Skills for Life!

Department of Electrical and Electronics Skills

Jubail Technical Institute
معهد الجبيل التقني

STUDENT HANDBOOK

Electronic Instrumentation

IENX2217

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Prepared by

Industrial Electronics Skills Team

Electronic Instrumentation

IENX 2217

Table of Contents

Unit 1: **The Operational Amplifier**

Lesson 1: Basic Op amp

In this module you will study operational amplifiers (op amps), a special type of amplifier which contains many transistors in an integrated circuit (IC). In addition to amplification the op amp performs many other functions, for example, summing (addition), subtraction, comparison, differentiation, and integration. You will see practical applications of the op amp in a later module when you learn about power supplies.

Operational amplifiers, or op amps, are integrated circuit amplifiers. Like other ICs, op amps contain diodes, transistors, resistors, capacitors, and connecting electrical paths on one small chip. Op amps come in a variety of packages (see Fig 1.1).

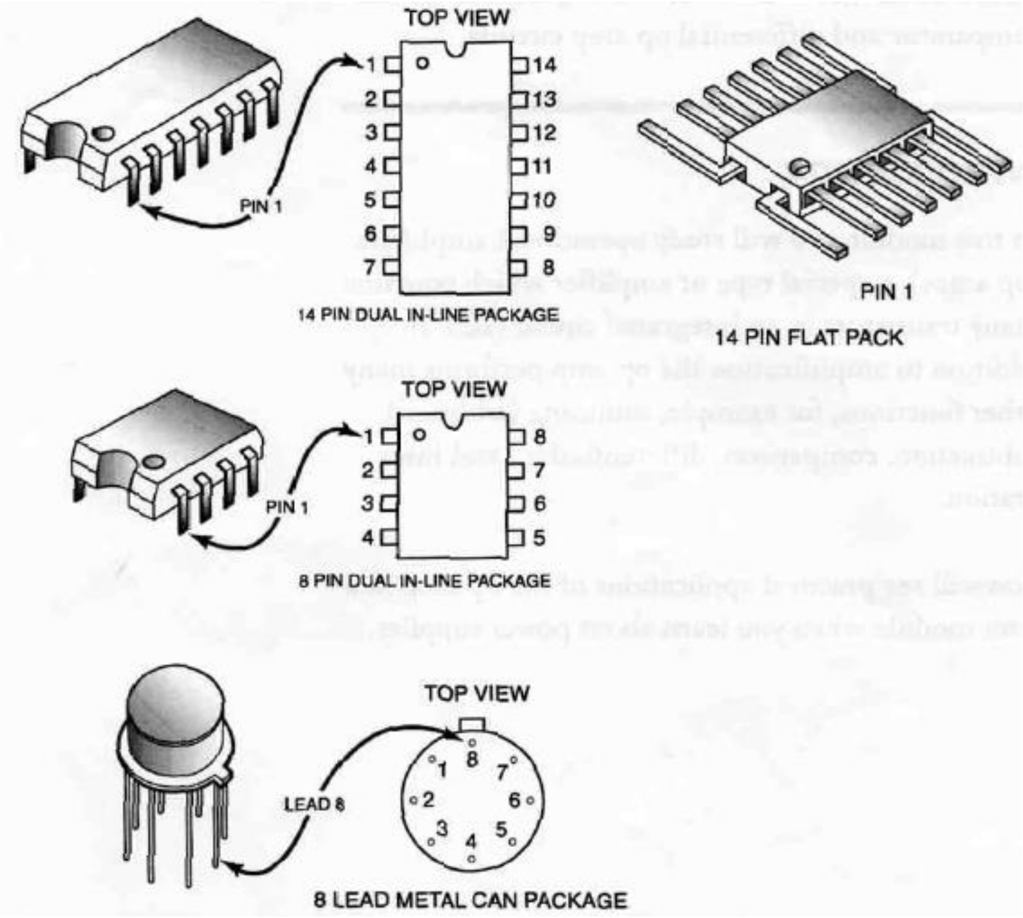


Figure 1.1

Dual In-line Packages (DIPs)

Because op amps come in a variety of packages and have different numbers of pins/leads, it is important to use care when identifying the pins/leads. Like other solid state devices, the pins/leads of an op amp can be identified by comparing the actual op amp with the manufacturer's drawing. Figure 1.1 shows the most common type of op amp packages. Note that the (DIPs) have an indentation and a small dot in one corner which indicates the position of pin 1. The flat pack has a small dot to indicate the position of pin 1. The metal can package has a small tab, the lead nearest to this is lead 8.

Operation of Op amp Circuits

Before we start looking at the actual operational amplifier circuits, we will briefly consider the operational amplifier, or op amp, by itself. Today's op amp is a very high gain DC amplifier that uses external feedback networks to control its response. An op amp has the following characteristics:

- very high gain;
- very high input impedance; and
- very low output impedance

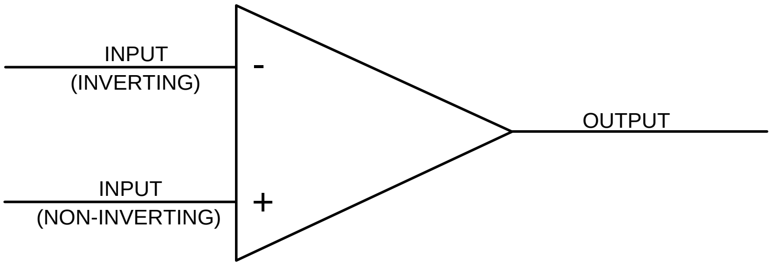


Figure 1.2

The symbol for an op amp does not show the internal circuitry. This is because the circuitry is not accessible. Since there is no way to repair the internal components, an op amp must be replaced when it fails (repair by replacement).
As a general rule, op amps combine two input signals into one output signal. Therefore, as shown in figure 1.2, most op amps have two input terminals and one output. One input terminal is labeled with a minus sign and the other is labeled with a plus sign. The negative input is called the INVERTING INPUT. The positive input is called NONINVERTING INPUT.

The DC supply connections may be included as shown in figure 1.3

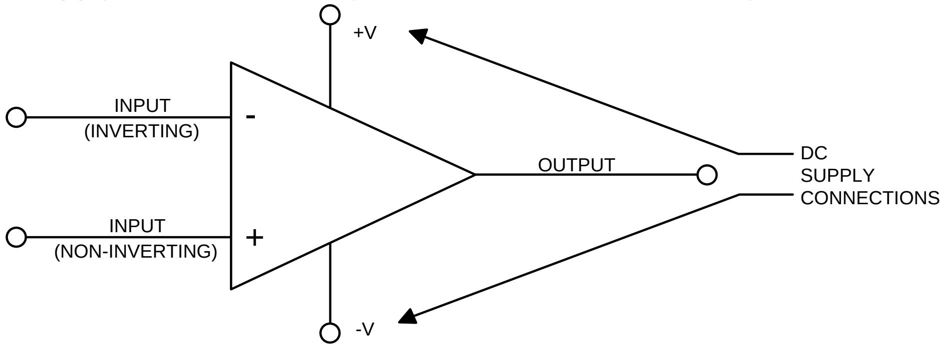


Figure 1.3

The DC supply and offset voltage (sometimes called offset null) connections may be included as shown in Figure 1.3. The op amp is normally energized by a dual polarity power source (equal positive and negative voltages with respect to circuit common), as indicated on the schematic symbols of Figures 1.3 and 1.4. This references the op amp output to circuit common *(zero* with no input signal) and allows the output to swing positively or negatively depending on the input signal.
Some method, such as a potentiometer adjustment (see Fig. 1.4), is provided when necessary for balancing the input differential amplifier for zero DC output with no signal applied. Balancing compensates for voltage errors occurring between the two inputs caused by inherent differences and unequal bias currents between the two halves of the differential amplifier.

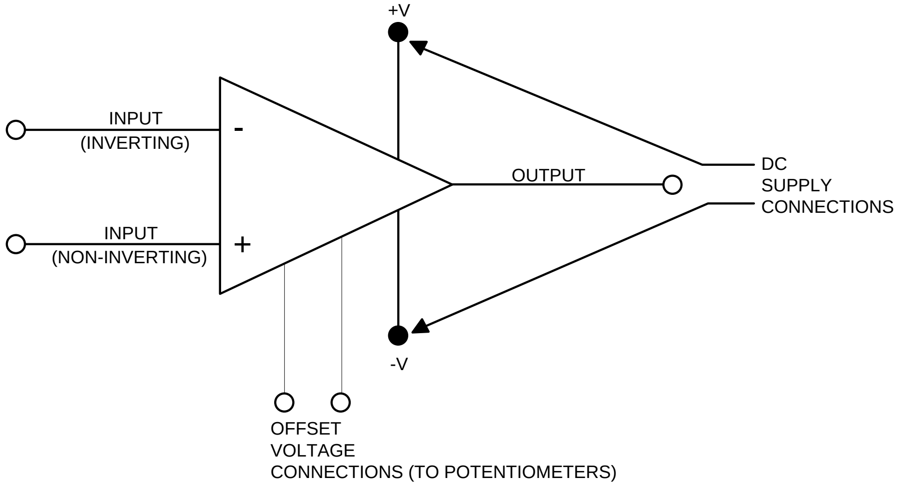


Figure 1.4

This voltage error is referred to as offset voltage; the difference between the two bias currents is known as the input offset current. When these errors are balanced out, the impedance between the two input leads is very high, giving the op amp its characteristically high input impedance.

DC Supply Requirements

Op amps are designed to be powered from a dual voltage supply which is typically in the range of 5 to 18 volts. That is, one supply is + 5 to + 18 volts with respect to ground, and the other supply voltage is - 5 to - 18 volts with respect to ground. See figure 1.5.

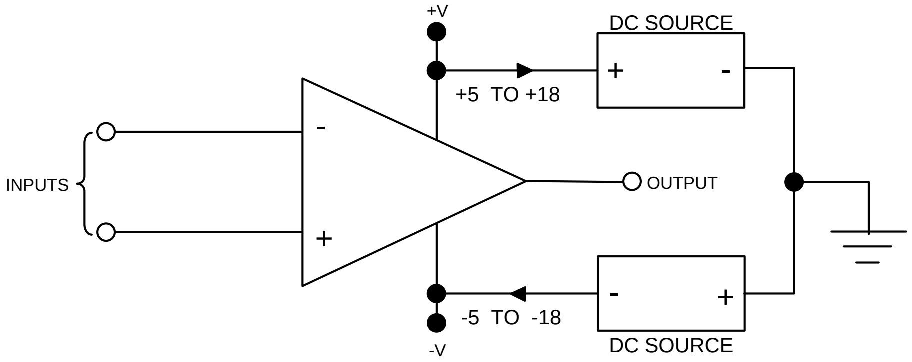


Figure1.5

Operational Amplifier (op-amp) is the most popular analog Integrated Circuit (IC) for wide range of applications, for example:

- Analog signal processing such as signal amplification, filtering and peak detection
- Sensor signal conditioning
- Variety of mathematical operations such as summation, integration and differentiation
- Comparator operation, Analog-to-Digital (ADC) and Digital-to-Analog (DAC) conversions

Symbolic Presentation of Op-amp

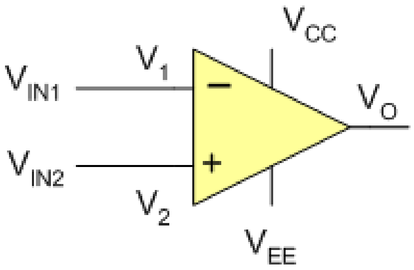


Figure 1.6

Pin Configuration of Op amp.
As shown in figure 1.7

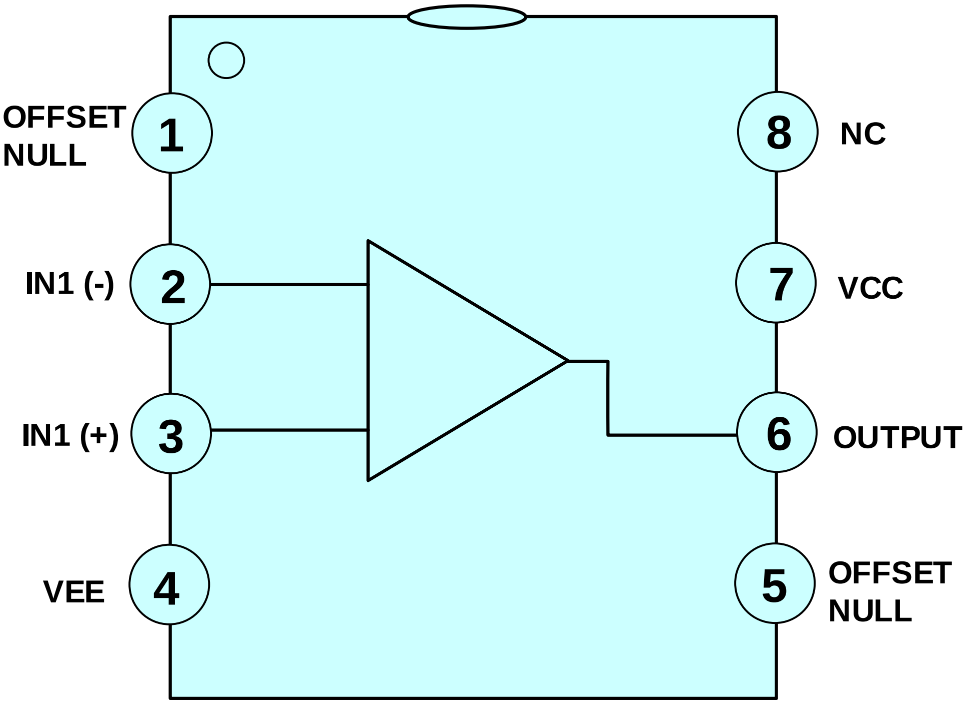


Figure 1.7

Exercise 1: Zero-Crossing Detector

Objective:

To understand the working of a zero crossing detector for AC and DC inputs.

Discussion:

The input signal (AC) is applied to one of the Non-inverting input. The Inverting terminal is connected to reference ground. The input and output are monitored simultaneously on the oscilloscope. A small increase in the voltage at the input results into switching of the operational amplifier output between the positive and negative saturation voltage.

Circuit Diagram:

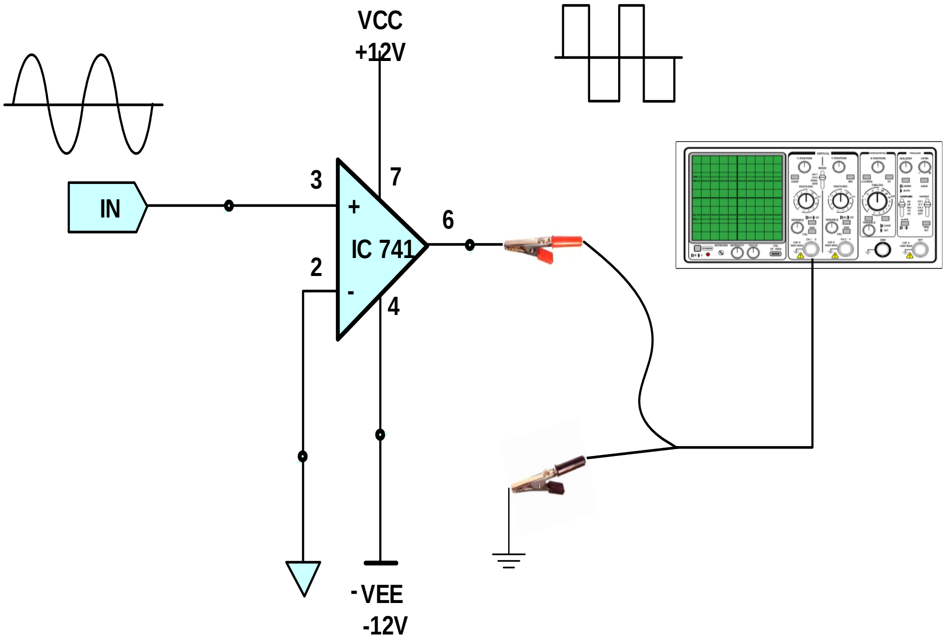


Figure 1.8

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
8.	Set of connection cables	-
9.	Connection plugs (jumpers)	-

Procedure:

As shown in the figure 1.8

1) Connect +12v and -12v to pin 7 and pin 4 respectively.
2) Select sine wave on function generator and connect it to one channel on oscilloscope.
3) Select volts millivolts on the function generator.
4) Connect the output of the opamp (pin 6) to the second channel of the oscilloscope.
5) Slowly increase the input voltage while monitoring the output.
6) At one stage a small increase in the millivolts will result into a square wave at the output.
7) Change the input from Ac to Dc. and repeat steps 5 and 6.
8) Change the polarity of the Dc input and repeat steps 5 and 6.

Observation:

<u>For AC input</u>

Enter the voltage on the inverting input V_{IN} when this switching occurs.

Switching value of V_{IN} = ________________ mV (inverting)

<u>For DC input</u>

Enter the voltage on the non-inverting input V_{IN} when this switching occurs.

Switching value of V_{IN} = __________________mV (inverting)

Enter the voltage on the inverting input V_{IN} when this switching occurs.

Switching value of V_{IN} = ____________________mV (Non- inverting)

Conclusion:
The switching of op-amp positive and negative saturation voltage is verified for

AC volts V_{IN} = _______________ volts

DC volts V_{IN} = _______________ volts (+ve)

V_{IN} = ___________ volts (-ve)

Trouble shooting:

Circuit Diagram.

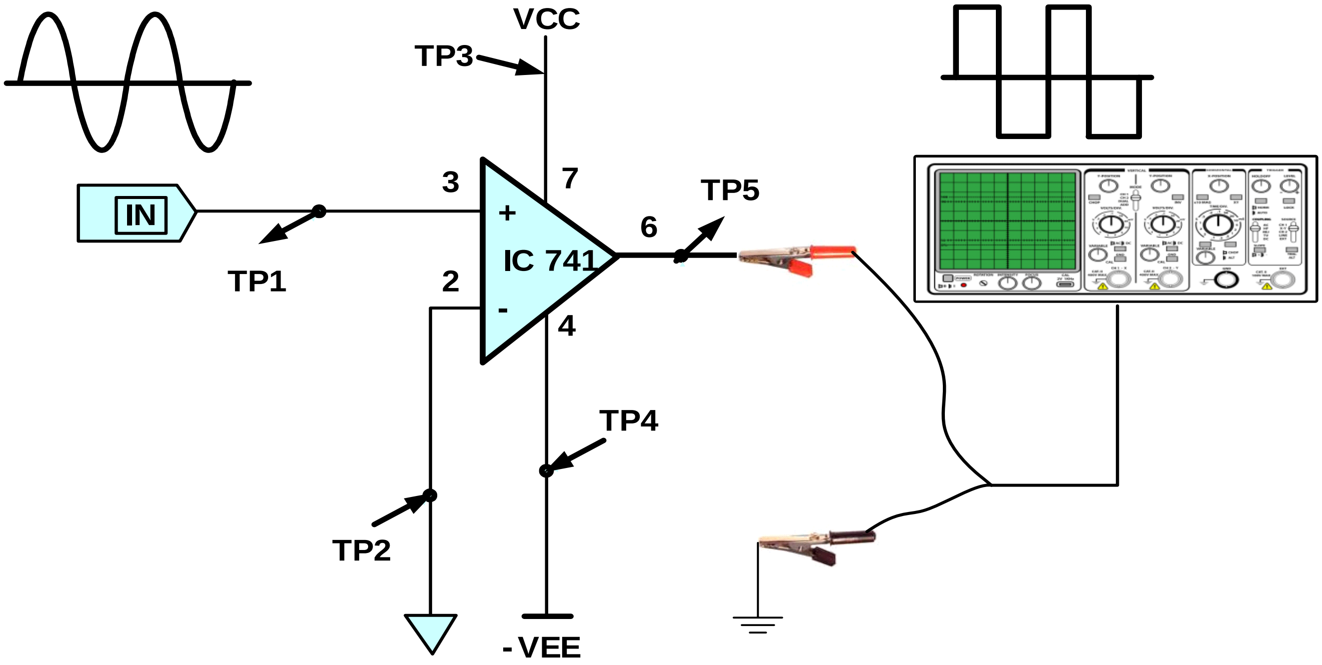


Figure 1.9

Caution!
Do not short the IC pins while testing the test points

Procedure:
With the circuit in working condition

1. Some test points are included in Figure 1.9
2. Check the supply voltages at TP3 and TP4
3. Check for input on TP1 using Oscilloscope/ Multimeter.
4. Check for the voltage at TP2
5. Check for the output on TP5
6. Record results in Table 1.1 as standard values

No.	Test Points	Voltage Readings	
		@ Normal Condition	@ Faulted Condition
1	TP1	V	V
2	TP2	V	V
3	TP3	V	V
4	TP4	V	V
5	TP5	V	V

Table 1.1

Review questions:

1. When the input is negative the output is positive, and when the input is positive the output is negative, what did you confirm?

……………………………………………………………………………………………

……………………………………………………………………………………………

2. When the input is positive the output is positive, what did you confirm? Note the gain.

……………………………………………………………………………………………

……………………………………………………………………………………………

Exercise 2: Reference Comparator

Objective:

To get familiar with a Comparator op amp circuit that is basically used to compare voltages. This circuit compares an input voltage with a reference voltage.

Discussion:

The action of comparator op amp is to compare the voltage on one of its inputs with that on the other. In this open loop amplifier circuit, the output voltage is switched between states, going high (positive) when the inverting input is more negative than the non-inverting input.

Circuit Diagram:

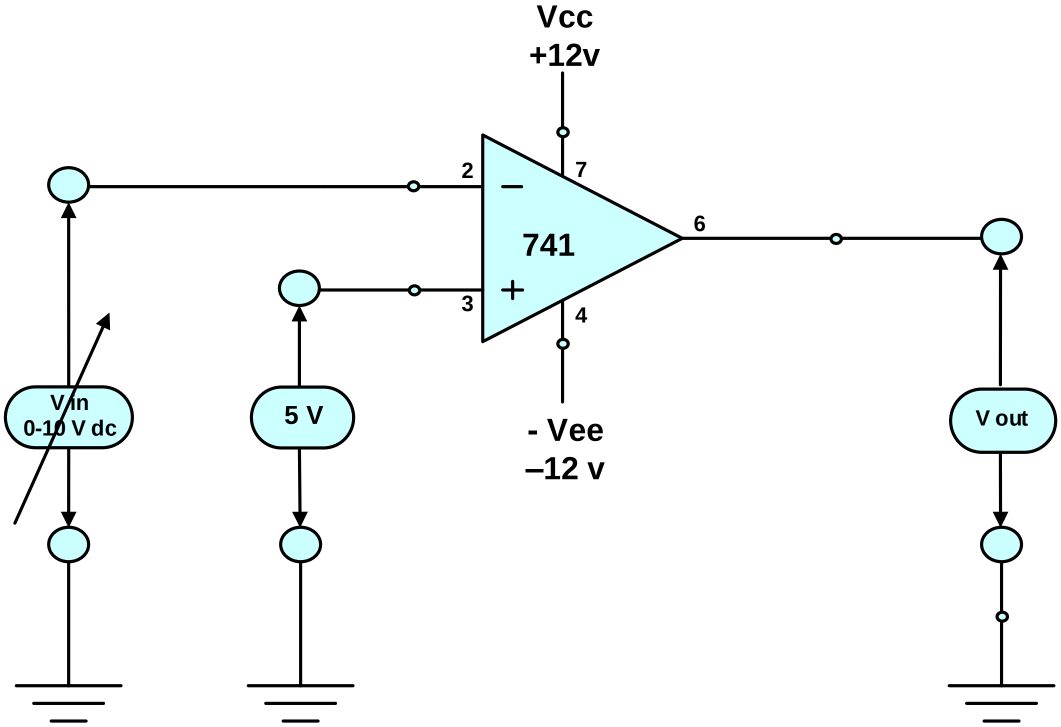


Figure 2.1

Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
6.	Set of connection cables, plugs and jumpers	-

Procedure:

1. Connect the circuit as shown in figure 2.1
2. Switch on power supplies.
3. Connect multimeter 1 on DC voltage range between pin 2 and common.
4. Connect multimeter 2 on DC voltage range between pin 3 and common.
5. Adjust the voltage $V_{IN.}$
6. Read from Multimeter 1 the input voltage at which switching occurs.
7. Connect the oscilloscope to monitor the output.

Observation Table:

Switching value of V_{IN} = ______________ V (inverting)

Input voltage	Reference voltage	Output voltage	Remarks

Table 2.1

Conclusion:

You will have observed that the op amp voltage always lies between the positive and negative power supply voltages. The maximum and minimum output voltages, which can be obtained under given power supply conditions, are known as the positive and negative saturation voltages.

Trouble Shooting:
Circuit diagram:

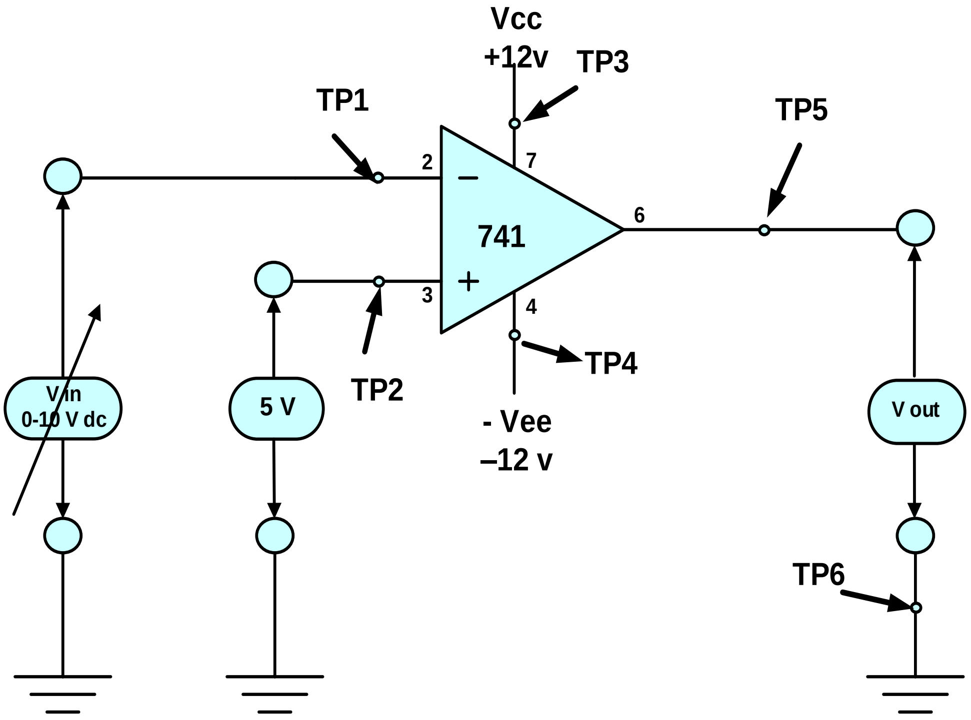


Figure 2.2

Procedure:

1. Assemble the circuit as shown in the Figure 2.2
2. Connect power supply connections to the op-amp as shown
3. Perform component testing as per the test points provided
4. Check voltages with load and without load
5. Record results in the table 2.2

Sr no.	Component Testing	Std Values	Voltage		Remarks
			Without error	With error	
1	TP1				
2	TP2				
3	TP3				
4	TP4				
5	TP5				
6	TP6				

Table 2.2

Review questions:

1. Explain the operation of the circuit?

……………………………………………………………………………………………

……………………………………………………………………………………………

2. Observe that the circuit again switches state as the inverting input voltage is made the same as the voltage on the non-inverting input.

……………………………………………………………………………………………

……………………………………………………………………………………………

3. Did you observe that the Op Amp voltage always lies between the positive and negative power supply voltages?

……………………………………………………………………………………………

……………………………………………………………………………………………

Exercise 3: Inverting Amplifier

Objective:

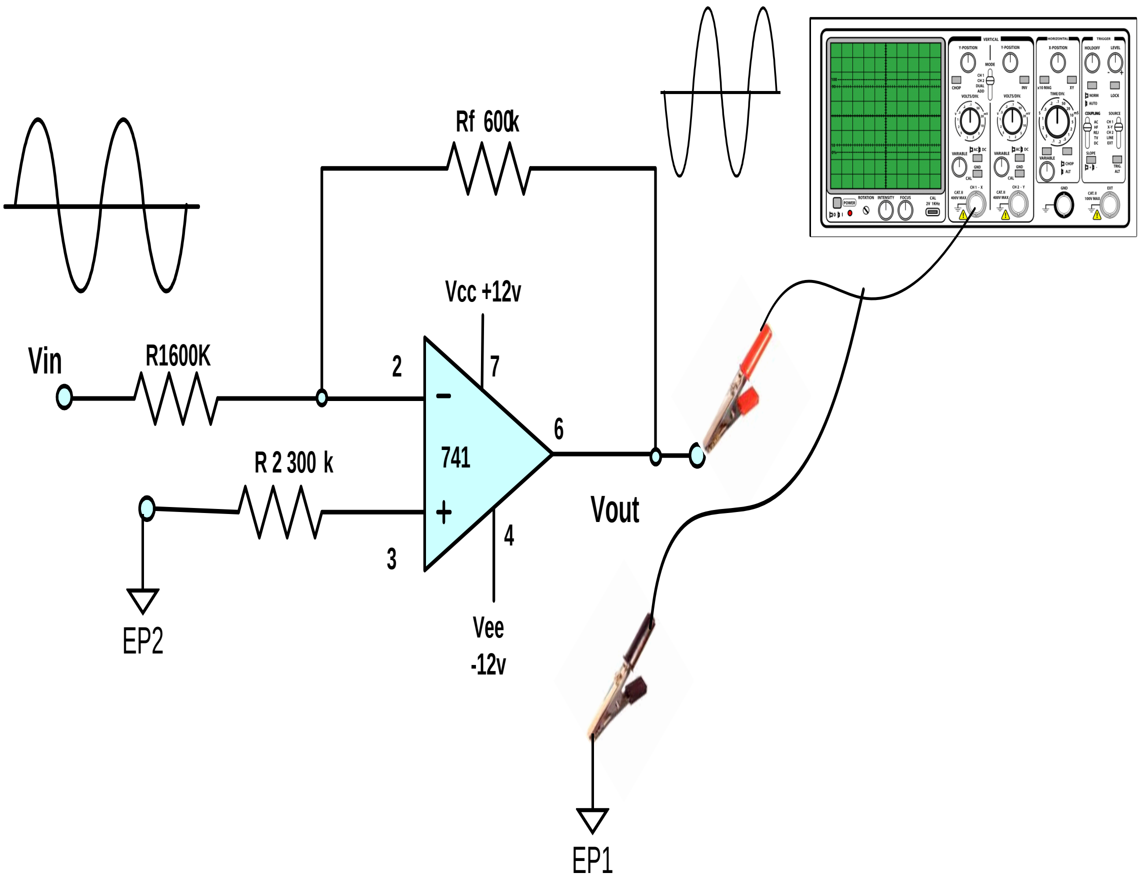
To discuss the working of a Closed-Loop Amplifier using an operational amplifier.

Discussion:

The output is sampled and feedback to the inverting input, to which the external input is applied. The amplifier therefore receives its input from two sources, the external input via Rin and the feedback via Rf, giving an output that has the opposite polarity to the input.

Circuit Diagram:

Figure 3.1



Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
6.	Set of connection cables	--
7.	Resistors	2 pcs

Procedure:

1. Connect the circuit as shown in figure 3.1 and switch on power supplies.
2. Connect multimeter 1 on DC voltage range between R1 and common and adjust voltage to give an input voltage Vin of +1V
3. Connect multimeter 2 on DC voltage range between pin 6 (Vout) and common
4. Record the result in the table 3.1

Vin (volts)	Vout (volts) Measured	Vout (volts) Calculated	Error Calculated - Measured
1			
2			
3			
-1			
-2			
-3			

Table 3.1

The equation for gain is given by

Av= - Vout / Vin;

where

Vout / Vin = - Rf / Rin

Conclusion: You will have observed that the output of op amp voltage always lies between the positive and negative power supply voltages.

Troubleshooting:

Circuit Diagram:

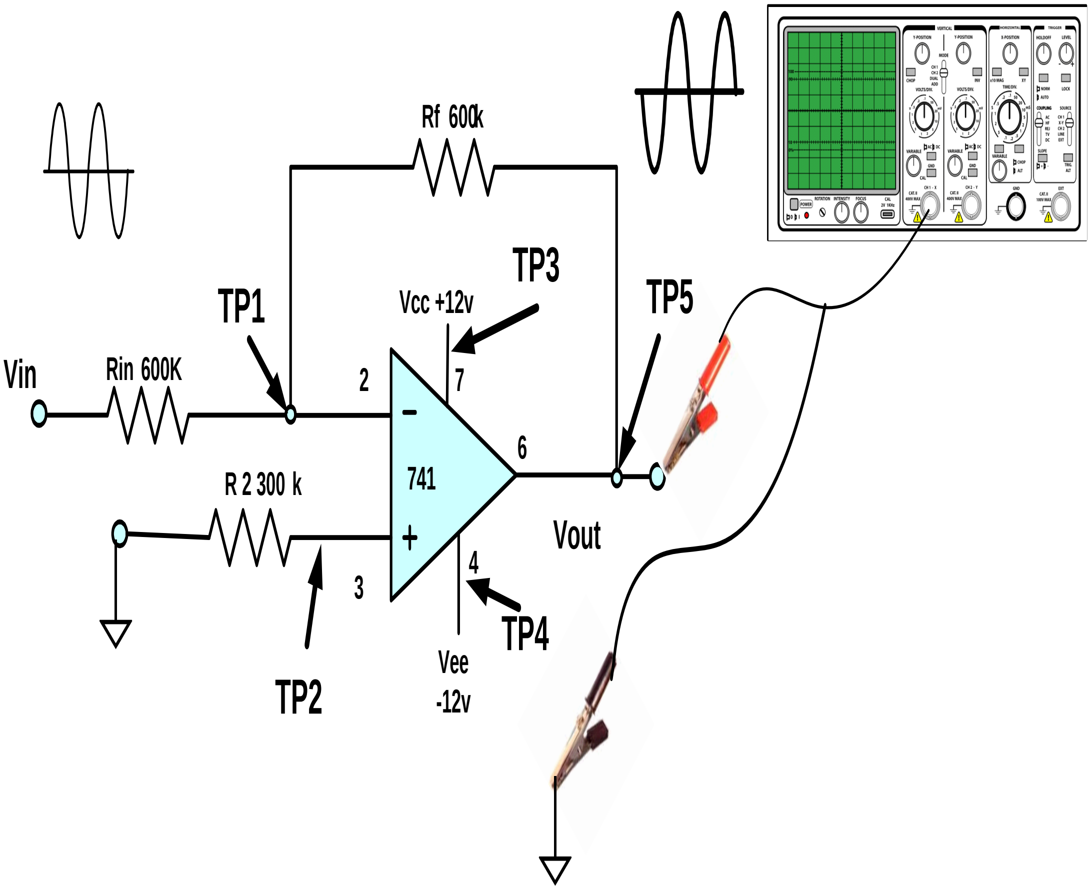


Figure 3.2

Observation:

The stage gain of the amplifier is determined by the ratio of these two resistors

$$Av = - Vout / Vin;$$

where

$$- Vout / Vin = - Rf / Rin$$

Procedure:

1. Assemble the circuit as shown in the Figure 3.2
2. Connect power supply connections to the op-amp as shown
3. Perform component testing as per the test points provided
4. Check voltages with load and without load
5. Record results in the table 3.2

Sr no.	**Component Testing**	**Std Values**	**Voltage**		**Remarks**
			Without error	**With error**	
1	TP1				
2	TP2				
3	TP3				
4	TP4				
5	TP5				
6					
7					

Table 3.2

Review questions:

1. Explain the operation of the circuit?

………………………………………………………………………………………………

2. With feedback applied the circuit is described as a ………………………………………………………………………………………………

3. Does the minus sign indicate an inversion of signal polarity?

………………………………………………………………………………………………

Exercise 4: Non-Inverting Amplifier

Objective:

To discuss the working of a Closed-Loop Amplifier using an operational amplifier.

Discussion:

The output is sampled and feedback to the inverting input, to which the external input is applied. The amplifier therefore receives its input from two sources, the external input via Rin and the feedback via Rf, giving an output that has the opposite polarity to the input.

Circuit Diagram:

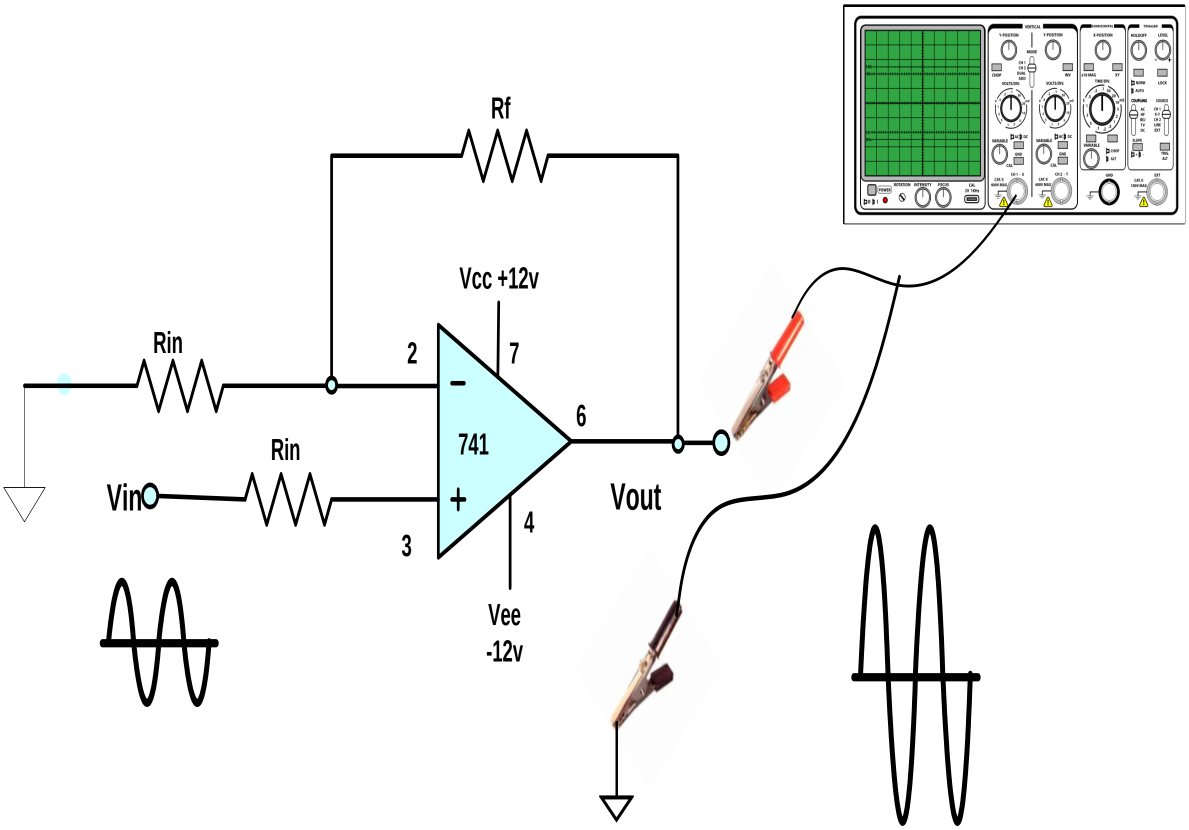


Figure 4.1

Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
6.	Set of connection cables	--
7.	Resistors	3 pcs

Procedure:

5. Connect the circuit as shown in figure 4.1 and switch on power supplies.
6. Connect multimeter 1 on DC voltage range between R1 and common and adjust voltage to give an input voltage Vin of +1V
7. Connect multimeter 2 on DC voltage range between pin 6 (Vout) and common
8. Record the result in the table 4.1

Vin (volts)	Vout (volts) Measured	Vout (volts) Calculated	Error Calculated - Measured
1			
2			
3			
-1			
-2			
-3			

Table 4.1

The equation for gain is given by

$$A_v = V_{out} / V_{in}$$

and

$$= 1 + (R_F / R_{in})$$

Conclusion: You will have observed that the op amp voltage always lies between the positive and negative power supply voltages. The maximum and

Troubleshooting:

Circuit Diagram:

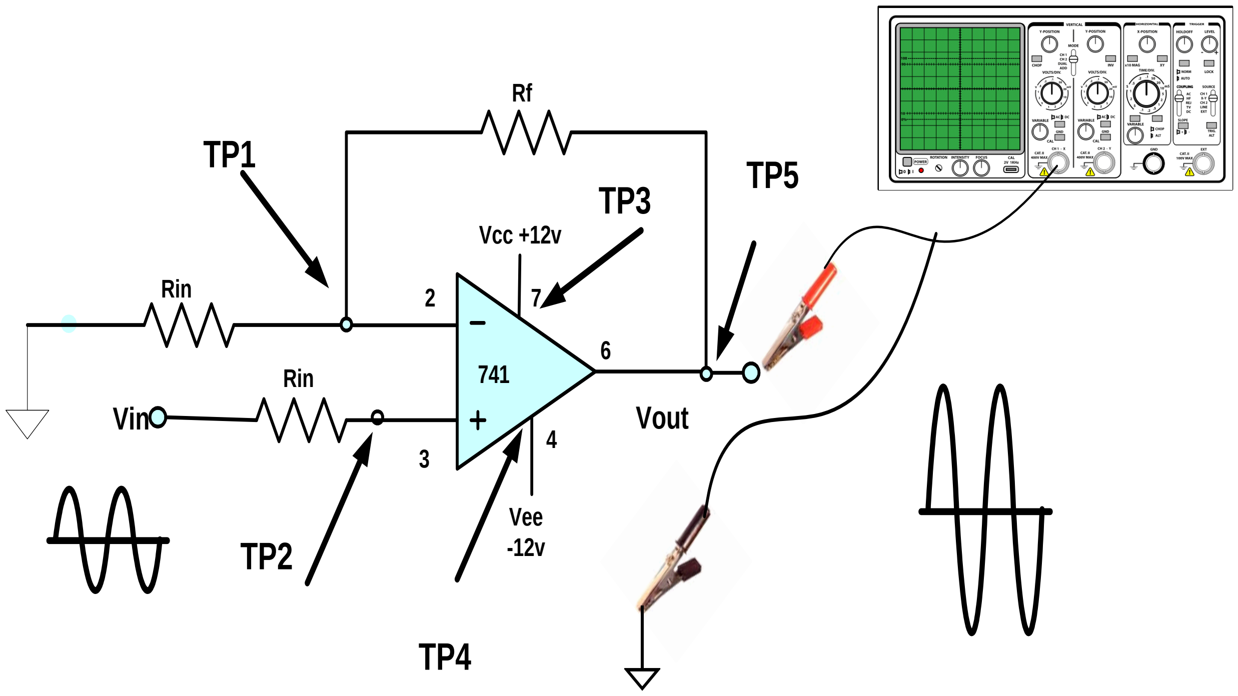


Figure 4.2

Procedure:

1. Assemble the circuit as shown in the Figure 4.2
2. Connect power supply connections to the op-amp as shown
3. Perform component testing as per the test points provided
4. Check voltages with load and without load
5. Record results in the table 3.2

Calculation:

The stage gain of the amplifier is determined by the ratio of these two resistors

$$A_v = V_{out} / V_{in}$$

and

$$= 1 + (R_F / R_{in})$$

Observation:

Sr no.	Component Testing	Std Values	Voltage		Remarks
			Without error	With error	
1	TP1				
2	TP2				
3	TP3				
4	TP4				
5	TP5				
6					
7					

Table 4.2

Review questions:

4. Explain the operation of the circuit?

………………………………………………………………………………………………

………………………………………………………………………………………………

5. With feedback applied the circuit is described as a ………………………………………………………………………………………………

………………………………………………………………………………………………

6. Does the minus sign indicate an inversion of signal polarity?

………………………………………………………………………………………………

………………………………………………………………………………………………

Exercise 5: Voltage follower Circuit

Objective:

To demonstrate a linear relationship between the output and the input of an operational amplifier.

Discussion:

The ratio of the feedback resistor to the input resistor determines the gain of the amplifier, provided the inverting input is used for connection of the feedback.

Circuit Diagram:

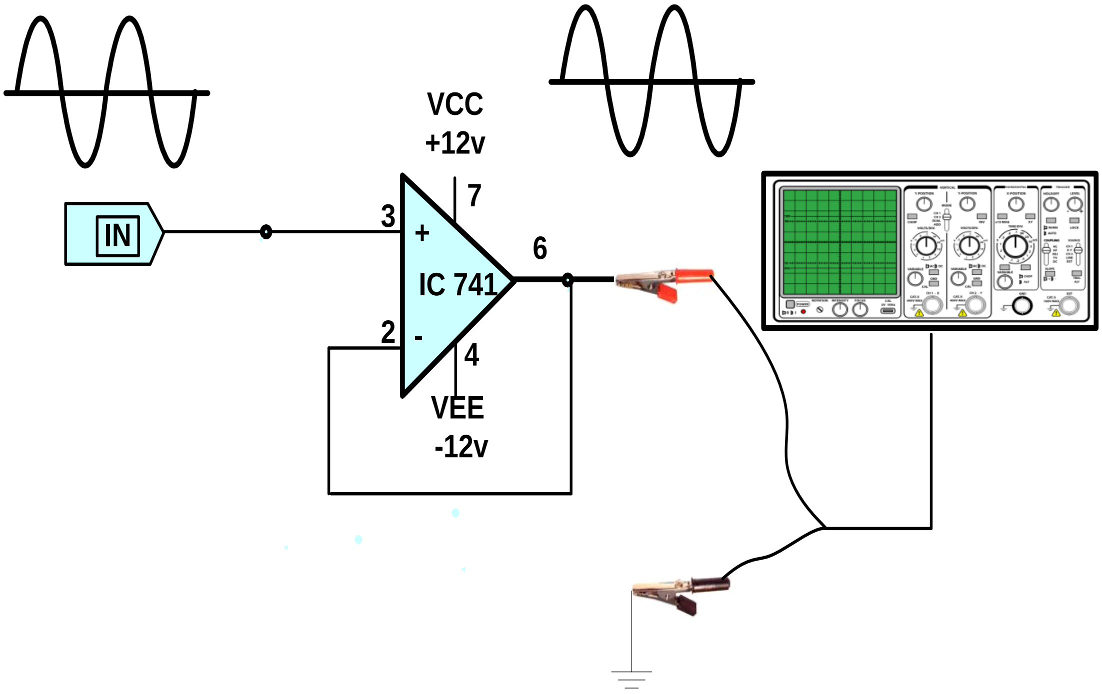


Figure 5.1

Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
7.	Set of connection cables	-
8.	Connection plugs (jumpers)	-

Procedure:

1. Connect the circuit as shown in figure 5.1 and switch on power supplies.
2. Connect multimeter 1 on DC voltage range between V1 and V2.
3. Connect multimeter 2 on DC voltage range between pin 6 (V_{OUT}) and common.
4. Record the result in Table 5.1 below.

Observation:

Vin (volts)	Vout (volts) Measured	Vout (volts) Calculated	Error Calculated - Measured
1			
2			
3			
-1			
-2			
-3			

Table 5.1

Equation to Calculate Standard values

Vout =Vin

Conclusion: You will have observed that the output of op amp voltage always lies between the positive and negative power supply voltages.

Troubleshooting:

Circuit Diagram:

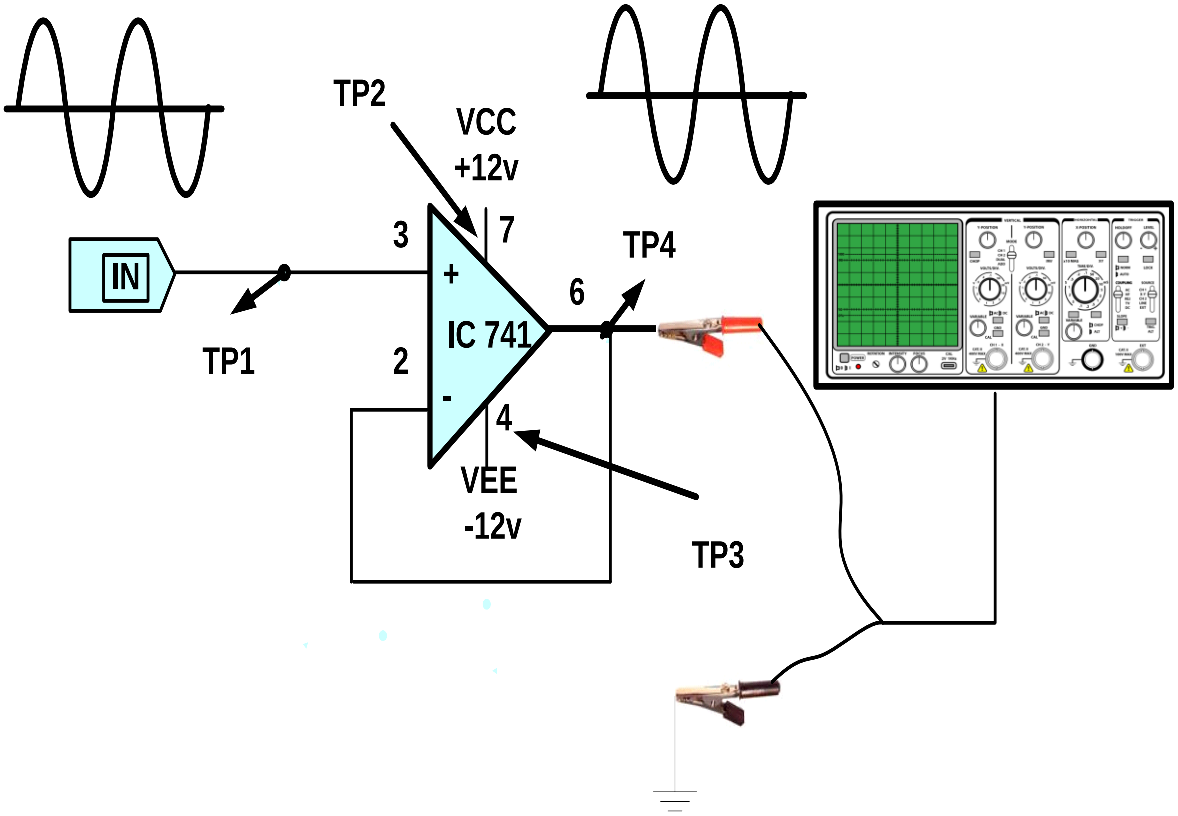


Figure 5.2

Procedure:

1. Assemble the circuit as shown in Figure 5.2.
2. Connect power supply connections to the op-amp as shown in the diagram.
3. Perform component testing as per the test points provided.
4. Check voltages with load and without load.
5. Record results in the Table 5.2.

Sr no.	**Component Testing**	**Std Values**	**Voltage**		**Remarks**
			Without error	**With error**	
1	TP1				
2	TP2				
3	TP3				
4	TP4				
5	TP5				

Table 5.2

Conclusion: You will have observed that the op amp voltage always lies between the positive and negative power supply voltages. The maximum and minimum output voltages, which can be obtained under given power supply conditions, are known as the positive and negative saturation voltages.

Review Questions:

1. What is the nature of the graph?

………………………………………………………………………………………

………………………………………………………………………………………

2. Determine the sensitivity from the graph

………………………………………………………………………………………

………………………………………………………………………………………

3. comment upon the working of the circuit?

………………………………………………………………………………………

………………………………………………………………………………………

Exercise 6: Differential Amplifier

Objective: To evaluate and trouble shoot a basic differential amplifier.

Discussion:

The differential amplifier is a combination of the inverting and non inverting amplifiers. The operation can best be understood by considering each input separately. Input 1 is an inverting input; a positive going signal applied at input 1 produces a negative going output. Input 2 is a non inverting input; a positive going input applied at input 2 produces a positive going output. The gains of both the inverting and non inverting inputs are determined by the ratio of Rf to R1.

Circuit diagram:

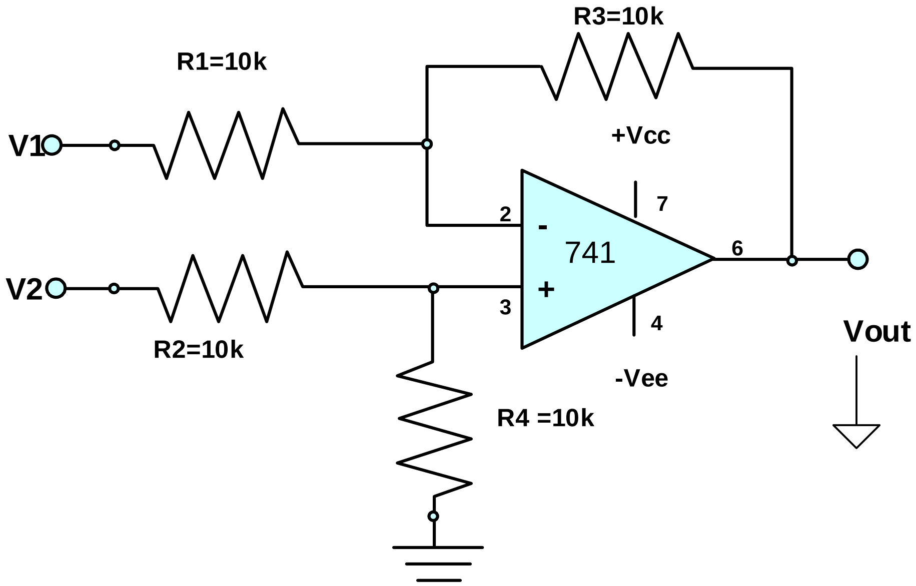


Figure 6.1

Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741	1 Pc
6.	Resistors	4Pcs
7.	Set of connection cables, jumpers	-

Procedure:

1. Connect the circuit as shown in figure 6.1 and switch on power supplies
2. Connect voltage V1 and V2 from power supply
3. Increase V1 and V2 Fixed
4. Then increase V2 and V1 fixed
5. Repeat for different values of V1 and V2
6. Record values on Table 6.1.

Observation:

Input V1 (volts)	Input V2 (volts)	Vout (volts) Measured	Vout (volts) Calculated	Error Calculated - Measured
1				
2				
3				
-1				
-2				
-3				

Table 6.1

Note:

For the amplifier to operate correctly in differential mode it is important that R1=R3 and R2=R4

Conclusion:

If the R1=R3 and R2=R4, the output voltage V_{OUT} from the op amp will given by the formula,

$$\mathbf{V_{OUT} = R_2/R_1 * (V_2 - V_1)}$$

$$\mathbf{V_{OUT} = A_V (V_2 - V_1)}$$

Verified = --------------------- Yes/No

Troubleshooting:

Circuit diagram:

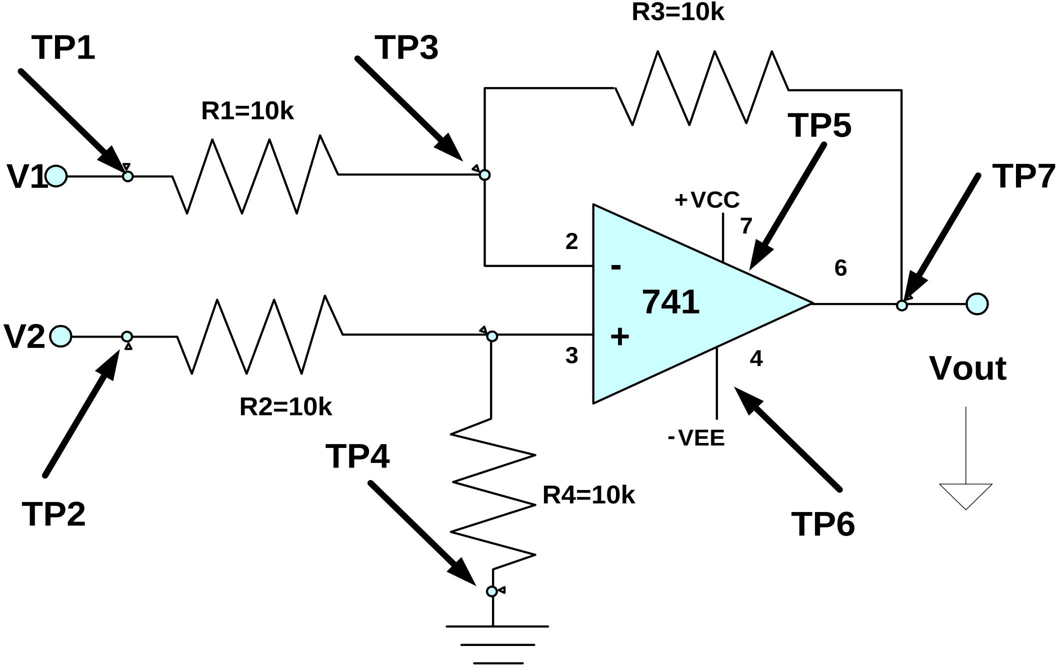


Figure 6.2

A circuit diagram of a differential amplifier made using an op amp is shown in Figure 6.2.

Procedure:

1. Assemble the circuit as shown in the Figure 6.2
2. Connect power supply connections to the op-amp as shown.
3. Perform component testing as per the test points provided.
4. Check voltages with load and without load.
5. Record results in the Table 6.2

Observation Table

Sr no.	Component Testing	Std Values	Voltage		Remarks
			Without errors	With errors	
1	TP1				
2	TP2				
3	TP3				
4	TP4				
5	TP5				
6	TP6				

Table 6.2

Review questions:

1. Demonstrates operation of Difference amplifier?

………………………………………………………………………………………………

………………………………………………………………………………………………

2. What is the amplitude of voltage at inverting terminal?

………………………………………………………………………………………………

………………………………………………………………………………………………

3. What is the amplitude of voltage at non- inverting terminal?.

………………………………………………………………………………………………

………………………………………………………………………………………………

4. is it possible to identify fault in the differential amplifier circuit?

………………………………………………………………………………………………

………………………………………………………………………………………………

Lesson 2: Introduction to Filters:

Discussion:

The band pass filter is constructed by combining a low pass filter and a high pass filter using a operational amplifier.
The capacitors impedance depends on frequency

$$\mathbf{Xc = 1/(2\pi fC)}$$

and the corner frequency of an RC filter is

$$\mathbf{Fc = 1/(2\pi RC).}$$

Low Pass Circuit

In figure 4.1 the capacitor is placed in parallel with the feedback resistor (R2). At low frequencies ($f << f_c$) the capacitors impedance (Xc) is much greater than R2 and therefore the parallel combination of R2 & Xc is about R2 (i.e. R2|| Xc = R2 when $f << f_{c)}$.

As frequency increases towards the corner frequency the impedance of the capacitor decreases and becomes comparable to that of the resistor. This lowers the impedance of the parallel combination of R2 & Xc and therefore the gain begins decreasing. When $f >> f_c$, R2|| Xc = Xc causing the gain to drop.

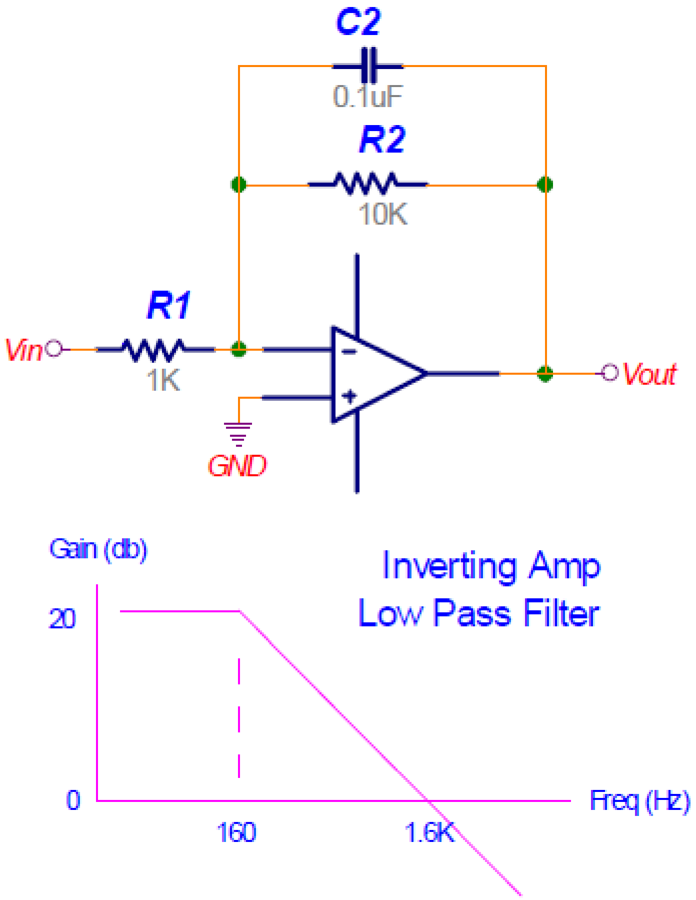


Figure. low pass

High Pass Circuit

The figure 4.2 has the capacitor in series with R1. When f << f_c the capacitors reactance is large and R1 + Xc = Xc. Therefore the gain is 1 + R2/ Xc which = 1 when Xc >> R2. When f >> f_c the capacitors reactance is small and R1 + Xc = R1. Therefore the gain is 1 + R2/ R1 which = 10 when Xc << R1.

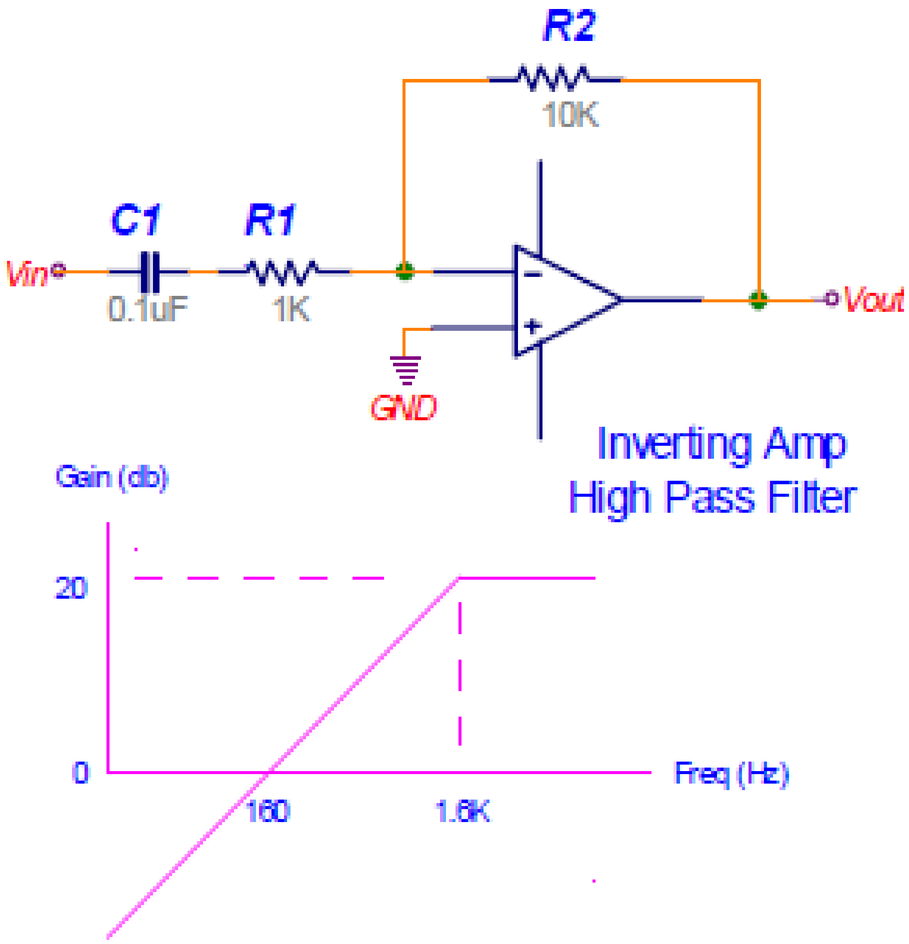
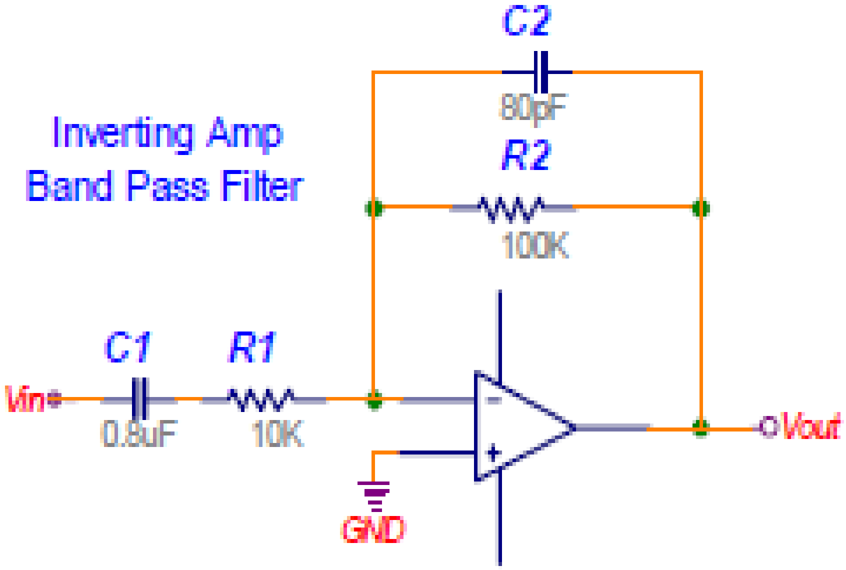


Figure. High pass

Band Pass Circuit

The low pass and high pass filter can be combined into a band pass filter. As shown in the figure 16.3, below the corner frequencies were chosen to be in the audio band (20Hz – 20KHz).

Notice the difference in the gain outside of the pass band. The gain of the inverting amplifier continues to drop as you get farther away from the pass band. The gain of the non-inverting amplifier only drops to 1 (0db)



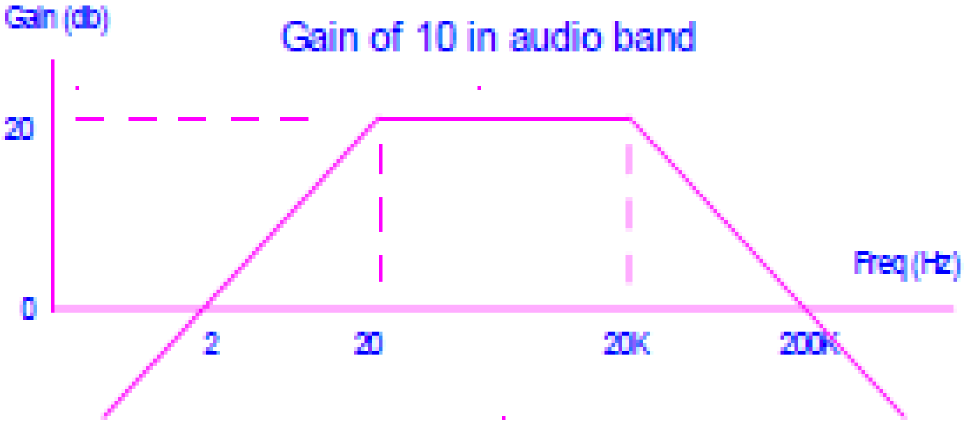


Figure . Band pass

Thus this active filter can be tested for different range of frequencies just by changing the values of capacitors.

Exercise 7 : The Analog Integrator

1) The Analog Integrator:

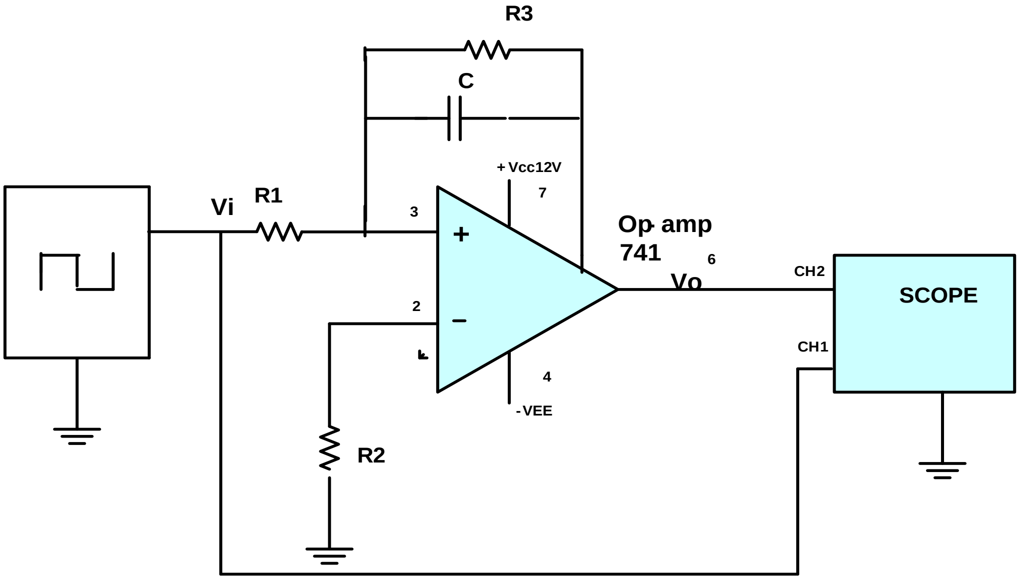


Figure 7.1

Caution!
Do not short the IC pins while testing the test points

Fig 7.1 shows a block diagram of an Analog Integrator. The unit is based on an Operational Amplifier with two inputs A & B and an output. Input B, the non-inverting input, is normally connected to 0V as indicated and a resistor R is connected between the input A and the inverting input of the Operational Amplifier.
A capacitor C is connected between the output and the inverting input of the amplifier for feedback as shown.

With the non-inverting input connected to 0V, the inverting input will also be at 0V due to the high gain of the circuit. (Virtual ground principle of the Operational Amplifier circuit.

The current in the resistor R will therefore be a constant value I, this being fixed by the input voltage and the resistance R.
Current I flows to the capacitor C, (because no current is taken by the inverting input of the Operational Amplifier), and the capacitor charges, the voltage

increasing linearly with time. This causes the output voltage to increase linearly in a negative direction, the rate of change of the voltage depending on the input voltage V and the magnitudes of R & C as shown in the equation below.
The minus sign indicates that the rate of change is negative (that is, the output increases in a negative direction) for a positive value of Vin. An increase in R or C reduces the rate of change of output voltage. An increase in input voltage V increases the rate of change of output voltage,
since it increases the charging current through the resistor R.

The value RC is referred to as the **'Time constant*** of the circuit.
The output voltage increases until the value reaches the applied (supply) voltage to the device. When this voltage is reached the output voltage will remain constant. Normally, it will be arranged that the output voltage does not reach this value.
Similarly, with a constant negative voltage applied to the input, the output voltage will increase linearly with time in a positive direction.
Feeding alternately positive and negative voltages to the input will produce an output triangular waveform as shown in Fig 7.1

Note: The output voltage is triangular only for conditions with the output voltage

Equipment:

No	**Name**	**Qty.**
1.	Function generator with integral AC/DC power	1 Pc
2.	Digital multimeter	1 Pc
3.	Oscilloscope	1 Pc
4.	Bread Board	1 Pc
5.	Op-amp 741,R1,R2,R3, 100k each	1 Pc
6.	Set of connection cables	-
7.	Connection plugs (jumpers)	-
8	Capacitors .01 uf	1 Pc

Procedure:

1. Assemble the circuit as shown in the Figure
2. Connect power supply connections to the op-amp as shown
3. Perform component testing as per the test points provided
4. Check voltages with load and without load
5. Record results in the table 7.2 given below

Observation Table

Sr no.	Input Frequency	Output Volts
1	TP1	
2	TP2	
3	TP3	
4	TP4	

Table 7.2

Conclusion: from the observation table it is observed that the above circuit works as a ______________ filter.

Review questions:

1) Explain the operation of the circuit?

………………………………………………………………………………………

………………………………………………………………………………………

2) Observe the output waveform?

………………………………………………………………………………………

………………………………………………………………………………………

3) Write down the peak-to-peak voltage?

………………………………………………………………………………………

………………………………………………………………………………………

Exercise 8: Duty Cycle Controller

Objectives:

- Recognize the operation of a duty cycle controller.
- Simulate an Astable multivibrator using IC 555 and understanding the concept of the duty cycle.
- Diagnose a fault in a duty cycle controller circuit.

Discussion:

Power dissipation in the transistor rises to a maximum at approximately half load current when Power in the load is varied by analog control (varying the current and voltage),. This waste can be prevented by use of digital (ON/OFF) control, varying the time for which power is applied to the load, thus reducing the power rating necessary for the transistor to a minimal amount.

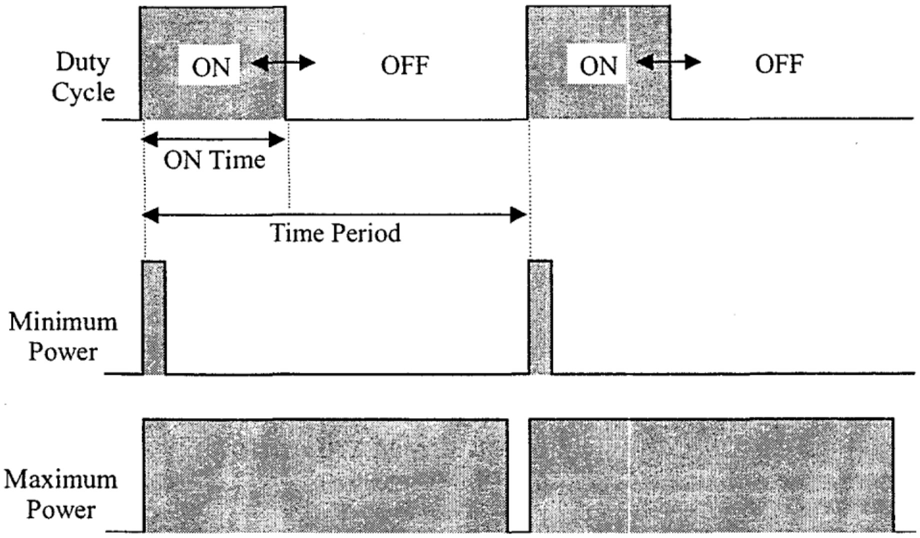


Figure 8.1

The transistor is operated in the digital (switching) mode, either OFF, (no current and therefore no power dissipation), or ON and SATURATED, (no voltage across the transistor and therefore no power).
Power is only dissipated in the transistor during the actual time of switching ON/OFF or OFF/ON, which should therefore be kept to a minimum.
A Pulse Width Modulator varies the Duty Cycle of the circuit.
ON time. The Duty Cycle is defined as the ratio of Time Period Equal On and OFF times gives a duty cycle of 0.5.

The internal schematic and circuit diagram for the astable multivibrator using IC 555 is shown in figure 8.1 and figure 8.2 respectively.

The time during which the output is either high or low is determined by the two resistors and a capacitor which are externally connected to the 555 timer.

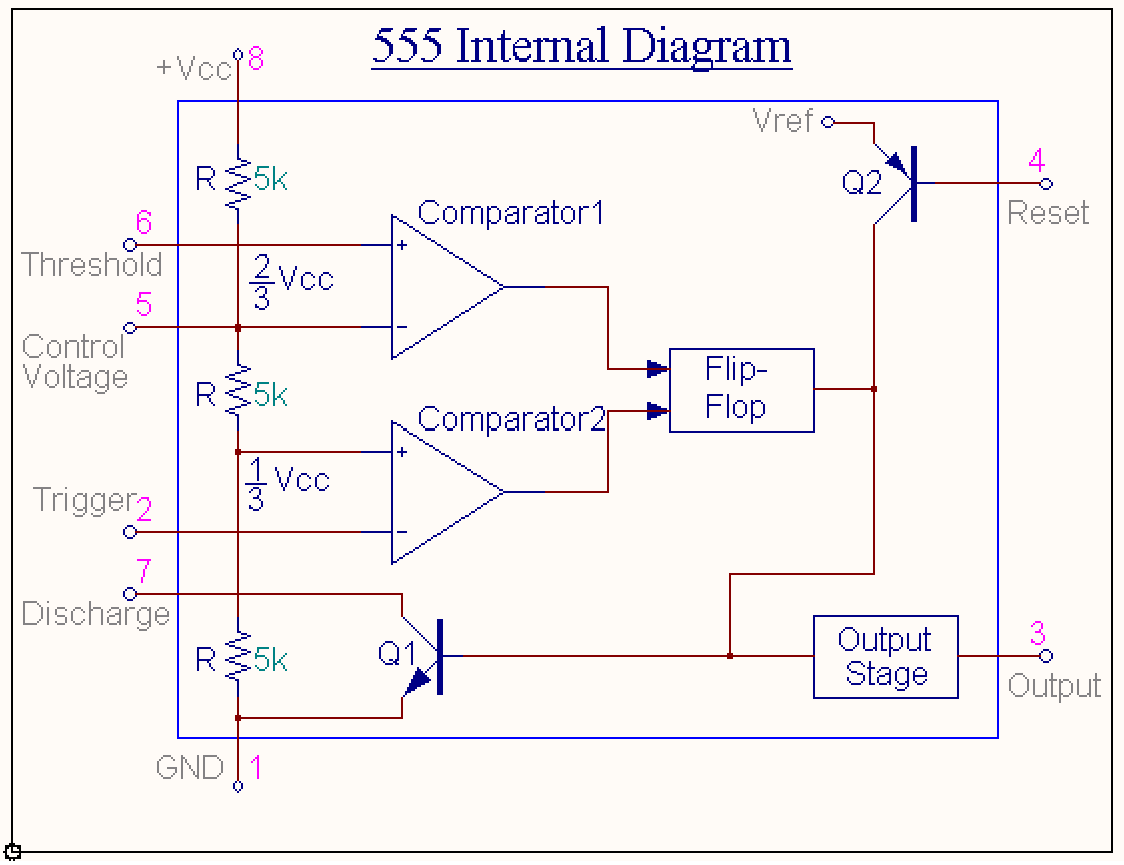


Figure 8.2

The time during which the capacitor charges from 1/3 V_{cc} to 2/3 V_{cc} is equal to the time the output remains high and is given by

$$t_c = 0.693(R_A + R_B)C$$

Where R_A and R_B are in ohms and C is in Farads. Similarly the time during which the capacitor discharges from 2/3 V_{cc} to 1/3 V_{cc} is equal to the time the output is low and is given by

$$t_d = 0.693R_BC$$

Thus the total time period of the output waveform is

$$T = t_c + t_d = 0.693(R_A + 2R_B)C$$

Therefore the frequency of oscillation

$$f = \frac{1}{T} = \frac{1.45}{(R_A + 2R_B)C}$$

Circuit Diagram: Astable Multivibrator

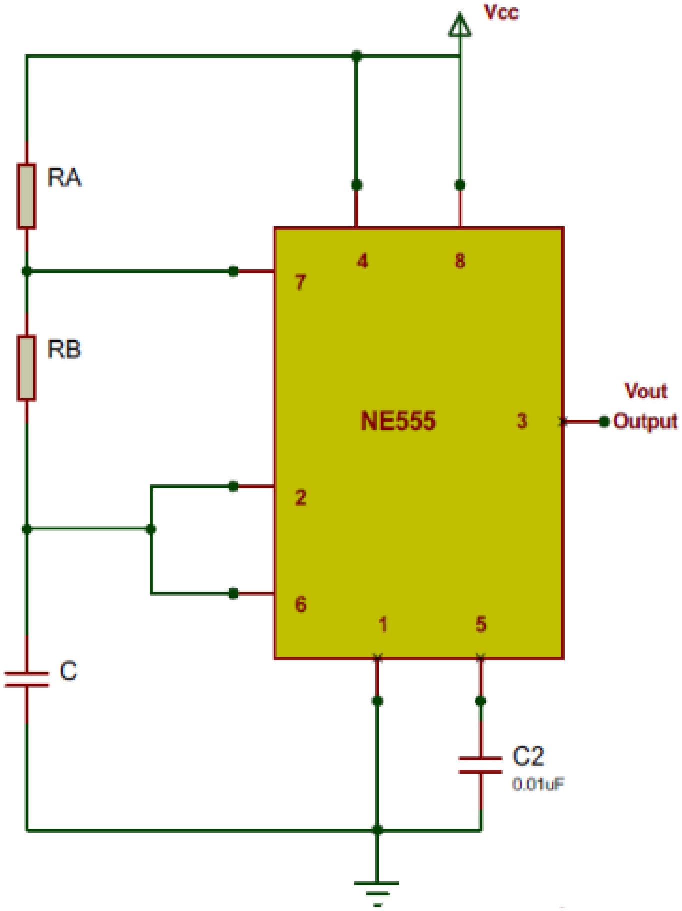


Figure: 8.3

Caution!
Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	AC/DC power supply	1 Pc
2.	Digital Multimeter	1 Pc
3.	Analogue Multimeter	1 Pc
4.	Universal panel	1 Pc
5.	Capacitor, 100 nF	1 Pc
6.	Capacitor, 10 nF	1 Pc
7.	Resistor, 10 KΩ	2 Pc
8.	IC 555	1 Pc
9.	Set of connection cables	-
10.	Connection plugs (jumpers)	-

Caution!
Do not short the IC pins while testing the test points

Procedure:

1. Assemble the circuit shown in figure 8.3 above.
2. Connect the power supply and turn ON the circuit.
3. Connect the output to one channel of CRO.
4. Draw the nature of output of waveform observed on CRO.

Review Questions:

1. What do you understand by the term “Astable”?

……………………………………………………………………………………

……………………………………………………………………………………

2. What is the function of IC 555?

……………………………………………………………………………………

……………………………………………………………………………………

3. What is meant by “Duty Cycle”?

……………………………………………………………………………………

……………………………………………………………………………………

Troubleshooting : Astable Multivibrator

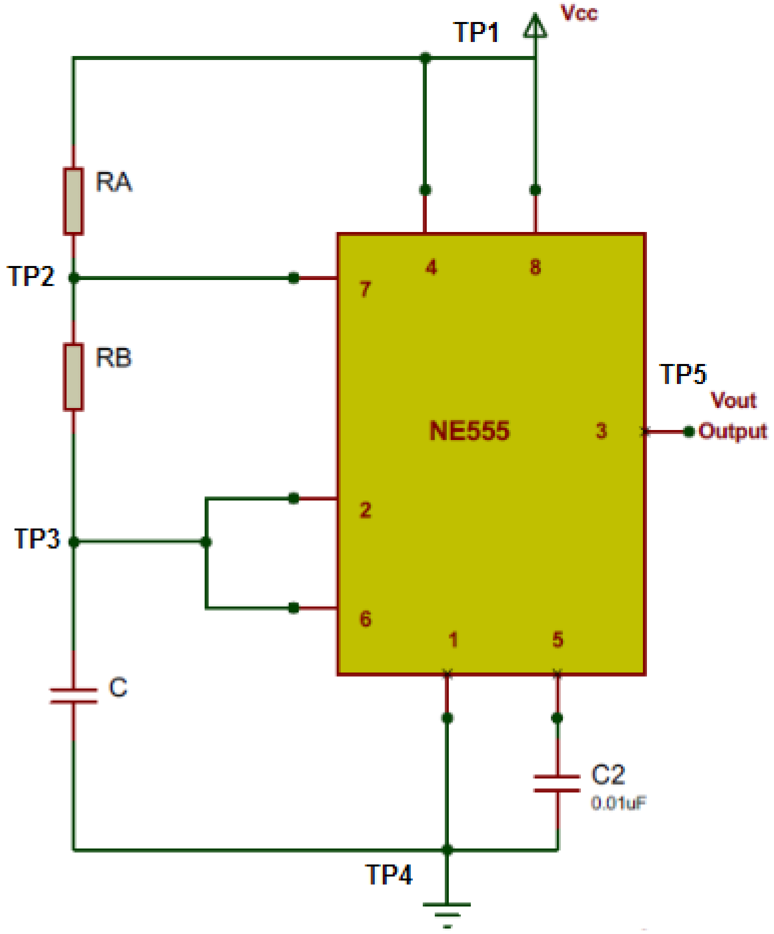


Figure: 8.4

Procedure:

1. Assemble the circuit as shown in the Figure 8.4
2. Connect power supply connections to the IC 555.
3. Perform component testing as per the test points provided
4. Check ouput on the CRO.
5. Introduce a fault by shorting the capacitor.
6. Note the nature of waveform observed on CRO
7. Change the value of the resistor and draw the changes in the waveforms.

Conclusion:

Shorting the value of capacitor results in --------------------------- at output.

Lesson 3: Transducers & signal Conditioning Circuits

All electronic instruments mostly have two parts

Transducers

Signal Conditioning Circuit

Electronic circuits can quickly process information that is introduced to the system by way of input media such as keyboards, switches, and external communication interfaces.

Output devices include displays for feedback to human operators and control circuits to control machinery or processes.

Input devices provide information in different format to the main control system which process data and produce output on any suitable output device.

One type of input medium is the Transducer. A transducer is a device that converts one form of energy into another. There are two basic transducer types: Input Transducer and Output Transducer.

Input transducer also called sensors convert a physical quantity into a proportional electrical signal that can be input into an electronic circuit.

Output transducers convert an electrical signal into a physical quantity that can be detected or used externally.

INPUT TRANSDUCER	**OUTPUT TRANSDUCER**
Heat, pressure, force, velocity, acceleration, displacement, humidity, light, sound, motion	Light, sound, vibration(mobiles)

In every day life thermostat is the best example. The thermostat in your home has an input transducer that senses room temperature and is used to control heating and air conditioning.

Input transducers convert's physical phenomena in to electrical output. For example a thermocouple produces output voltages in mV. There are other temperature transducers like IC temperature transducer produces an output current, thermistor & RTD produces output resistance.

To measure touch & position sensing one can use capacitance sensor which produces output in capacitance.

A strain gauge transducer can measure strain on the surface of the object and produces output in resistance. Strain gauge application includes the measurement of weight, linear displacement, linear position, acceleration, force, torque, vibration and pressure.

Signal Conditioning Circuits

Transducer produces output in different electrical quantities like mV, resistances, capacitance so there is a need to convert in to measurable electrical voltages or current.

“Signal conditioning circuits converts transducers output in measurable electrical quantities”

Later in this course we will discuss about different transducers and perform practical.

Circuit Board

There are eight different types of transducers on the TRANSDUCER FUNDAMENTALS circuit board.

IC Transducer

Thermistor

RTD

Thermocouple

Strain Gauge

Capacitance Sensor

Ultrasonic Transducer

Infrared Controller

The oven consists of eight resistors that are wired in series forming a heating element. Oven regulates its temperature by sensing heat through IC transducer. With the help of a jumper one can set point to the regulator.

The IC transducer, Thermister, Thermocouple and RTD are located inside the oven. All these transducer sense heat to produce an output parameter. Their use depends on the particular application.

The instrumentation amplifier is used to amplify the outputs of the transducer circuits. Gain can be selected using dip switches. There are four gain settings (x1, x10, x100, and x1000). The instrumentation amplifier has jacks that can be used as test points and or making connection. Three jacks are on the input side.

Temperature measurement circuit requires calibration for precise operation.

Transducers have different properties and characteristics that are used to determine their suitability to particular applications. Examples include

Output type
Operating Range
Linearity
Stability and cost

The STRAIN GUAGE circuit block has a transducer mounted to a thin metal beam in a fixture. A strain gauge measures the strain on the surface of the object to which it is attached.

Capacitance sensor transducer can be used as touch sensor, proximity detector, position sensor, and displacement measuring devices.

The capacitance sensor converts mechanical motion in to an electrical signal. It consists of a fixed and movable plate. The fixed plate is solid copper which is etched onto circuit board. The movable plate's position is indicated by the scale located on the left guide.

The ULTRASONIC TRANSDUCER circuit has separate TRANSMITTER and RECEIVER sections. There is an ultrasonic transducer on each section.

Ultrasonic transducer can be used to measure distance, Tank level. It has also got a very good application in medical science.

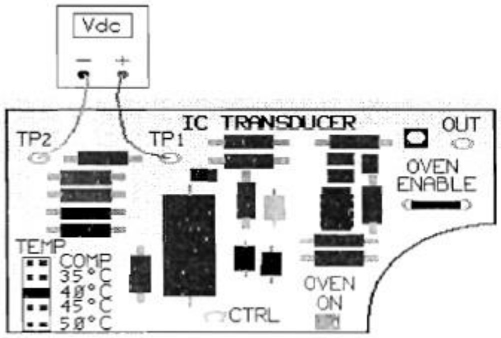
The INFRARED CONTROLLER circuit block uses infrared light to send and receive digital codes. Familiar applications of infrared sensors are in wireless remote control of TV's, DVD's, and others.

The infrared controller circuit block has separate RECEIVER and TRANSMITTER sections.

Exercise 9: Basic Operation of Transducer devices

Objectives:

To describe the basic operation of transducer devices by measuring basic transducer output parameters.



Procedure

1. On the IC transducer circuit block, place the shunt on the TEMP header in the 40˚C position. Insert a two-post connector in the OVEN ENABLE position.

   These connections tell the oven controller circuitry to regulate the oven temperature at 40˚C. Since you started at room temperature (typically 25˚C), the oven needs a minute or two to rise to 40˚C.

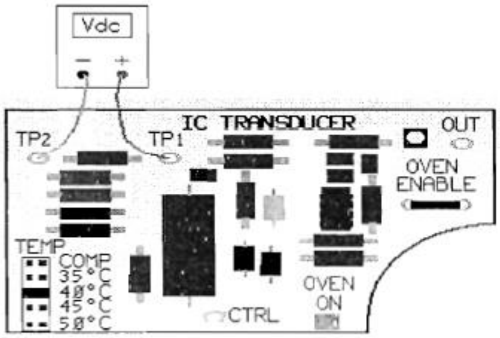
   Complete the following steps as you wait for the oven to reach the new temperature.

2. Set your multimeter to measure Vdc and connect the leads to TP1 (+) and TP2 (-).

   The IC transducer outputs a current that is a function of temperature. The 1 kΩ resistor (R_1) between TP1 and TP2 is in series with the transducer, and therefore has the same current flowing through it.

   By measuring the resistor voltage, you can calculate the transducer current (I_T) as follows.

   $I_T = V_{R1} / R_1$



3. Observe the voltmeter for several seconds. What is happening as the temperature is rising to 40˚C?

   a. Voltage increases.
   b. Voltage decreases.
   c. Voltage remains about the same.

   The way a transducer's output changes with temperature is defined by its ***temperature coefficient***.

Because the voltage is increasing, the current is also increasing, the current is also increasing. A temperature transducer whose output parameter increases as temperature increases is said to have a ***positive temperature coefficient***.

If a device had a ***negative temperature coefficient***, its output parameter would **decrease** as temperature **increases**.

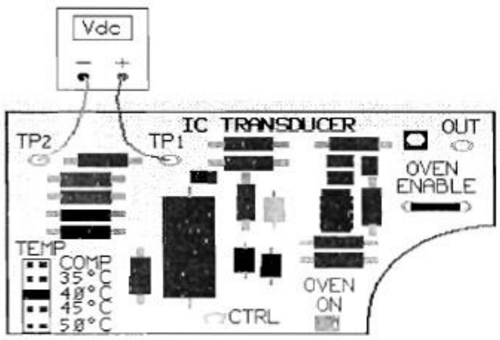
You can determine when the oven temperature has stabilized by watching the OVEN ON LED, which indicates when power is applied to the heater resistors.

When you first turned on the oven controller, the LED was on for a long period of time. As the oven temperature approaches the 40˚C, the heater will cycle on and off to maintain that temperature.

4. Observe the OVEN ON LED and allow it to complete several on/off cycles. The temperature is now stable at 40˚C.

5. Record the voltage across R_1.

   V_{R1} = ……………… mV



6. Calculate the current out of the IC transducer.

   $I_T = V_{R1} / R_1$

   = ………… mV / 1 kΩ

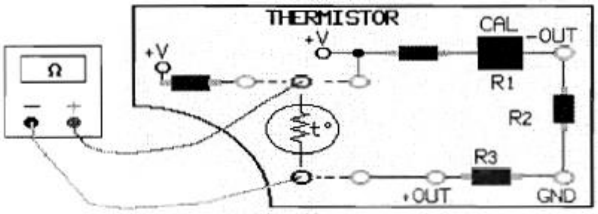
   = ………… μA

   Use the voltage measurement (V_{R1}) from step 5 for this calculation.

   The manufacturer's nominal output current for the IC transducer at 40˚C is 313.2 μA.

   Is your calculation of I_T close to this value?

   a. yes
   b. no



7. Remove the meter connections and set the meter to read ohms.

8. Make sure there are no two-post connectors in the Thermistor circuit block. Connect the meter leads as shown.

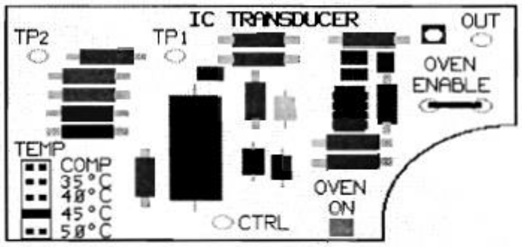
   The thermistor is a temperature transducer whose resistance is a function of temperature. With no two-post connectors in the circuit block, you are directly reading the thermistor's resistance.

9. Record the thermistor's resistance at 40˚C.

   R_{TH} = ………………. Ω

   The manufacturer's nominal value is 5327Ω at 40˚C.

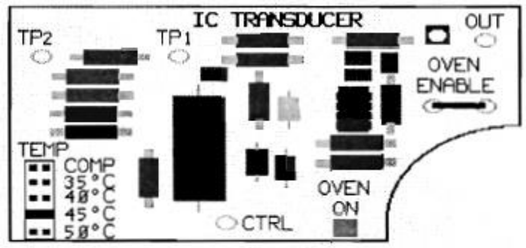
   Is your measurement close to this value?
   a. yes
   b. no



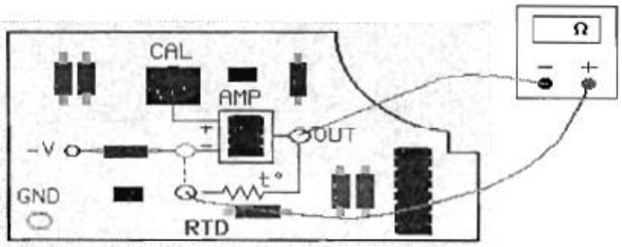
10. In the IC transducer circuit block, move the TEMP shunt to the 45˚C position to increase the oven temperature.

11. Observe the thermistor resistance on the meter for several seconds.

    Thermistors can have a positive or negative temperature coefficient. The ohmmeter reading indicates that the temperature coefficient of the thermistor on your circuit board is:
    a. positive.
    b. negative.

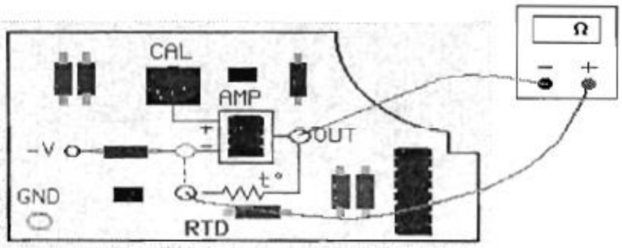


12. Return the TEMP shunt to the 40˚C position.



13. Make sure there are no two-post connectors in the RTD circuit block.

14. Remove the ohmmeter leads from the Thermistor circuit block and connect them across the RTD as shown. Make sure the negative meter lead is in the OUT jack.



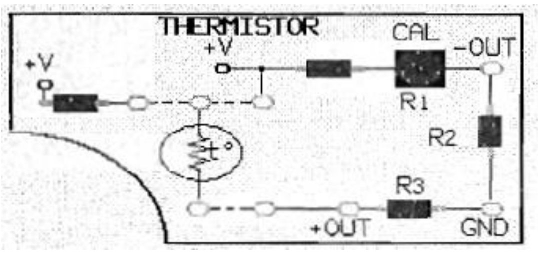
15. The RTD (resistance temperature detector) is a transducer whose resistance is a function of temperature. What other transducer has a temperature-dependent resistance output?

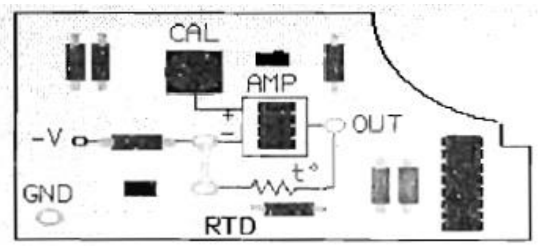
    a. IC transducer
    b. thermistor
    c. thermocouple

16. Observe the OVEN ON LED and allow it to complete several cycles to make sure the oven temperature has returned to 40˚C.

17. Record the RTD resistance at 40˚C.

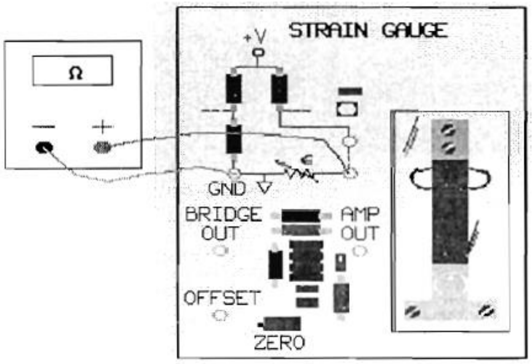
    R_{RTD} = …………….. Ω

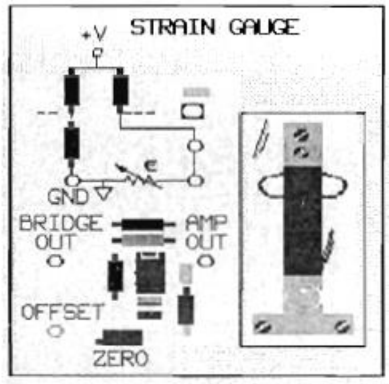




Why must the resistance of the thermistor and the RTD be measured without two-post connectors in the circuit?

a. The resistance of the connector can cause measurement errors.
b. The transducer must be isolated from other components that would affect the measurement.
c. Both of the above.





18. Remove the two-post connector in the IC transducer circuit block to turn off the oven.

    The strain gauge circuit block allows you to measure stress and strain that is applied to a metal beam when it is flexed.

    The strain gauge is a transducer whose output is a resistance that is a function of the strain on the surface of the object to which it is attached.

19. Make sure there is no two-post connectors in the Strain Gauge circuit block. Connect the ohmmeter across the transducer as shown.

    The adjustment knob allows you to bend the beam upward or downward to create compression or tension, respectively.

20. Turn the knob fully counterclockwise (CCW) and measure the stain gauge resistance.

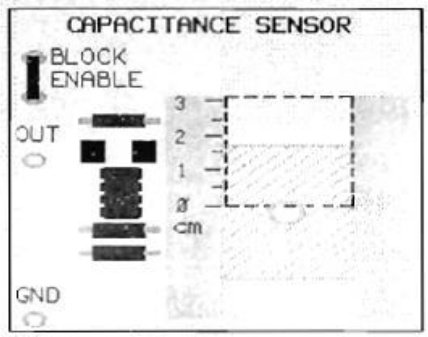
    R_{CCW} = ………………… Ω

21. Turn the knob fully clockwise (CW) and measure the resistance.

    R_{CW} = ………………… Ω

Because there is a very small resistance change, the strain gauge is a good example of a transducer whose output needs to be increased for practical applications.

The circuit block includes a resistance bridge and an amplifier to generate a relatively wide voltage swing for the range of force measured.



The variable capacitor in the Capacitance Sensor circuit block is connected to an RC oscillator whose output frequency is a function of the movable plate's position.

This block demonstrates how additional circuitry can change the form of transducer's output. In this case, a variable capacitance is converted to a variable frequency.

22. Insert a two-post connector in the BLOCK ENABLE position. The block enable connection supplies power to the circuit block.

23. Connect oscilloscope CH 1 to OUT and ground the probe to the GND jack.

24. Adjust the scope controls to view a square wave output from the Capacitance Sensor circuit block.

25. Slide the movable plate up and down while observing the scope.

    What happens to the waveform?
    a. The frequency changes.
    b. The amplitude changes.
    c. Both of the above.

26. Insert a two-post connector in the BLOCK ENABLE position of the Ultrasonic Transducers circuit block.

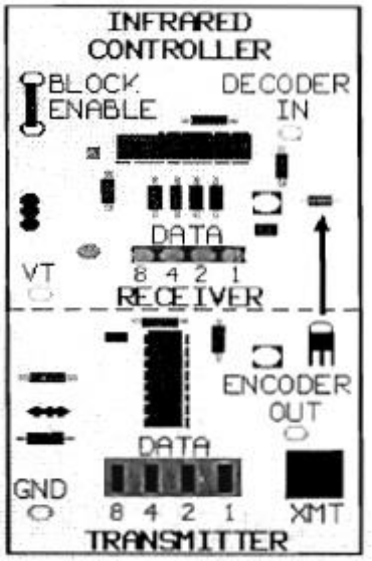
27. Connect the channel 1 oscilloscope probe to the left pin of the transmitter. Ground the scope probe to the GND jack.

28. Set channel 1 for 2 V/DIV and the sweep to 1 ms/DIV. Trigger on channel 1.

    What type of signal appears on the scope?
    a. square wave
    b. dc level
    c. short bursts of pulses

    You are viewing the ultrasonic bursts that the transmitter sends out to be echoed back to the receiver.

29. Remove the two-post connector from the Ultrasonic Transducers circuit block and in insert it into the BLOCK ENABLE position of the Infrared Controller circuit block.



    The Infrared Controller circuit block has both an input and an output transducer. The infrared LED is an output transducer. The infrared LED is an output transducer that converts electrical pulses into light pulses.

    The light sensor is an input transducer that senses infrared light pulses and converts them to electrical signals.

30. Observe the DATA LEDs in the Reciever section as you perform the following steps.

31. Set the DIP switches in the Transmitter section to 0000 (all switches down) and press the XMT button.

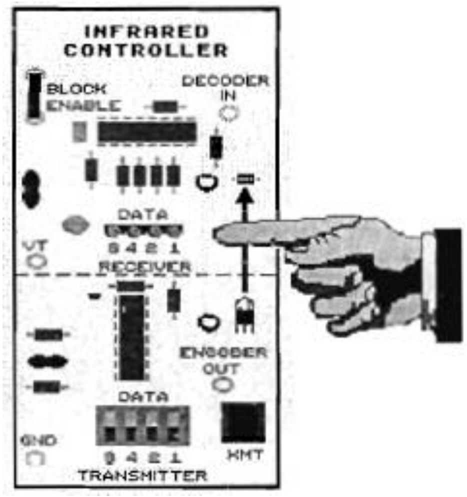
32. Set the DIP switches to 1111 (all switches up) and press XMT. You can see that each time you press XMT, the DIP switch code is sent to the DATA LEDs.

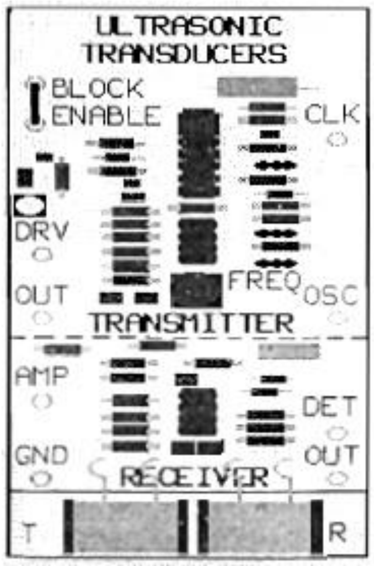
33. Place your finger on the circuit board at a point between the infrared LED and the light sensor.

34. Set the DIP switches to 0000 and press XMT. What can you conclude from the DATA LEDs?
    a. The code was received by the Receiver section.

b. The code was not received.
c. Only part of the code was received.

35. Remove the BLOCK ENABLE two-post connector from the Infrared Controller circuit block.





Conclusions:

36. Input transducers (sensors) convert a physical quantity into a proportional electrical signal.

37. Output transducers convert an electrical signal into a physical quantity that can be detected or used externally.

38. In some cases, you can directly measure a transducer's output parameter.

39. Transducers often require additional circuitry to amplify the output or to convert the output parameter to another form.

Review Questions:

40. A transducer converts:

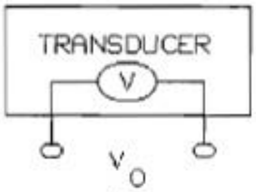
    a. temperature to resistance.
    b. force into current.
    c. position into voltage.
    d. one form of energy into another.

41. Which circuit block on the Transducer Fundamentals circuit board shows a schematic symbol of a transducer whose output is a change in resistance?

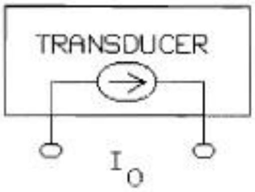
    a. Thermistor
    b. RTD
    c. Strain gauge
    d. All of the above

42. Which device on the Transducer Fundamentals circuit board is an output transducer?

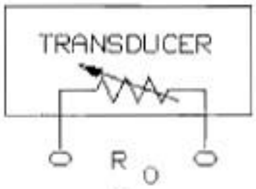
    a. strain gauge
    b. infrared LED
    c. RTD
    d. thermistor



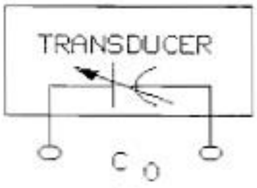
A



B



C



D

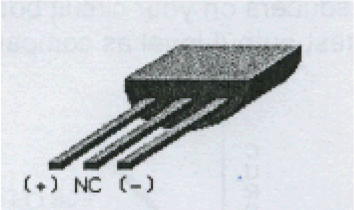
43. Which figure represents the output type for the IC temperature transducer?

    a. A
    b. B
    c. C
    d. D

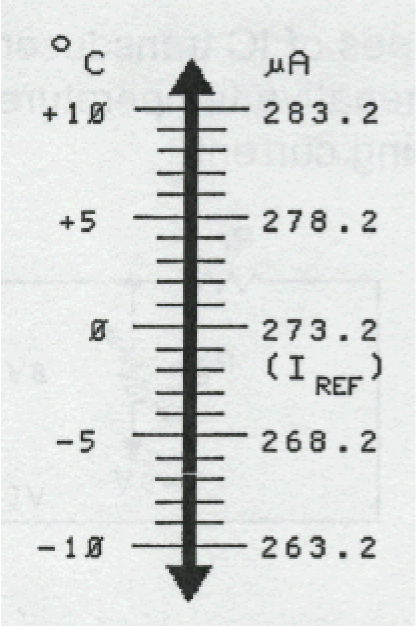
44. Which circuit block senses the position of an object by emitting pulses and measuring the time it takes for the pulses to echo back?

    a. Infrared Controller
    b. Capacitance sensor
    c. Ultrasonic transducer
    d. Strain gauge

Exercise 10: The IC Temperature Transducer



.
The 1C functions as a current source whose output current is a function of temperature.

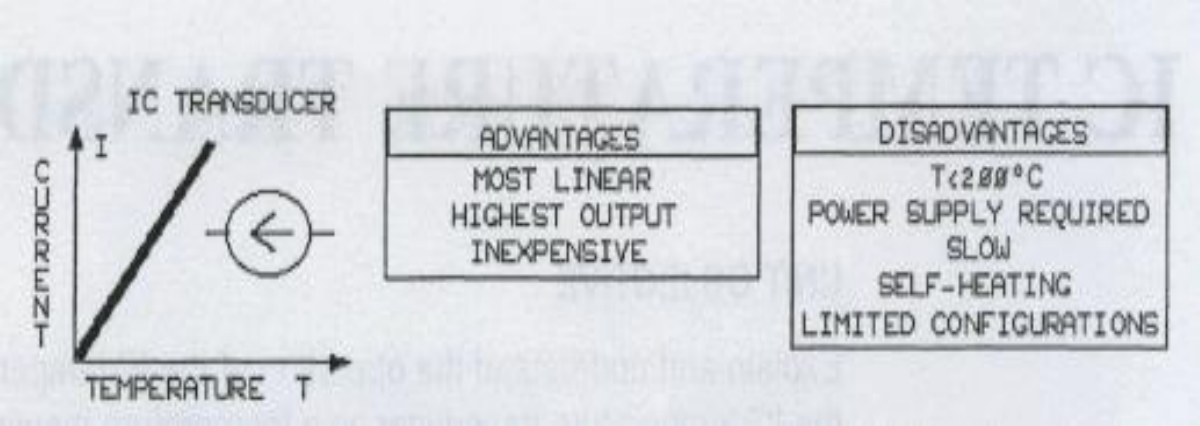


At a reference point of 0°C (the freezing point of water), the output current (|ref) is 273.2 µA.

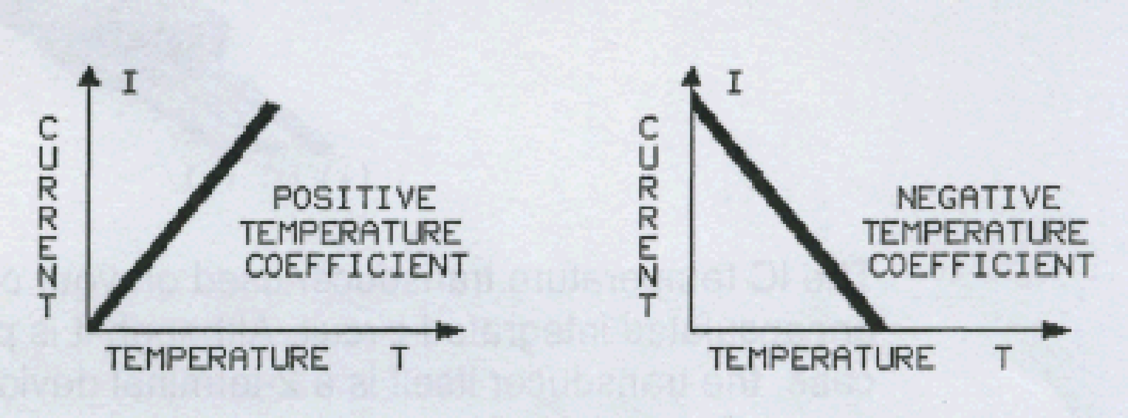
Every temperature transducer has a temperature coefficient that describes the way the transducer's characteristics change as temperature changes. The temperature coefficient a (the Greek letter alpha) of the 1C transducer on your circuit board is one micro amp per degree Celsius (α= 1 µA/°C).

A positive or negative temperature change from the 0°C reference point causes a positive or negative current change of 1 µA/°C.

For any temperature T, the current at that temperature (IT) may be expressed as follows: IT = (α x T) + 273.2 µA (where IT is in µA, T is in °C, and α = 1 µA/°C).



This figure shows the output characteristics, schematic symbol, and a list of advantages and disadvantages for the 1C temperature transducer. The advantages and disadvantages are relative to the other types of temperature transducers on your circuit board. For example, the 1C transducer has the highest output level as compared to the thermocouple, thermistor, and RTD.



The 1C temperature transducer on your circuit board has a positive temperature coefficient. This means that the transducer's temperature-dependent parameter (current) increases as temperature increase.

Other types of 1C transducers can have a negative temperature coefficient. With a negative temperature coefficient, increasing temperature causes decreasing current.

The major use of IC Transducers is to measure the temperature inside of electronic devices. Some of the electronic devices produce heat during operation like computers, variable speed drives. To control or monitor the temperature inside the devices IC transducers most widely used.

Objectives:

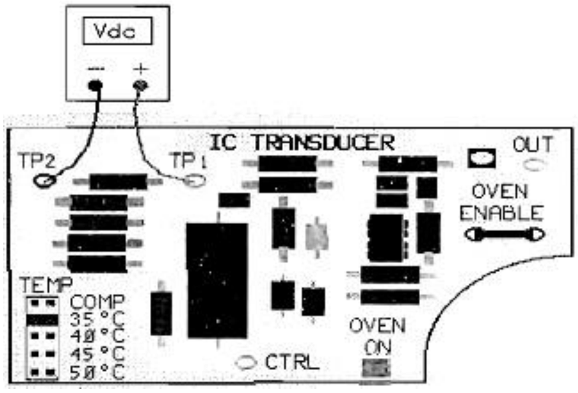
To be able to explain and demonstrate the use of a IC Temperature tramsducer in a temperature measurement application.

Equipment List:

Base unit
Transducer Fundamentals circuit board
Multi meter
Oscilloscope
Patch leads
Two-post connectors

Procedure:

In this procedure, you will make observations and measurements on the current-to-voltage converter section of the IC transducer circuit block.
The procedure also involves the use of the IC temperature transducer as an oven controller.



1 Set the multimeter for volts dc and connect the leads to TP1 (+) and TP2 (-).

2 Place the shunt on the TEMP header in the 35˚C position.

3 Insert a two-post connector in the OVEN ENABLE position.
The LED is:
a. on
b. off

The LED indicates the status of the oven heater. The LED is on when the heater is on and off when the heater is off.

You have turned on the oven with a set point of 35˚C in order to take a voltage reading at that temperature.

For an accurate reading, you must wait for the oven temperature to rise to 35˚C. When the oven reaches the set point, the LED will cycle on and off at a slow rate. Proceed to the next step while the oven is heating up.

4 Calculate the transducer current at 35˚C.

I_{AD} = ……………… μA

$I_T = (\alpha \times T) + 273.2\ \mu A$
Where T = set point temperature and α = 1 μA/˚C

$V_{OUT} = (T - 30˚C) \times 0.5\ V/˚C$

5 Calculate the op amp output voltage at 35˚C:

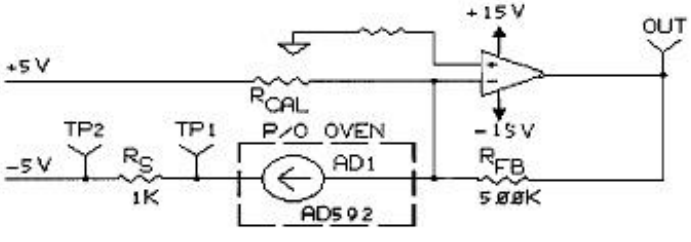
V_{OUT} = …………… Vdc

6 Observe the LED and make sure it completes several on/off cycles to confirm that the oven temperature has stabilized.

7 Read the meter just as the LED turns back on, and record the voltage across R_S:

VRS = ……………. mVdc

8 Determine the transducer current by using Ohm's law:



$I_{AD1} = I_{RS} = V_{RS} / R_S$

= …………… *mV / 1 kΩ*

= …………… *μA*

Use the measured voltage (V_{RS}) from step 7 for the calculation.

Is the value you determined from you V_{RS} measurement close to your calculated value (Step4) ?

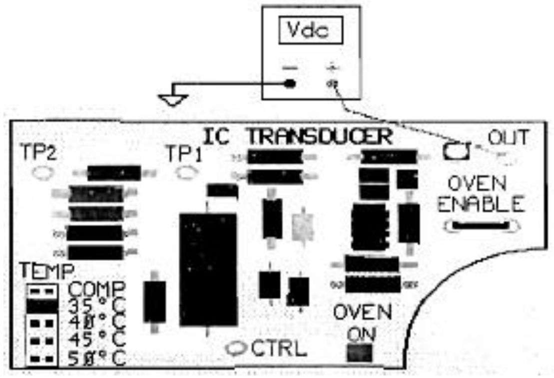
a. yes
b. no

9 Connect the + meter lead to OUT and the – lead to a circuit ground point.

10 Measure the circuit output voltage at 35˚C:

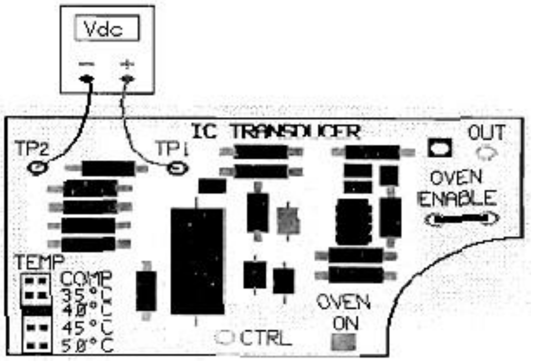
V_{OUT} = ……………… Vdc

Is the value you measured close to your calculated value (Step5)?
a. yes
b. no



11 Move the TEMP shunt to the 40˚C position. The oven temperature is now rising toward 45˚C.

12 Connect the meter leads to TP1 (+) and TP2 (-).



13 Calculate the transducer current at 40 ˚C:

I_{AD1} = ……………… μA

$I_T = (\alpha \times T) + 273.2\ \mu A$
Where T = set point temperature and
$\alpha = 1\ \mu A/˚C$

$V_{OUT} = (T – 30˚C) \times 0.5\ V/˚C$

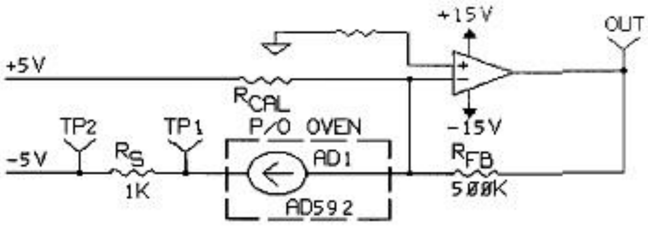
14 Calculate the op amp output voltage at 40˚C:

V_{OUT} = ……………… Vdc

15 Observe the LED and make sure it completes several on/off cycles. Read the meter just as the LED turns back on and record the voltage across R_S:

V_{RS} = ……………… mVdc

16 Determine the transducer current by using Ohm's law:



$I_{AD1} = I_{RS} = V_{RS} / R_S$

$= \ldots\ldots\ldots\ldots mV / 1\ k\Omega$

$= \ldots\ldots\ldots\ldots \mu A$

Use the voltage measurement (V_{RS}) from step 15 for this calculation.

Is this value close to your calculated value (Step13)?

a. yes
b. no

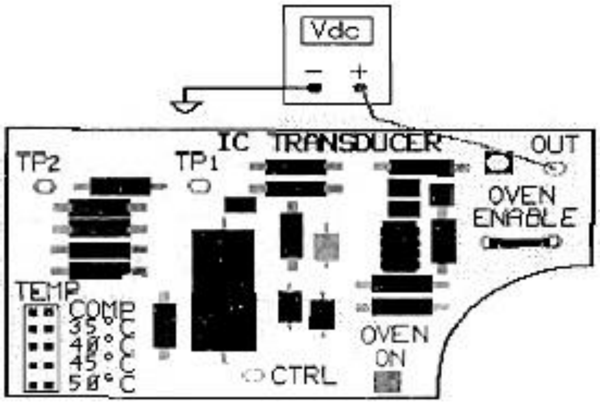
17 Connect the + meter lead to OUT and the – lead to a circuit ground point.

18 Measure the circuit output voltage at 40˚C:

V_{OUT} = ……………… Vdc

Is the voltage you measured close to your calculated value (Step14) ?

a. yes
b. no

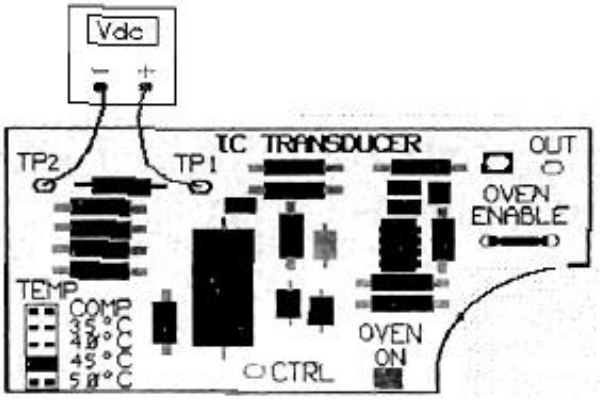


19 Move the TEMP shunt to the 45˚C position. The oven temperature is now rising toward 45˚C.

20 Connect the meter leads to TP1 (+) and TP2 (-).

21 Calculate the transducer current at 45˚C:

I_{AD} = ……………… μA



$I_T = (\alpha \times T) + 273.2\ \mu A$
Where T = set point temperature and α = 1 μA/˚C

$V_{OUT} = (T – 30˚C) \times 0.5\ V/˚C$

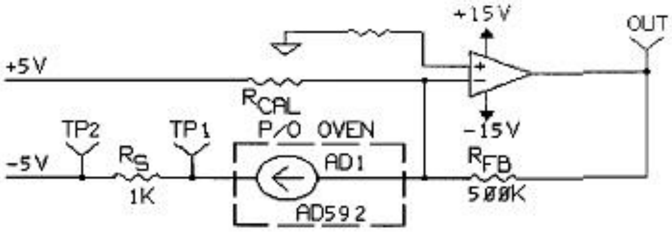
22 Calculate the op amp output voltage at 45˚C:

V_{OUT} = ……………… Vdc

23 Observe the LED and make sure it completes several on/off cycles. Read the meter just as the LED turns back on and record the voltage across RS:

V_{RS} = ……………… mVdc

24 Determine the transducer current by using Ohm's law:



$I_{AD1} = I_{RS} = V_{RS} / R_S$

= ………… *mV / 1 kΩ*

= ………… *μA*

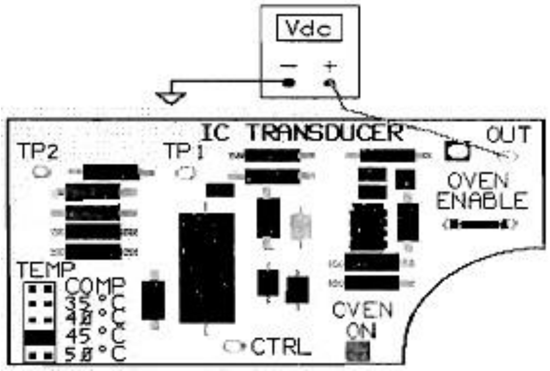
Use the measured voltage (V_{RS}) from step 23 for the calculation.

Is the value you determined from your VRS measurement close to your calculated value (Step12)?

a. yes
b. no

25 Connect the + meter lead to OUT and the – lead to a circuit ground point.

26 Measure the circuit output voltage at 45˚C:

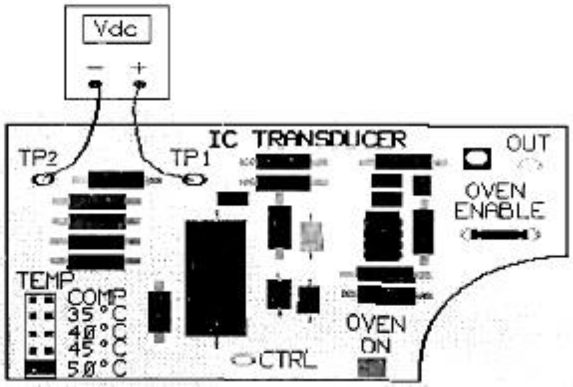


V_{OUT} = ……………… Vdc

Is the value you measured close to your calculated value (Step22)?

a. yes
b. no

27 Move the TEMP shunt to the 50˚C position. The oven temperature is now rising toward 50˚C.



28 Connect the meter leads to TP1 (+) and TP2 (-).

29 Calculate the transducer current at 50˚C:

I_{AD} = ……………… μA

$I_T = (\alpha \times T) + 273.2\ \mu A$

Where T = set point temperature and α = 1 μA/˚C

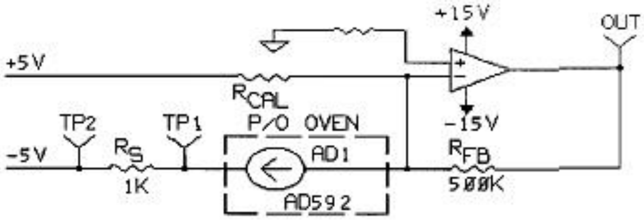
$V_{OUT} = (T – 30˚C) \times 0.5\ V/˚C$

30 Calculate the op amp output voltage at 50˚C:

V_{OUT} = ……………… Vdc

31 Observe the LED and make sure it completes several on/off cycles. Read the meter just as the LED turns back on and record the voltage across R_S:

V_{RS} = ……………… mVdc



32 Determine the transducer current by using Ohm's law:

$I_{AD1} = I_{RS} = V_{RS} / R_S$

= ……….. $mV / 1\ k\Omega$

= ……….. μA

Use the measured voltage (V_{RS}) from step13 for the calculation.

Is the value you determined from your V_{RS} measurement close to your calculated value (Step29)?

a. yes
b. no

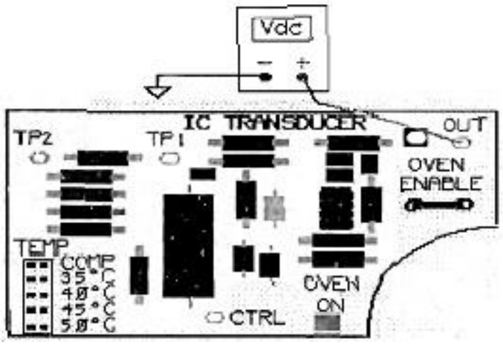
33 Connect the + meter lead to OUT and the – lead to a circuit ground point.

34 Measure the circuit output voltage at 50˚C:

V_{OUT} = ……………… Vdc

Is the value you measured close to your calculate calculated value (Step30)?

a. yes



b. no

35 Remove the two-post connector from the OVEN ENABLE jacks.

Temperature (˚C)	Transducer Current (µA)
35	
40	
45	
50	

Write the IC temperature transducer currents you determined at the four oven set points into the table (Step 8, 16, 24, and 32)

What transducer characteristic(s) can you recognize from the data?

a. positive temperature coefficient
b. linear response
c. both of the above

Write down the voltages you read at the output of the current-to-voltage converter at the four oven set points into the table (Steps 10, 18, 26, and 34).

Does your data confirm that the circuit's conversion factor is about 0.5 V/˚C?

a. yes
b. no

Conclusions

36 The IC transducer outputs a current that is a function of temperature.

37 The IC transducer has a linear response.

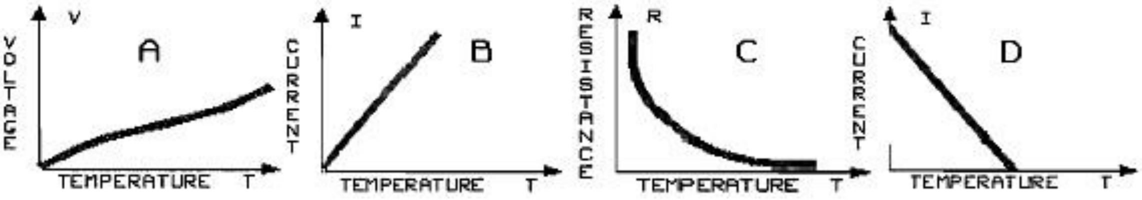
38 The IC transducer in you circuit board has a positive temperature coefficient (current increases as temperature increases).

39 You can use a current-to-voltage converter to obtain a voltage that is proportional to the IC transducer's temperature.

40 You can measure the IC transducer's current or the converter's output voltage to determine temperature.

Review Questions

41 What parameter of the IC temperature transducer on your circuit board changes with temperature?
    a. resistance.
    b. voltage
    c. current
    d. capacitance

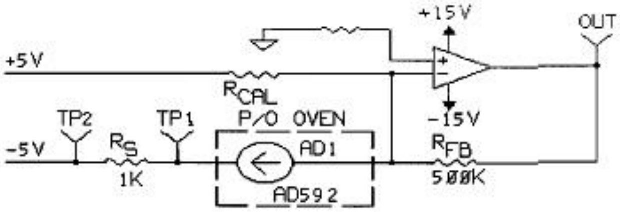


42 Which figure shows the response of the IC temperature transducer on your circuit board?
    a. A
    b. B
    c. C
    d. D

$I_T = (\alpha \times T) + 273.2\ \mu A$
Where T = set point temperature and α = 1 μA/˚C

43 What is the IC transducer's output current (IT) at -17˚C?
    a. 256.2 μA
    b. 290.2 μA
    c. 273.2 μA
    d. -17 μA

44 In this circuit, you can determine temperature by measuring
    a. the op amp output voltage.
    b. the voltage across R_S.
    c. The op amp input voltages.
    d. either a. or b.

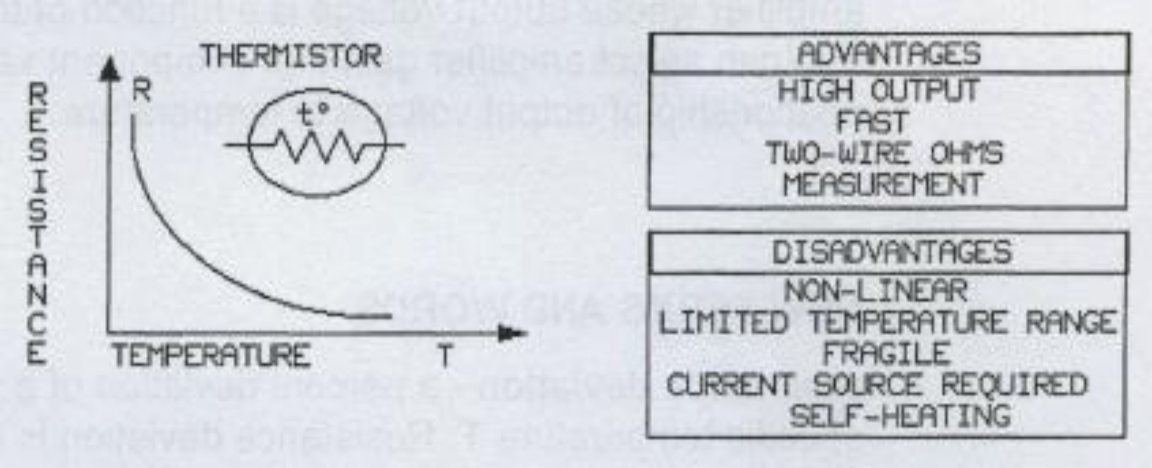


45 From the response curve, you can determine that the IC temperature transducer has a
    a. current output that is a function of temperature.
    b. positive temperature coefficient.

c. linear response.
d. all of the above

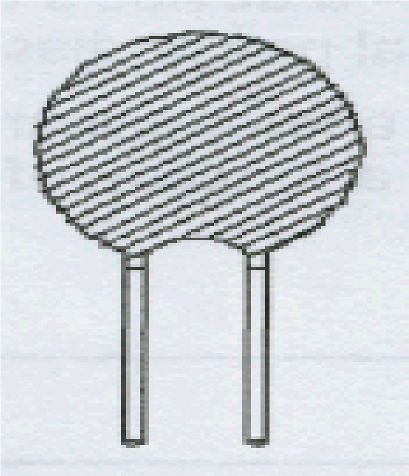
Exercise 11: Introduction to Thermistor

A thermistor is a two-wire temperature transducer whose resistance is a function of temperature. The thermistor's schematic symbol is similar to that of a resistor, except that the symbol t° is used to indicate temperature dependence.



Although most thermistors , including the one on your circuit board, have a negative temperature coefficient, positive types are also available.
Thermistors are popular temperature transducers because of their high output, or relatively large resistance change per degree.

Self-heating is a disadvantage for several temperature transducers, including thermistors. Self-heating is a device's tendency to heat up beyond its surrounding (ambient) temperature due to its own power dissipation.



Mostly thermistor used to measure/monitor the temperature of big motors winding.

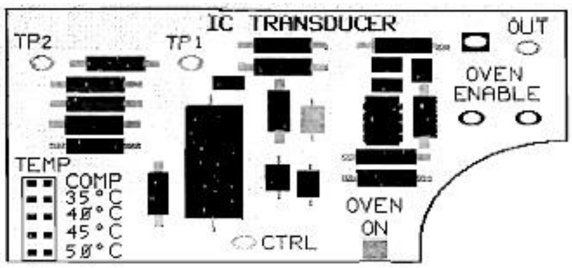
Objective:

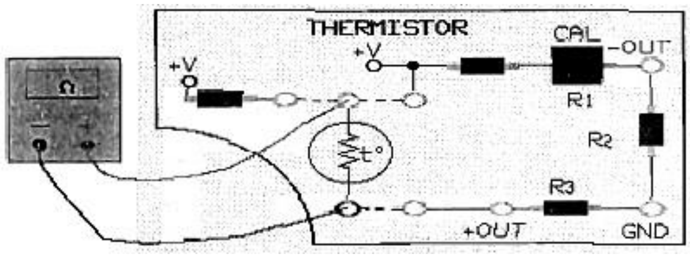
To be able to describe and demonstrate the characteristics of thermistors.

Procedure:

In this procedure, you will measure the thermistor's resistance at several temperatures and compare your results to values calculated from the RT table. You will demonstrate the effect of self-heating on the thermistor's resistance.

1. In the following steps, you will measure the thermistor's resistance at room temperature. Make sure there is **not** a two-post connector in the OVEN ENABLE position in the IC transducer circuit block. If the oven has recently been on, allow it to cool down to room temperature.





3 Set your multimeter to measure ohms, and connect the leads across the thermistor. There should be no two-post connectors in the Thermistor circuit block.

4 Record the thermistor's room-temperature resistance value (R_{RT}).

R_{RT} = ……………… kΩ

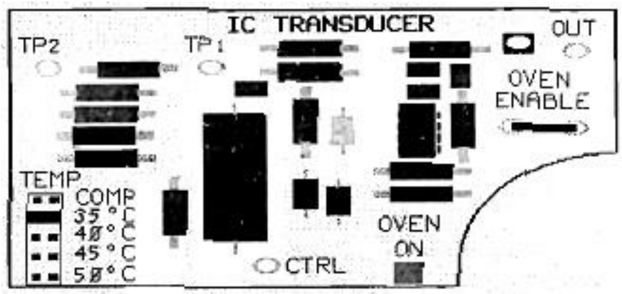
Room temperature is typically 25˚C, but can range between 15˚C and 35˚C. The corresponding resistance range is 6.531 kΩ. Does your measurement fall in this range?

5 a. yes
b. no

If the table were expanded to 1˚C intervals , you could use your measured value to find the exact temperature in the table.

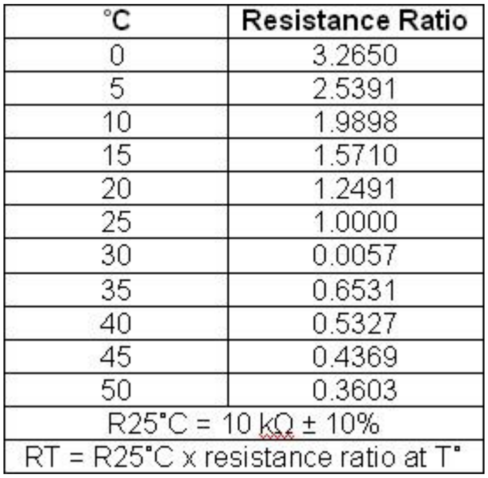
6 Place a shunt in the 35˚C position in the IC transducer circuit block and insert a two-post connector in the OVEN ENABLE position.

Complete the following steps as you allow the oven to reach its set point temperature.



7 Calculate the thermistor's resistance at 35˚C:

$R_{35^\circ C}$ = ……………… kΩ

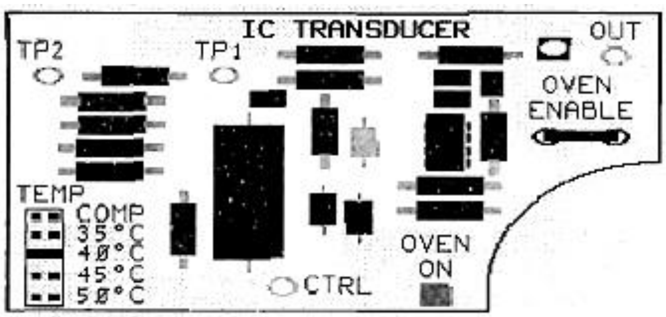


˚C	Resistance Ratio
0	3.2650
5	2.5391
10	1.9898
15	1.5710
20	1.2491
25	1.0000
30	0.0057
35	0.6531
40	0.5327
45	0.4369
50	0.3603
R25˚C = 10 kΩ ± 10%	
RT = R25˚C x resistance ratio at T˚	

8 Observe the LED and make sure it completes several on/off cycles to make sure the oven has reached the set point.

9 Measure the thermistor's resistance at 35˚C:

$R_{35^\circ C}$ = ……………… kΩ

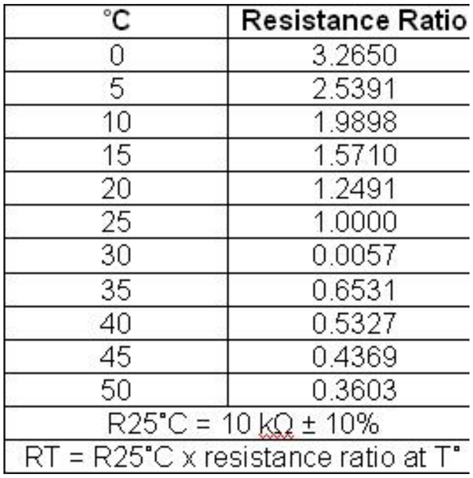


10 Move the TEMP shunt to the 40˚C position. Complete the following steps as you allow the oven temperature to rise to the new set point.

11 Calculate the thermistor's resistance at 40˚C:

$R_{40^\circ C}$ = ……………… kΩ

12 Observe the LED and make sure it completes several on/off cycles to make sure the oven has reached the set point.



°C	Resistance Ratio
0	3.2650
5	2.5391
10	1.9898
15	1.5710
20	1.2491
25	1.0000
30	0.0057
35	0.6531
40	0.5327
45	0.4369
50	0.3603
R25°C = 10 kΩ ± 10%	
RT = R25°C x resistance ratio at T°	

13 Measure the thermistor's resistance at 40˚C:

$R_{40^\circ C}$ = ……………… kΩ

14 Move the TEMP shunt to the 45˚C position. Complete the following steps as you allow the oven temperature to rise to the new set point.

15 Calculate the thermistor's resistance at 45˚C:

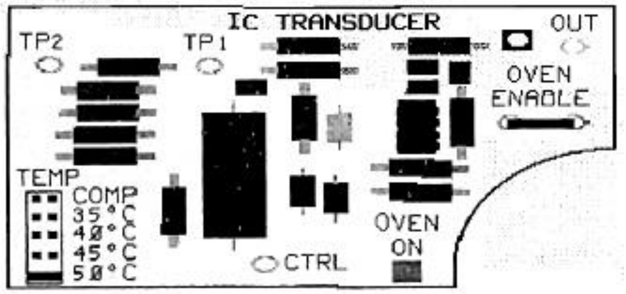
$R_{45^\circ C}$ = ……………… kΩ

16 Observe the LED and make sure it completes several on/off cycles to make sure the oven has reached the set point.

17 Measure the thermistor's resistance at 45˚C:

$R_{45^\circ C}$ = ……………… kΩ

18 Move the TEMP shunt to the 50˚C position. Complete the following steps as you allow the oven temperature to rise to the new set point.



19 Calculate the thermistor's resistance at 50˚C:

$R_{50^\circ C}$ = ……………… KΩ

20 Observe the LED and make sure it completes several on/off cycles to make sure the oven has reached the set point.

21 Measure the thermistor's resistance at 50˚C

$R_{50^\circ C}$ = ……………… KΩ

22 Turn off the oven by removing the two-post connector from the IC transducer circuit block.

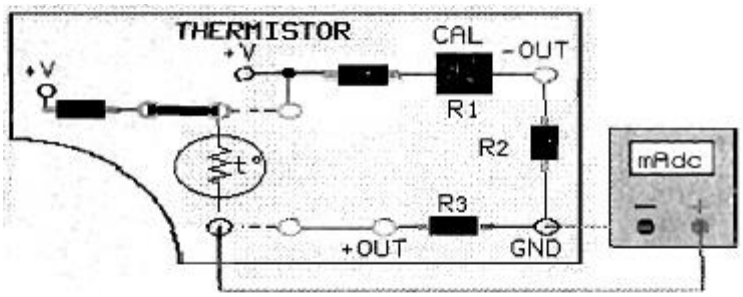
TEMP.	R (calculated)	R (measured)	Δ R
35˚C			-----
40˚C			
45˚C			
50˚C			

23 Record your calculated and measured resistance values for the four set points in the table.

Are the calculated and measured values about the same at each temperature?
a. yes
b. no

From this data you can conclude that the thermistor
a. has a negative temperature coefficient.
b. is non-linear.
c. Both of the above.

24 The following procedure steps require the oven to be at room temperature. Make sure there is no two-post connector in the OVEN ENABLE position in the IC transducer circuit block. Allow the oven to cool down if necessary.



25 Set the multimeter to measure dc milliamps and connect the leads between the thermistor (+) and the GND (-) jack as shown.

26 Insert a two-post connector in the position shown.

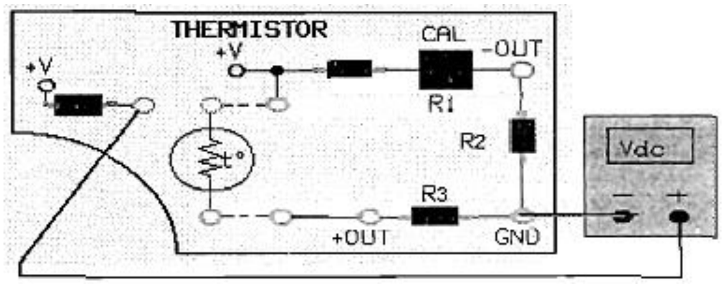
This configuration connects +V (+15Vdc) through a 1.2 kΩ resistor, the thermistor, and the milliammeter to ground.

27 The following steps require that current flows through the thermistor for at least one minute.

Time a one minute interval before continuing to the next step.

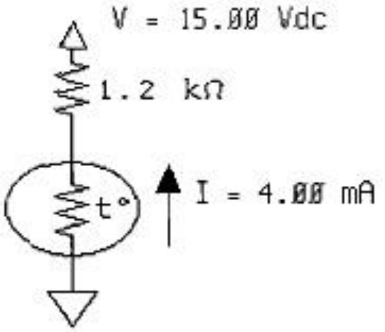
28 Read the thermistor current:

I_{TH} = ……………… mA



29 Disconnect the + meter lead and set the meter for Vdc. Remove the two-post connector and connect the + meter lead as shown.

30 Measure the supply voltage:



+V = ……………… Vdc

You measured the supply voltage and the thermistor current, which equals the current through the series circuit. The total resistance is 1.2 kΩ plus the thermistor resistance (R_{TH}). You can apply the following Ohm's law equation:

$R = E / I$

$R_{TH} + 1.2\ k\Omega = V / I_{TH}$

31 Rearrange the equation to solve for the thermistor resistance.

$R_{TH} = (V / I_{TH}) - 1.2\ k\Omega$

= ……………… kΩ

You initially measured the thermistor resistance of ……………. kΩ at room temperature. After current flowed trough the thermistor for one minute, you calculated a resistance of ……………. kΩ. The resistance is greater after one minute because:

a. of self-heating.
b. the oven controller raised the oven temperature.
c. the oven controller lowered the oven temperature.

Conclusions:

32 A thermistor is a semiconductor temperature transducer whose resistance is a function of temperature.

33 A thermistor's response is non-linear.

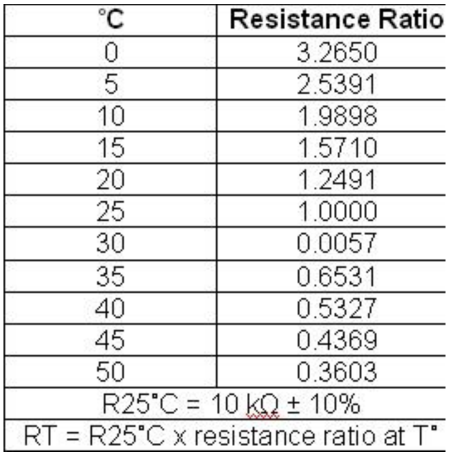
34 The thermistor on your circuit board has a negative temperature coefficient (resistance decreases as temperature increases.

35 At a given temperature, you can use an RT table to determine the thermistor's resistance and temperature coefficient.

Review Questions:

36 The resistance of the thermistor on your circuit board decreases as temperature increases because of its:
   a. non-linearity.
   b. resistance deviation.
   c. negative temperature coefficient.
   d. positive temperature coefficient.

37 At a specific temperature what parameter can you look up in a thermistor's RT table?
   a. resistance
   b. resistance ration
   c. resistance deviation
   d. temperature coefficient



°C	Resistance Ratio
0	3.2650
5	2.5391
10	1.9898
15	1.5710
20	1.2491
25	1.0000
30	0.0057
35	0.6531
40	0.5327
45	0.4369
50	0.3603
R25°C = 10 kΩ ± 10%	
RT = R25°C x resistance ratio at T°	

38 A thermistor's tendency to heat up beyond its ambient temperature is due to
   a. its temperature coefficient.
   b. self-heating.
   c. non-linearity.
   d. resistance deviation.

39 What is the thermistor's resistance at 0°C?
   a. 0 kΩ
   b. 0.3265 kΩ
   c. 3.265 kΩ
   d. 32.65 kΩ

Unit 2: Optoelectronics

Lesson 3: Fiber Optic Devices

Light Transmitters - High Efficiency LED

:

Optoelectronic devices have been designed to be compatible with optic fiber terminations. Special LED's have been developed with physical access to the primary area of light radiation. The substrate material is Gallium Arsenide, the same semiconductor that is used for indicator LED's and Bar graphs.

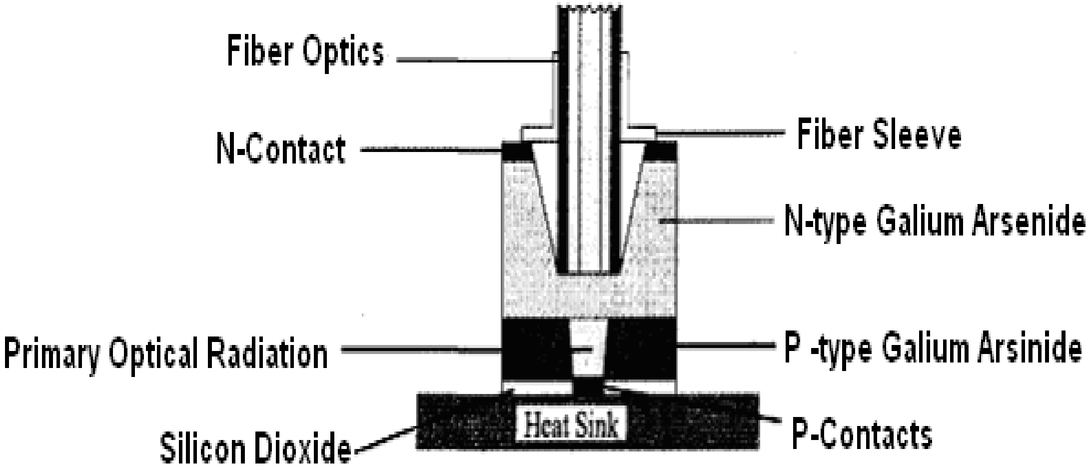


Fig L3.1

Exercise 12: Phototransistor

Introduction:

A phototransistor can be used as a photo detector to sense the light level and, for example, control a lamp via a comparator and driver.
The amplifier A is used to improve the sharpness of switching.
The phototransistor responds to the light falling upon it, the leakage current decreasing as the lighl level reduces. Reduced current causes the voltage across VR2 to fall. This output voltage, generated by the phototransistor, is compared with the reference voltage (vref = 2.5V) in the Comparator C. If the voltage falls low then the Comparator output switches high, and energizes the Driver to supply the Lamp with 12V.
The circuit remains the same as discussed earlier for a lamp load using a phototransistor. as discussed earlier in exercise 12.1

Objective: To study the function and trouble shooting of a phototransistor circuit:

Discussion:

The leakage current of a transistor On increases if the semiconductor material is exposed lo light irradiation. This current flows in the base-emiller junction of the transistor and is amplified by the current gain of the transistor.

A load resistor, connected in series with the transistor, will develop a voltage across it that will vary with the leakage current (lowing, and therefore be proportional to the light fading upon the phototransistor.

The operational amplifier output switches to negative saturation voltage thereby removing the drive to the base of the driver transistor.

This in turn makes the relay off and the lamp is off.

This proves that in presence of light the lamp is off.

Equipment:

No.	Description	Quantity
1	IC 741, relays, lamp	1
2	Resistor Re 300 kΩ	2
3	Resistor R 600 kΩ	1
4	Multimeter	1
5	Phototransistor	1
6	Transistor BC 147	1
7	Breadboard , connecting wires	1

Circuit Diagram:

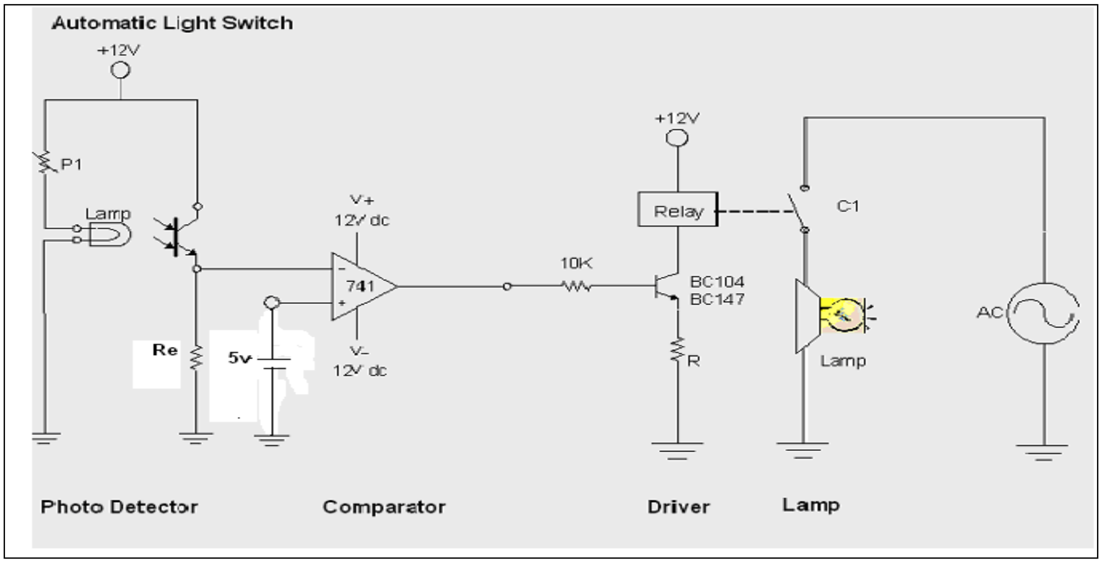


Figure 12.1

Caution!
Do not short the IC pins while testing the test points

Procedure:

1) Measure the voltage across Re in the presence of ambient light.
2) Measure the voltage drop across Re with the base of transistor fully covered.
3) Measure the voltage drop across Re with the base of transistor fully exposed to lamp fully lit.

Note and record the voltage as indicated on the multi meter under ambient lighting conditions (that is, without the optical fiber plugged in) in Table 12.1.

Observation Table:

With Ambient Light V	Covered V	Driven by LED V

Table 12.1

Conclusion :

Trouble Shooting of a Photo Transistor Circuit:

Circuit Diagram

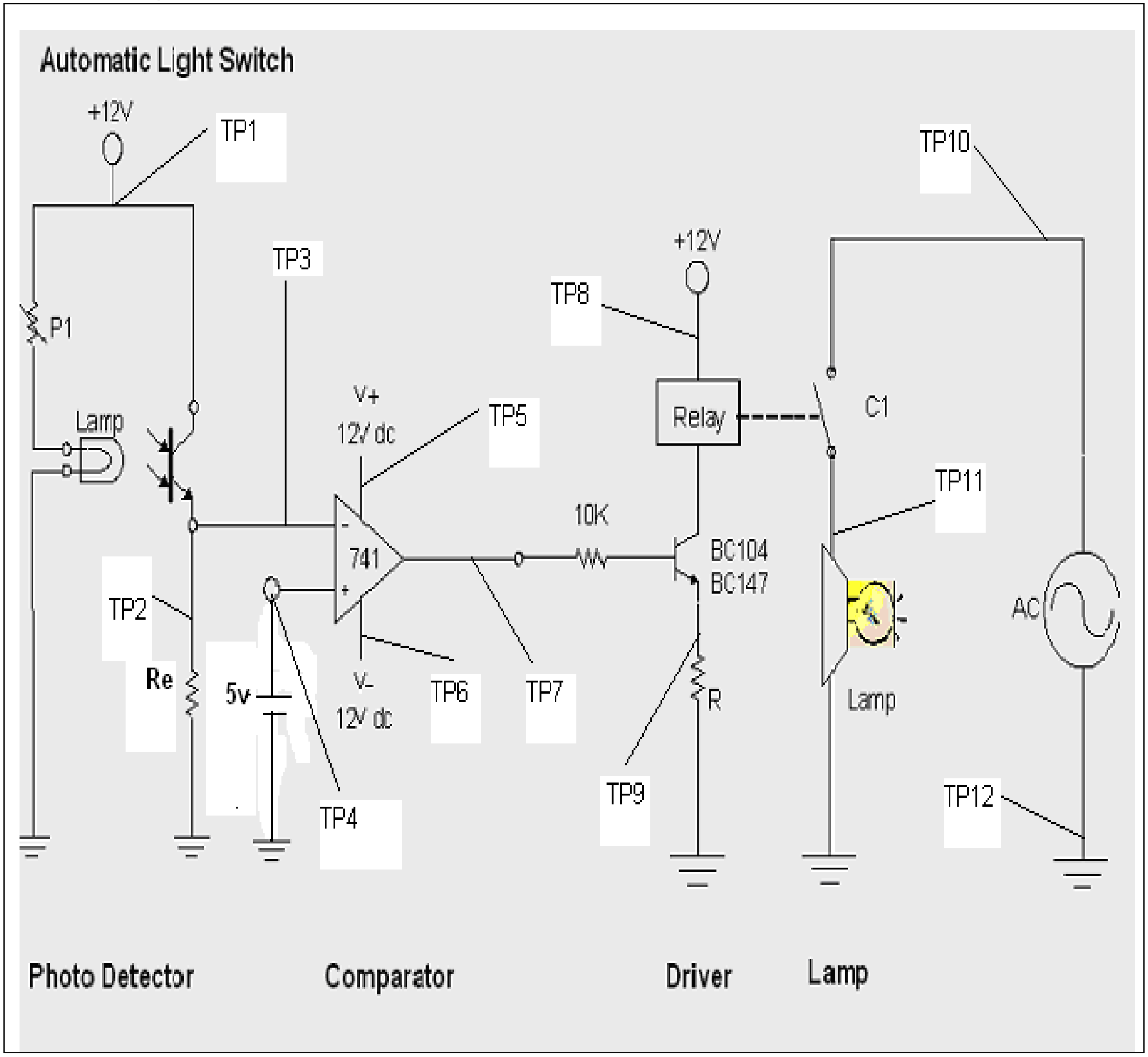


Fig: 12.2

Procedure:

1. Assemble the circuit on the bread Board as shown in figure 12.2

2. Several test points are shown in the circuit.

3. Adjust the sensitivity at the ambient temperature.

4. Without further disturbing the settings make a record of standard signals on mentioned test points.

5. Complete the schedule for diagnosis table 12.2

Introduce faults and take one more set of reading.

Compare and identify the area of fault

Observation table

No.	Test Points	Voltage Readings	
		@ Normal Conditon V	@ Faulted Condition V
1	TP1		
2	TP2		
3	TP3		
4	TP4		
5	TP5		
6	TP6		
7	TP7		
8	TP8		

Table 12.2

Conclusion:

Type of Fault --

Action Taken --

.

Exercise 13: Infra-Red Link

Objective: To study and trouble shoot a Infra Red Link and Batch Counter.

Discussion:

Figure 14.1 shows a infrared LED transmitter and a infrared photodetector circuit.In the presence of objects It will obstruct the base drive of the transistor.
The output is monitored across the Resistor connected in the emitter terminal of photodetector.Thus if the output is observed on CRO or on multimeter it has two stages either ON or OFF.
This can further be used as a clock input to the counting circuit**.**

Equipment:

No.	Description	Quantity
1	Infra red LED	1
2	Resistor 330 kΩ	2
3	Resistor 10 kΩ	1
4	Multimeter	1
5	Photo transistor	1
6	Power supplies	1
7	Breadboard	1
8	Connecting wires	-

:

Circuit Diagram:

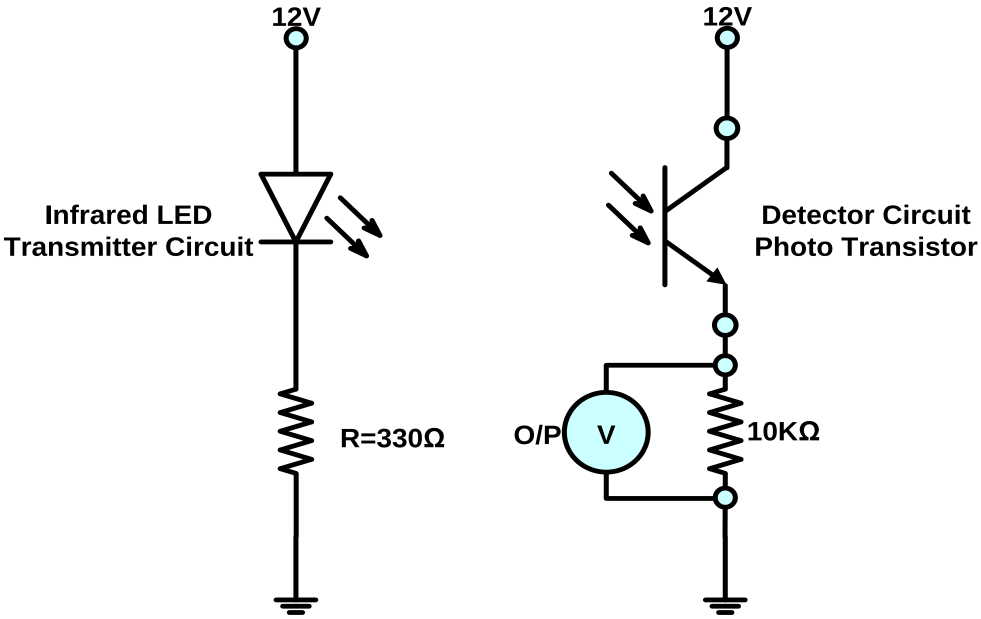


Figure 13.1

Caution!

Do not short the IC pins while testing the test points

Procedure:

1. Connect the circuit shown in figure 13.1 on the bread Board.
2. Supply voltage of 12 v is to be used.
3. The resistor is connected to the transmitter and detector circuit.
4. Output is monitored by obstructing the emitted radiation from transmitter.
5. Operation of detector circuit is tested.
6. Complete the observation table 13.1 below.

Observation table:

Observation number	Infrared Transmitter	Output volts	remarks
1	Off		
2	On		

Table 13.1

Conclusions:

The output measured is ------------------------- (transmitter off)

The output measured is ------------------------- (transmitter on)

Trouble shooting of infra red link circuit:

Connection Diagram:

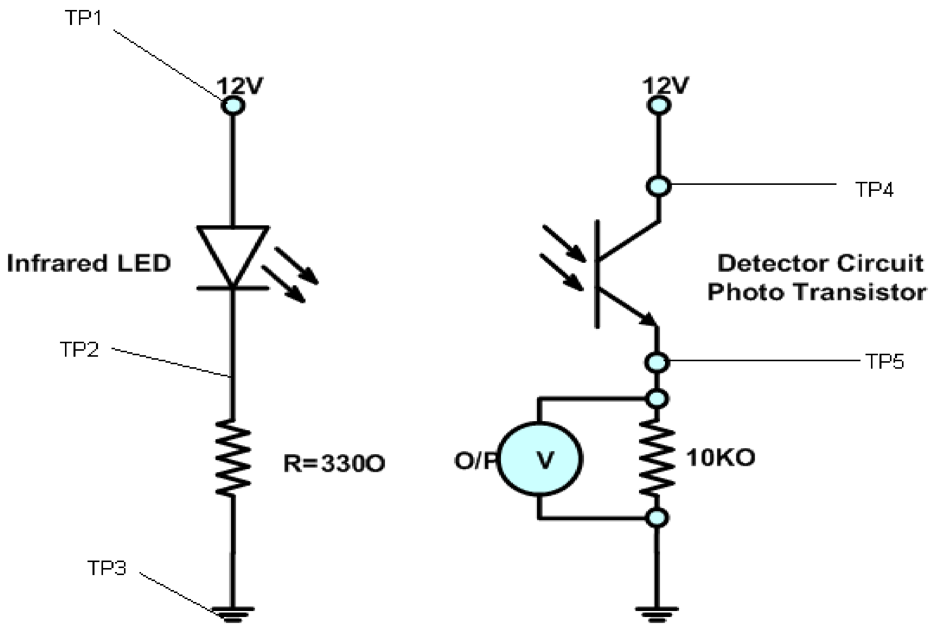


Figure 13.2

Procedure:

1. Assemble the circuit as shown in figure 13.2 in fully working condition.
2. Measure voltages at given test points.
3. Make a note in the diagnosis table 13.2
4. Introduce a fault into the circuit and make a note of readings after fault
5. Compare the values before and after fault

Diagnosis Table :

No.	Test Points	Voltage Readings

		@ Normal Conditon v	@ Faulted Condition v
1	TP1		
2	TP2		
3	TP3		
4	TP4		
5	TP5		

Table 13.2

Conclusion:

Type of Fault ------------------------------------

Action Taken -----------------------------------

Exercise 14 : Infra Red Batch Counter:

Objective : To verify and trouble shoot a Infra Red Batch Counter **.**

Discussion: The output of the detector stage is coupled to a binary/decade counter circuit. Every batch at the input of detector results in a clock pulse at the output of emiiter in detector. This clock pulse provides a trigger input to the decade counter and advances the count by one each time. This is indicated on the display.

Procedure:

1. As seen in the circuit diagram 14.1,
2. The first stage is infra red link that produces pulses at the emitter of detector stage depending on the presence of object.
3. The second stage is a BCD counter which keeps advancing its counts based on clock pulse received from 1st stage.
4. The third stage is a LCD/LED driver.
   Depending on the output of decade counter according to 8421 code, it will produce the output to drive the LCD.
5. The 4th stage is display unit**.**

Equipment:

No.	Description	Quantity
1	IC 741, relays, lamp	1
2	Resistor Re 300 kΩ	2
3	Resistor R 600 kΩ	1
4	Multimeter	1
5	Phototransistor	1
6	Transistor BC 147	1
7	Breadboard	1
8	Connecting wires	-

Circuit Diagram:

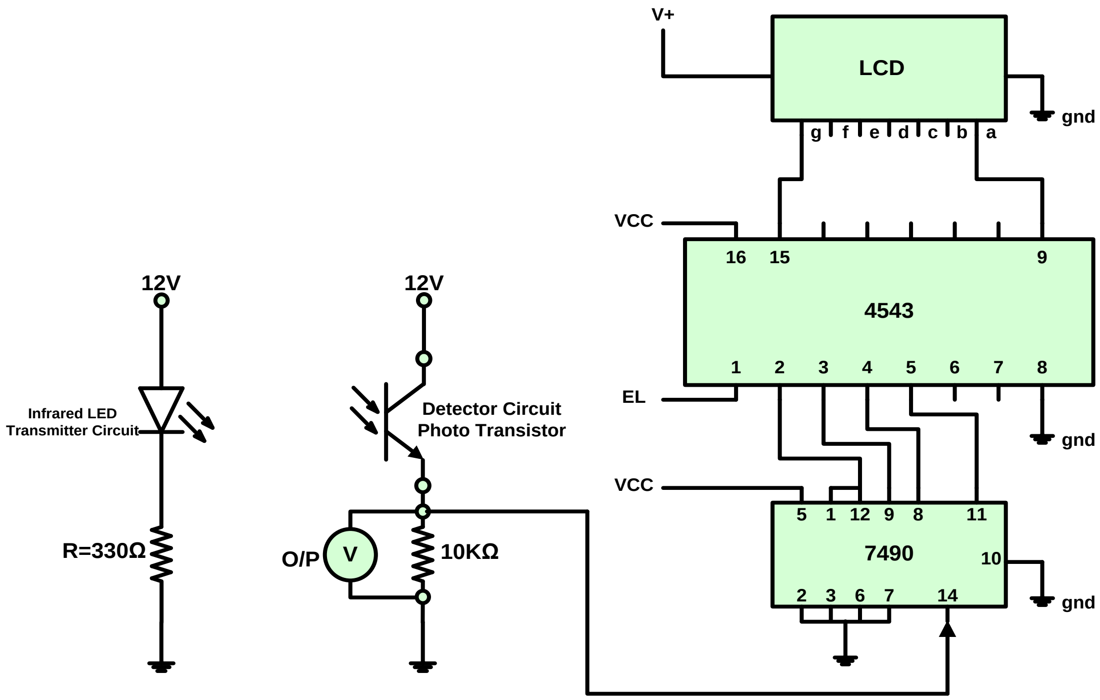


Fig 14.1

Caution!
Do not short the IC pins while testing the test points

Observation Table:

Measure the supply voltages at the transmitter circuit = ------------------- volts

Measure the voltages at the detector circuit = ------------------- volts

Measure the voltage on IC 7490 = ------------------ volts

Measure the voltage on IC 4543 = ------------------ volts

Measure the voltage on LCD = ------------------ volts

By obstructing the path of the transmitter circuit and removing the change in the output voltage indicated on the voltmeter is observed.

This acts as a clock input to the decade counter stage.

Conclusion:

The operation of the batch counter is verified for --------------- inputs

Note: These are the supply voltages and needs to be adjusted once.
Care is to be taken to ground all the earth terminals. Never attempt to short the terminals of power supply

Troubleshooting of Batch Counter:

Cicruit Diagram:

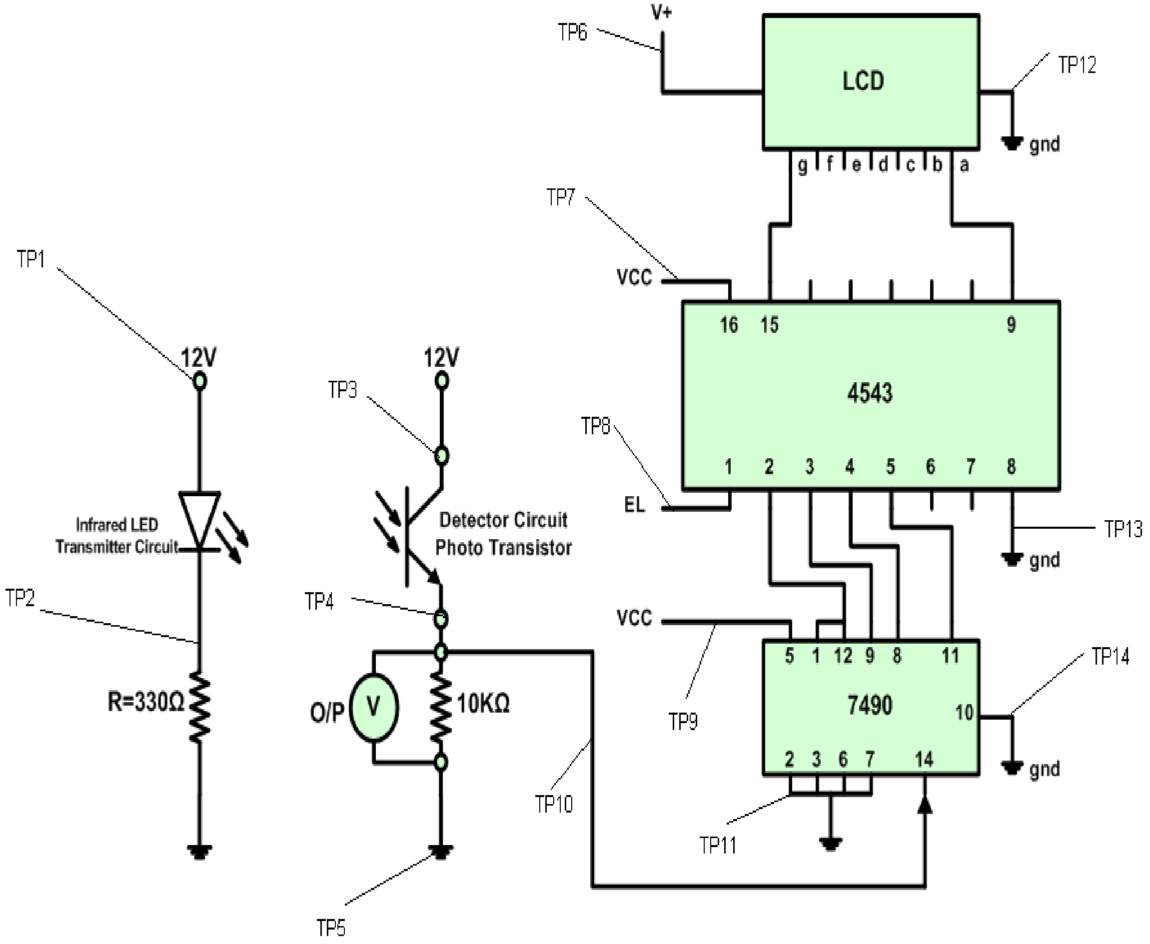


Figure 14.2

Procedure:

1. Assemble the ckt in fully working condition as shown in figure 14.2.
2. Measure voltages at given test points.
3. Make a note in the diagonisis table 14.3
4. Introduce a fault into the circuit and make a note of readings after fault
5. Compare the values before and after fault

No.	Test Points	Voltage Readings	
		@ Normal Conditon V	@ Faulted Condition V
1	TP1		
2	TP2		
3	TP3		
4	TP4		
5	TP5		
6	TP6		
7	TP7		
8	TP8		
9	TP9		
10	TP10		
11	TP11		
12	TP12		

Table 14.3

Conclusion:

Type of Fault --
Action Taken --

Lesson 4 : Introduction to Burglar Alarm System

Objective: To be able to understand the basic principles of burglar alarm system.

Discussion:

Figure L5.1 discusses the basic building blocks for a burglar alarm. The purpose of a burglar alarm is security. It must, therefore, itself, be secure. The cunning burglar can soon become aware of the presence of infrared rays protecting possible entrances. If a change in direct voltage at the output of the infrared detector is used to activate the alarm, the system can easily be over- ridden by shining a simple light source of sufficient power onto the detector.

Block diagram:

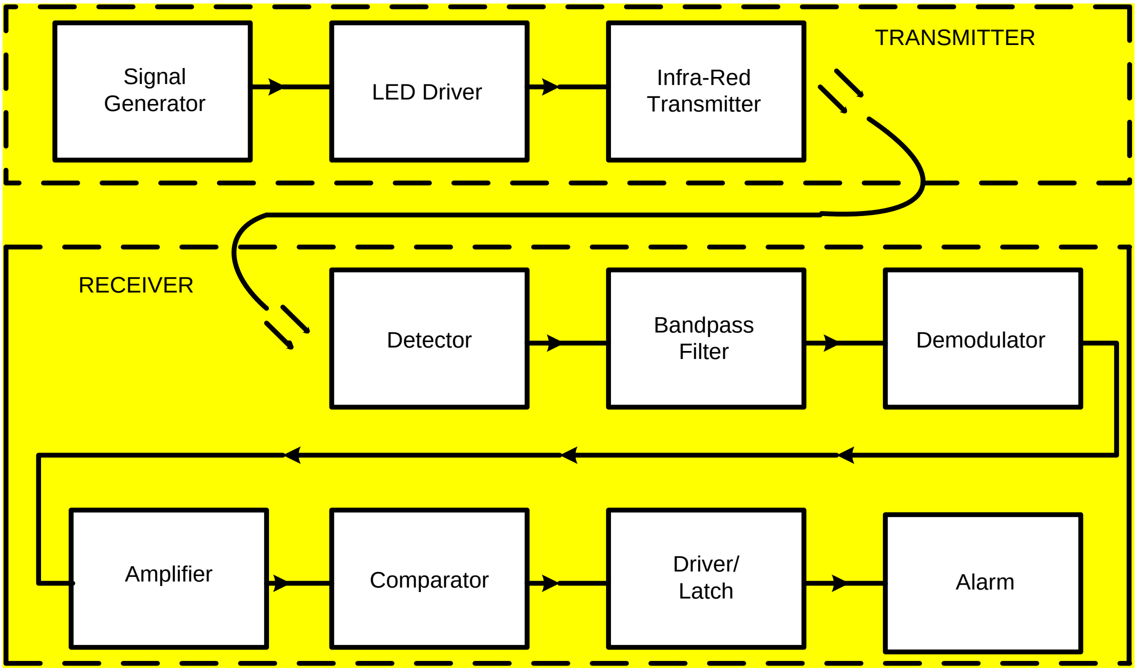


Fig L4.1

In the transmitter, the infrared LED is driven by a signal at a predetermined frequency and maximum amplitude. This signal is received by the detector and the output amplitude adjusted for a large output with minimum distortion. The detector output signal is passed through a bandpass filter (BPF) which allows only the pre-determined signal frequency to pass through, all other frequencies being stopped. The output of the BPF is demodulated (rectified) to produce a direct voltage. Note that only if the received signal is at the correct frequency will there be any demodulator output.

The output of the demodulator is passed through an amplifier so that it is greater than the reference voltage (VREF) of the comparator. With the amplified direct signal present the output of the comparator is low and the alarm activated. If the beam is interrupted the output of the demodulator falls to zero and the Comparator output switches high, operating the Latch and tuning on the Alarm. Note: The Driver/Latch circuit is used in its Latch mode. The alarm is required to continue once tripped into operation and until manually turned off. A simple light activated lamp circuit discussed in exercise 12 can be used for this burglar alarm. Only the lamp at the output is to be replaced by a buzzer to sound an alarm.

Unit 3 : Power Transistor Applications

Exercise 15: Current Booster - DC Drive

Objectives:

- To discuss the performance and maintenance of a current booster using a Complementary Darlington Pair Emitter Follower circuit.

Discussion:
This circuit is based on Complementary Darlington Pair Emitter Followers.
The Darlington Pair configuration has two advantages:

1. Very high current gain, and
2. Very high input impedance.

The high current gain is achieved by taking the output (emitter) current from the first transistor and coupling it directly as the input (base) current of a second transistor to be amplified again.

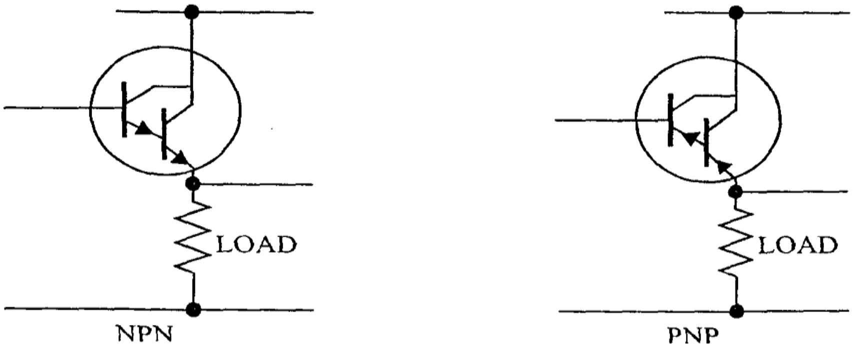


Figure 15.1

With very high current gain, the input current to TR1 must be very small. This means that the input impedance is very high, since the applied voltage produces such a very small current.
The operation of the circuit is as follows,
When the input voltage (VR1) is taken positive, TR2 conducts and the current flows down through the load to ground and when the input is negative, TR3 conducts and the current flows upward from ground, towards the -1 2V supply.

Circuit Diagram:

The circuit diagram is shown in figure 15.2.

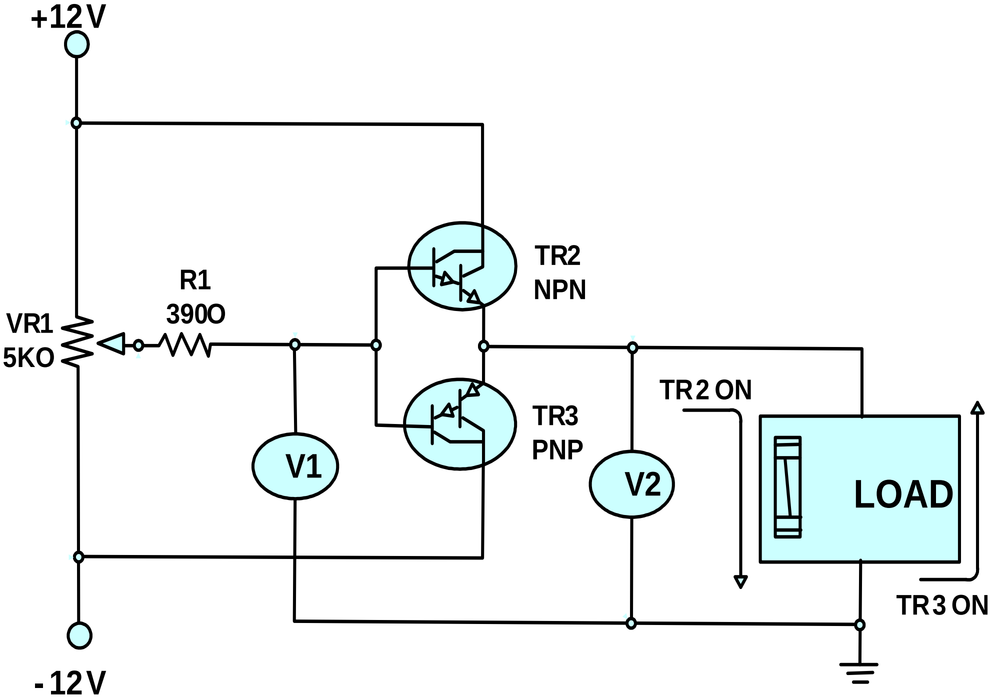


Figure 15.2

Caution!

Do not short the IC pins while testing the test points

Equipment:

No	Name	Qty.
1.	AC/DC power supply	1 Pc
2.	Digital Multimeter	1 Pc
3.	Analogue Multimeter	1 Pc
4.	Universal panel	1 Pc
5.	TR2(NPN)	1 Pc
6.	TR3(PNP),	1 Pc
7.	Resistor, 390Ω	1 Pc
8.	Potentiometer, 5kΩ	1 Pc
9.	Set of connection cables	-
10.	Connection plugs (jumpers)	-

Procedure:

1. Assemble the circuit shown in figure 15.2.
2. Connect the power supply and turn ON the circuit.
3. Connect multimeter 1, on DC voltage range to positive and any convenient ground socket (common) to measure V1, the input voltage to the transistors.
4. Connect Multimeter 2, similarly on DC voltage range, to positive and another convenient ground socket (common) to measure V2, the output voltage feeding the load.

5. Switch ON the power supplies.
6. Vary the setting of VR1 and note that the lamp brightness can be controlled through its range as the input voltage is taken either positive or negative. (Reverse the connections to any analog multimeter(s) used as the voltage is taken negative.)
7. Use VR1 to set the input voltage (V1) to -6V.
8. Note the output voltage V2 as indicated on multimeter 2 and record in Table16.1.
9. Adjust VR1 to give input voltages as specified in observation table15.1, note the corresponding output voltage at each step.

Note: Either analog or digital multimeters may be used .However since the voltages can be either positive or negative, digital instruments will be more convenient to overcome the need for reversing polarity of connections with analog instruments as the voltage is taken negative.

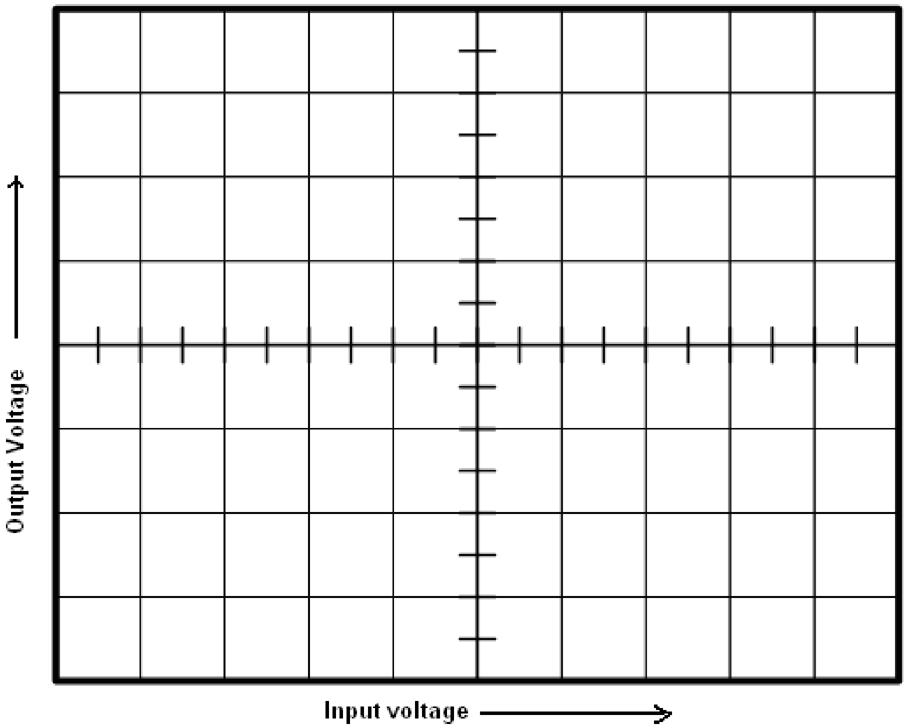
Observation Table:

Input (volts)	Output (volts)	Input (volts)	Output (volts)
0		0	
1		-1	
2		-2	
3		-3	
4		-4	
5		-5	
6		-6	

Table 15.1

10. Plot the graph (Transfer Characteristic) of output voltage against input voltage on the x-y axis provided in Graph 16.1.

11. From the readings, enter the average forward voltage required to turn on a Darlington Pair of silicon transistors



Graph 15.1

Conclusion:

The “Dead Zone” for the positive quadrant side of the 0V axis is ------------- Volt.
The “Dead Zone” for the negative quadrant side of the 0V axis is ------------- Volt.

Troubleshooting:

Circuit Diagram:

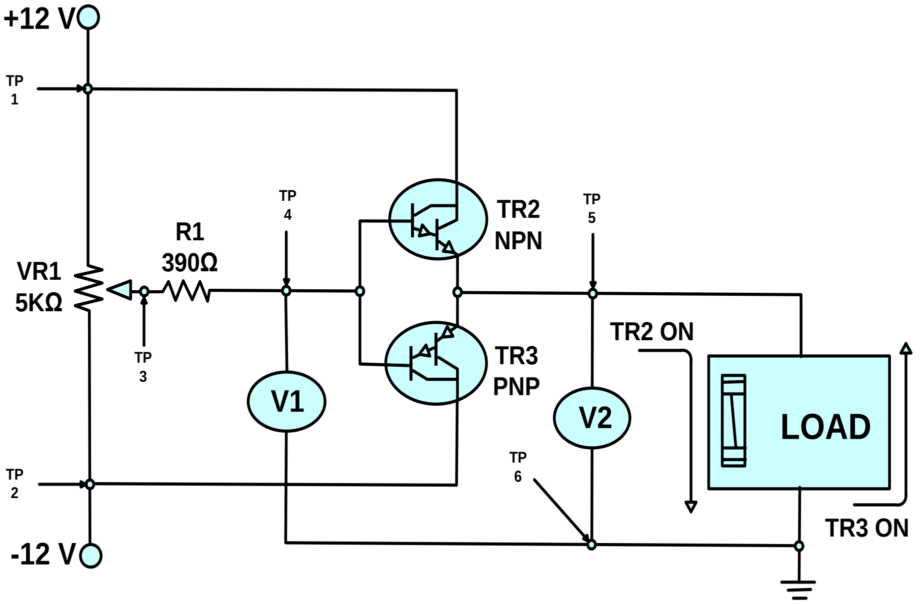


Figure 15.3

Procedure:

With the circuit in working condition

1. Check the supply voltage at test point 1 and 2 (TP1 and TP2).
2. Check the input signal at TP3 using Oscilloscope/Multimeter.
3. Check the input voltage signal V1 to the common bases of transistors pair at TP4 w.r.t ground i.e. TP6.
4. Check the output V2 across the load i.e. (across the TP5 & Tp6).
5. Record all the measured values in the table 16.2.

No.	Test Points	Voltage Readings	
		@ Normal Condition	@ Faulted Condition
1	TP1	V	V
2	TP2	V	V
3	TP3	V	V
4	TP4	V	V
5	TP5	V	V
6	Tp6		

Table 15.2

Review Questions:

1. Does the circuit operate well at low frequencies?

   ………………………………………………………………………………………

   ……….…………………….………………………………………………………….

2. Can the power supply be changed from DC to AC for this circuit?

   ………………………………………………………………………………………

   ……….…………………….………………………………………………………….

3. What is effect of the circuit operation at high frequencies?

   ………………………………………………………………………………………

   ……….…………………….………………………………………………………….

Exercise 16: Audio Amplifier – Waveforms

Objectives:

- Check the operation and troubleshooting an audio power amplifier.

Discussion:

Audio amplifiers are required to deliver a high power output to the loudspeaker; it can be in the order of tens or even hundreds of watts.
An extra Buffer stage is added incorporating a “feedback loop” between the output of the power amplifier and the buffer stage input.
An extra Buffer stage is added incorporating a “feedback loop” between the output of the power amplifier and the buffer stage input.

A sample of the output is fed back into the inverting (-) input of the Buffer stage, which compares this with its non-inverting (+) input and automatically corrects its own output waveform to overcome any distortion.

Circuit Diagram:

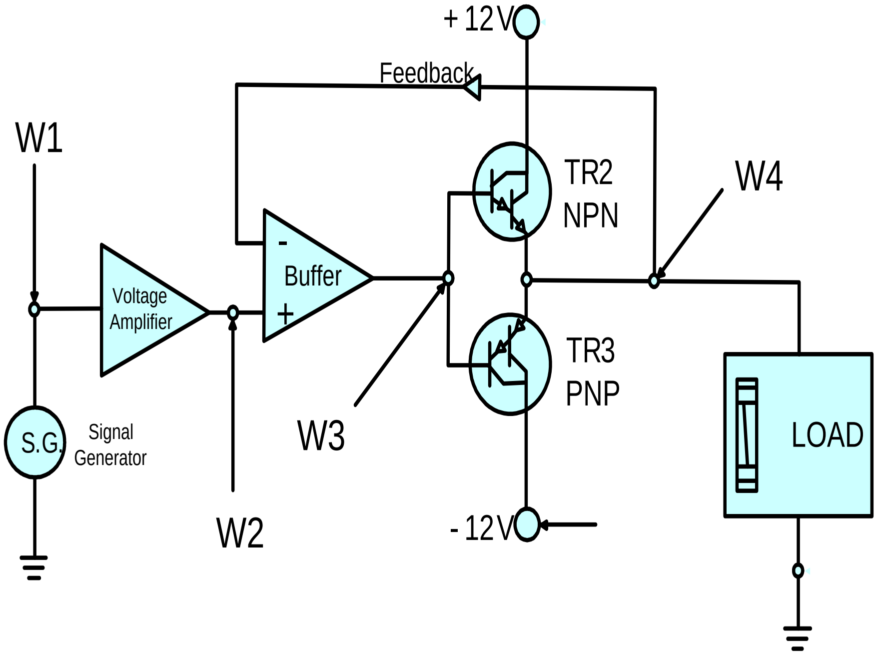


Figure 16.1

Caution!
Do not short the IC pins while testing the test points

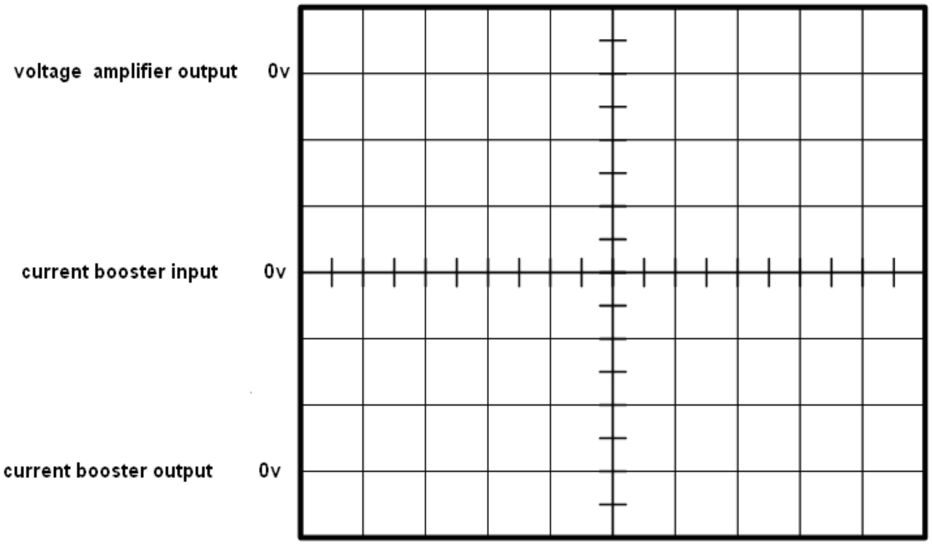
Equipment:

No	Name	Qty.
1.	AC/DC power supply	1 Pc
2.	Digital Multimeter	1 Pc
3.	Voltage amplifier	1 Pc
4.	Buffer	1 Pc
5.	TR2(NPN)	1 Pc
6.	TR3(PNP),	1 Pc
7.	Universal panel	1 Pc
8.	Signal generator	1 Pc
9.	Set of connection cables	-
10.	Connection plugs (jumpers)	-

Procedure:

1. Set up the oscilloscope as follows:
   Time base to 0.2ms/div
   Locate the CH. 1 trace two divisions down from the top of the display.
   Locate the CH.2 trace two divisions up from the bottom of the display.
   CH 1 Y amplifier gain to 0.5V/div, AC input.
   CH.2 Y amplifier gain to 5V/div, AC input.

2. Connect CH l of the oscilloscope to monitor the Voltage Amplifier Input.
3. Connect CH2 to monitor the output to the load.
4. Set the Amplifier Gain control to maximum (fully clockwise) and the Amplifier Offset control to midpoint (arrow pointing upwards).
5. Switch ON the Power Supplies.
6. Set the signal generator to 1 kHz sine wave and its amplitude control to give an input of 1 Vp-p.
7. Adjust the Amplifier Offset control to remove any distortion of the output as seen on CH.2 of the oscilloscope.
8. Transfer CH.2 of the oscilloscope to the output stage of Voltage Amplifier to monitor the Voltage Amplifier Output/Buffer Input and sketch both waveforms in the graph 17.1.
9. Mark each of your waveform sketches with their peak-to-peak voltages as indicated on the oscilloscope and record the time base setting (Time Scale) in the space provided in graph 16.1.



Graph 16.1

10. Keeping CH.1 connected at same position for phase reference, transfer the CH.2 lead to the output stage of Buffer to examine the output waveform of the Buffer (input of the Current Booster) and add this to your waveform sketches.
11. Connect the CH.2 lead across the load to examine the output waveform of the Current Booster (output to the load) and add this to your other waveform sketches.

Examine your waveform sketches carefully and note that the waveform of the Buffer output has been modified by the action of feedback to compensate for the "dead zone" at the crossover point of the Current Booster stage.

Voltage gain is = Output Voltage / Input Voltage
The voltages may be expressed in any units (peak-to-peak or RMS), provided they are both in the same units.

Conclusion:
Voltage gain for the Voltage Amplifier is

Output voltage of the ------------------- / Input voltage to the -------------------------

Voltage gain for the circuit is

Output voltage of the ------------------- / Input voltage to the -------------------------

Troubleshooting:

Circuit Diagram:

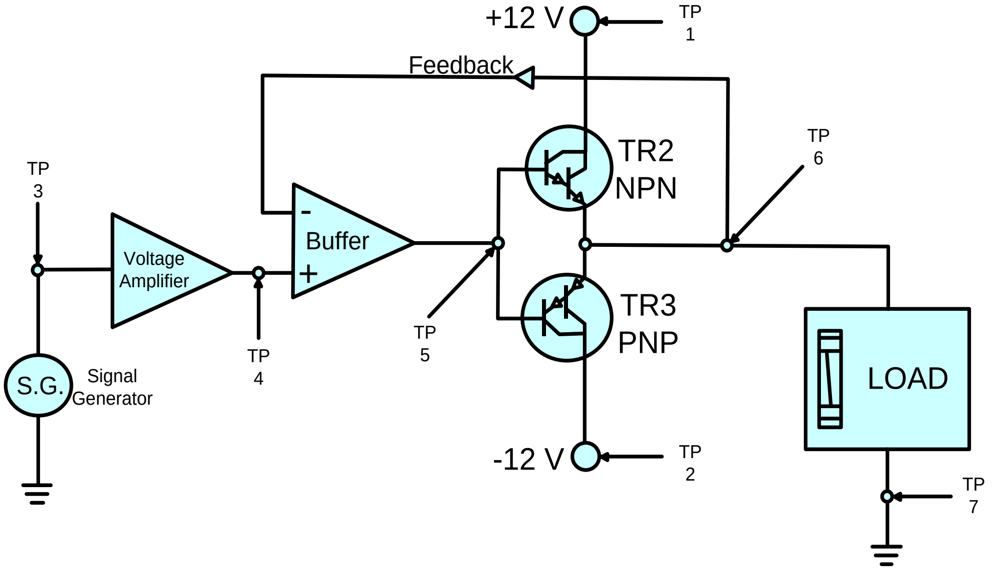


Figure 16.2

Procedure:

With the circuit in working condition

1. Check the supply voltage at test point 1 and 2(RP1 and TP2).
2. Check the input signal at TP3 using Oscilloscope/Multimeter.
3. Check the amplified voltage signal of voltage amplifier at TP4 which is used as input signal to buffer.
4. Check the output signal of buffer at TP5.
5. Check the amplified power at TP6.
6. Record all the measured values in the table 16.1.

Observation table:

No.	Test Points	Voltage Readings (Volts)	
		@ Normal Condition	@ Faulted Condition
1	TP1		
2	TP2		
3	TP3		
4	TP4		
5	TP5		
6	TP6		

Table 16.1

Review Questions:

1. Draw the waveform at the output of the Buffer stage.

   ……………………………………………………………………………………

   ……………………………………………………………………………...…………

2. How the voltage gain of the voltage amplifier is calculated?

   ……………………………………………………………………………………

   ……………………………………………………………………………………

3. What units should be used for input and output voltages?

   ……………………………………………………………………………………

   ……………………………………………………………………………………