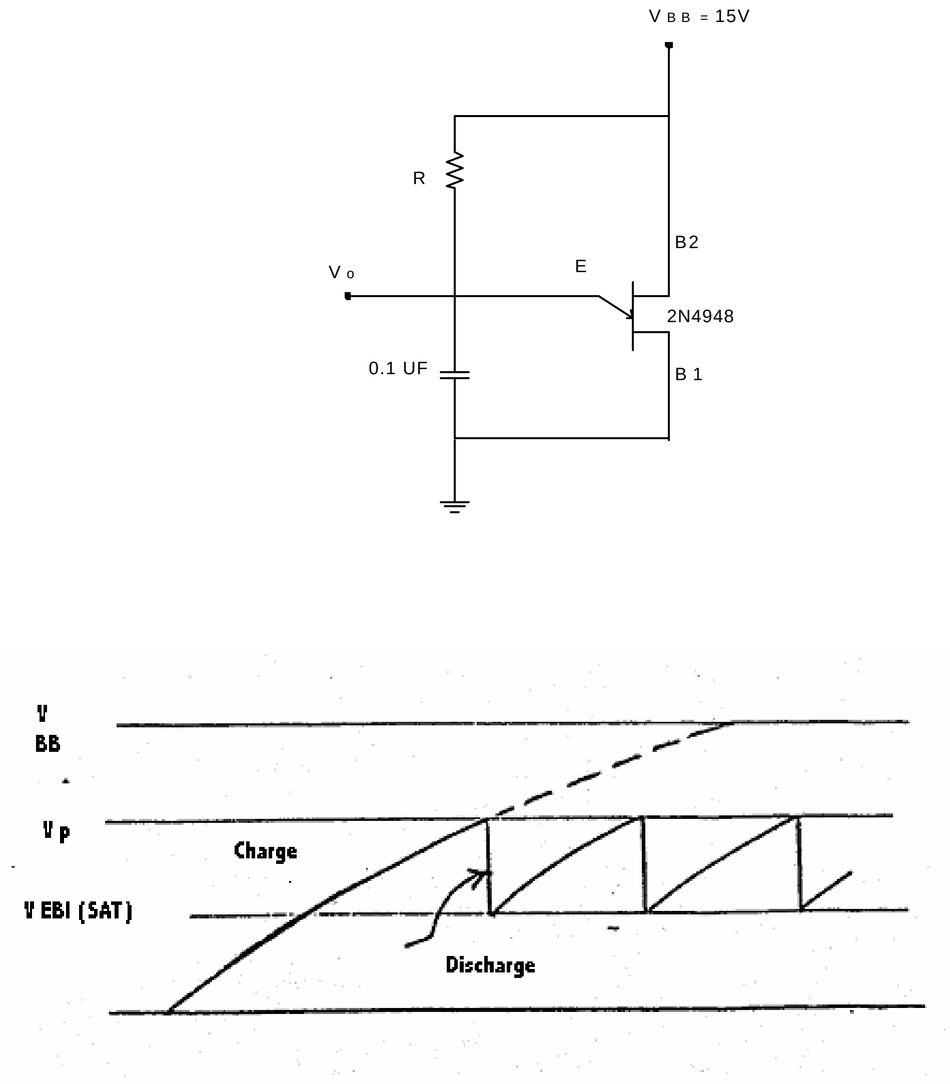


Fig.1: Capacitor Charging Using UJT

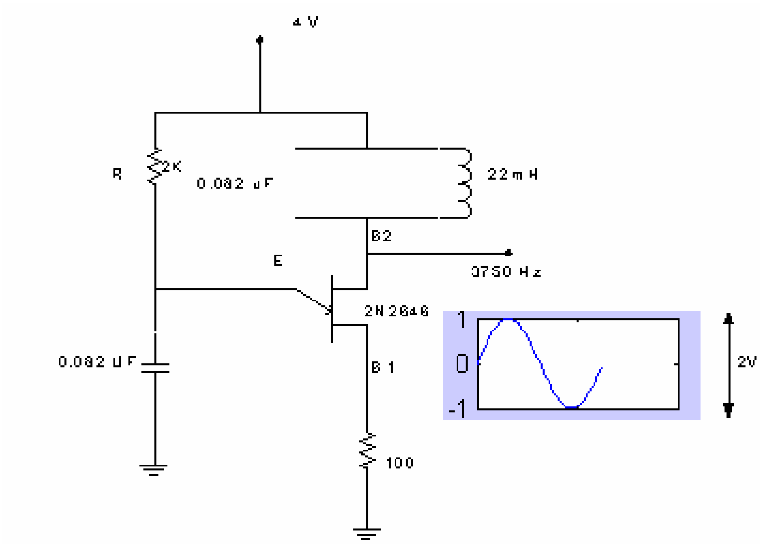


Fig.4: Modified Circuit of Fig.2

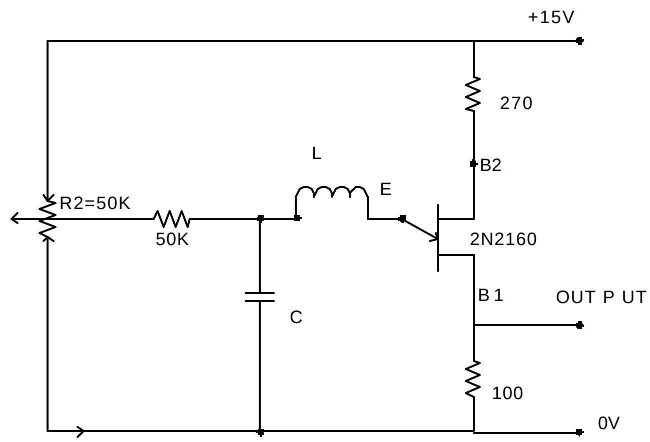


Fig.5: UJT Negative Resistance Used to Cancel-Out the Physical Resistance of the Coil

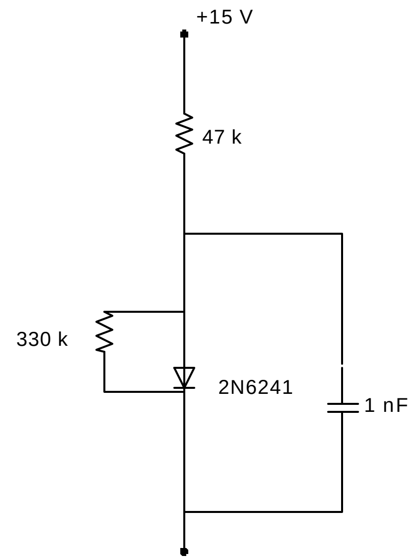


Fig.6: SCR Used for Oscillations Generation

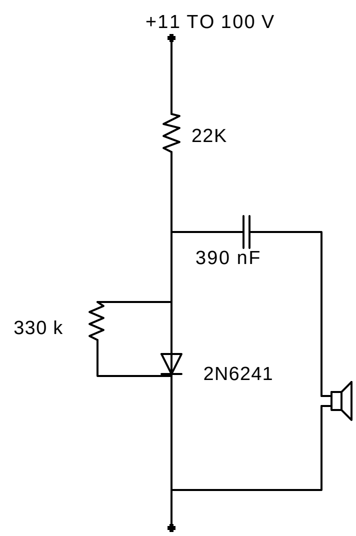


Fig.7: Improved Circuit for Oscillations Generation

Appendix

(LABORATORY REGULATIONS AND SAFETY RULES)

The following Regulations and Safety Rules must be observed in all concerned laboratory location.

1. **It is the duty of all concerned who use any electrical laboratory to take all reasonable steps to safeguard the HEALTH and SAFETY of themselves and all other users and visitors.**
2. **Be sure that all equipment is properly working before using them for laboratory exercises. Any defective equipment must be reported immediately to the Lab. Instructors or Lab. Technical Staff.**
3. **Students are allowed to use only the equipment provided in the experiment manual or equipment used for senior project laboratory.**
4. **Power supply terminals connected to any circuit are only energized with the presence of the Instructor or Lab. Staff.**
5. **Students should keep a safety distance from the circuit breakers, electric circuits or any moving parts during the experiment.**
6. **Avoid any part of your body to be connected to the energized circuit and ground.**
7. **Switch off the equipment and disconnect the power supplies from the circuit before leaving the laboratory.**
8. **Observe cleanliness and proper laboratory house keeping of the equipment and other related accessories.**
9. **Wear the proper clothes and safety gloves or goggles required in working areas that involves fabrications of printed circuit boards, chemicals process control system, antenna communication equipment and laser facility laboratories.**
10. **Double check your circuit connections specifically in handling electrical power machines, AC motors and generators before switching "ON" the power supply.**
11. **Make sure that the last connection to be made in your circuit is the power supply and first thing to be disconnected is also the power supply.**
12. **Equipment should not be removed, transferred to any location without permission from the laboratory staff.**
13. **Software installation in any computer laboratory is not allowed without the permission from the Laboratory Staff.**
14. **Computer games are strictly prohibited in the computer laboratory.**
15. **Students are not allowed to use any equipment without proper orientation and actual hands on equipment operation.**
16. **Smoking and drinking in the laboratory are not permitted.**

All these rules and regulations are necessary precaution in Electrical Laboratory to safeguard the students, laboratory staff, the equipment and other laboratory users.