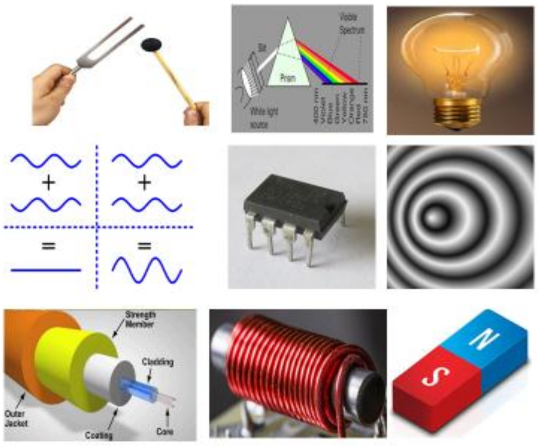
PHYSICS
PRACTICAL MANUAL
FOR
UG & PG

Dr. Dinesh V Kala

Physics Practical Manual for UG & PG



Dr. Dinesh V Kala
Head, Department of Physics
Guru Nanak Khalsa College Autonomous

InSc
Unit of SDPL
www.insc.in

TITLE OF THE BOOK: Physics Practical Manual for UG & PG

EDITION: First, 2020

ISBN: 978-81-948317-6-1

ISBN 978-81-948317-6-1
9 788194 831761

MRP: ₹ 350/-

PUBLISHER: Selfypage Developers Pvt. Ltd.
Pushpagiri Complex, Beside SBI
Housing Board, K.M. Road
Chikkamagaluru Karnataka
Tel.: +91-8861518868
E-mail: iph@insc.in

IMPRINT: INSC Publishing House (IPH)

PRINTER: Selfypage Developers Pvt. Ltd.
Pushpagiri Complex, Beside SBI
Housing Board, K.M. Road
Chikkamagaluru Karnataka
Tel.: +91-8861518868
E-mail: iph@insc.in

Preface

This book, in the form of manual, is an outcome of my thirty-three years of experimentations at various levels, from UG to PG. I dedicate this book to my weak students during my teaching journey, their questions & queries forced me to include more acceptable, susceptible pedagogy for teaching.

Passion for teaching through experimentation, always & every time motivates me, to teach a particular experiment in a more innovative way. After so many years of teaching to all possible levels from UG to PG, finally, I have enough knowledge of my own to share and I strongly feel, will definitely help many mentors & students in the coming days.

The content of the book gradually grew from basics to experiments to finally most probable questionnaire. I've gained a new perspective in understanding and implementing the experimentation and I feel strongly to share my ideas through this book. I always feel necessary to explain the theoretical back ground of the experiment and whenever possible through appropriate demonstration. Any person interested in experimentation with the concept behind the experiment, will surely appreciate learning through this manual.

Every aspect of a novice learner is taken care in writing the manual. The true inspiration to write this book is my intention to teach every experiment very precisely & nicely to the best of my capability. This book is for everyone who is keen to learn experiments in a very systematic way.

However, I don’t claim that the content in the manual would be totally errorless, will be happy to share if any suggestions or corrections from any corner.

I fully enjoyed the whole journey of learning and consequently translating the whole concept in the form of book, I am sure, learning will be more fruitful and delightful to each & everyone.

Acknowledgement

First & foremost, praises to the almighty, for his shower of blessings throughout. Because of his blessing, I could complete the manual successfully. I would like to express my deep and sincere gratitude to my lovely mother and my loving father. I am grateful for the love, care, sacrifices & prayers of my parents, to bring in me, the best of my capacity & capability.

I am thankful to my wife, my sons for their love, understanding and continuing support throughout the journey of my learning, teaching & finally translating my ideas & concepts into a book.

I express my sincere gratitude to my guide, guru and mentor, Dr Sureshchandra J Gupta Ji for his uninterrupted motivation, invaluable guidance and infinite blessings. His dynamism, vision and sincerity, deeply inspired me since my research days. It is a great pleasure to work under his guidance.

My heartfelt thanks to my dedicated and sincere students, Ms Devi Dinesh, Ms Raveena Amin, for their suggestions from students' perceptive. Special thanks to my colleagues, Mrs Bhavana Suri & Omkar Sawant for their valuable suggestions & corrections. Last but not the least, lot of thanks to very close friend of mine, Suryakant, always motivated me to express myself in the form of book.

Finally, with the blessings and support of all, a very good book in the form of manual has come into existence.

Index

Basics

A. Density (g/cc):

Copper	**8.93**
Lead	**11.37**
Iron (cast)	**7.3**
Iron (wrought)	**7.6**
Steel	**7.8**
Alcohol	**0.79**
Glycerine	**1.28**
Mercury	**13.6**
Turpentine Oil	**0.84**

B. Mechanics:

1. If one milli-meter is divided into 10 equal parts or 100 equal parts, is it possible that our eye can see the 10^{th} or the 100^{th} part? Obviously, NO. Then the question arises: how to measure the dimensions of 10.4 mm or 10.47 mm? The magic is done by the Vernier scales of Vernier Calipers, Travelling Microscope & Circular scale of Micro-Meter Screw Gauge. The extent of accuracy of measurement is decided by the least count of the measuring device. Lesser the least count, more accurate is the measurement i.e. screw gauge gives more accurate measurement than the vernier caliper for the same dimensions.

2. Elasticity of a body is its ability to regain its original shape and size when the deforming force is removed. Elasticity of a material is measured by elastic constants Y, ŋ and k. Higher is the value of these constants, more elastic is the material. For a gaseous system the pressure of the gas represents the elasticity of the medium. Railway track is made of highly elastic material.

C. Sound:

1. Sound waves are longitudinal in nature, unlike light, which is transverse in nature; hence light waves can be polarized & sound waves can't be polarized.
2. The velocity of sound is about 332m/s. Velocity of sound varies with temperature, density & humidity of the medium; but it remains unchanged with variation in pressure of the medium.
3. Supersonic, the one having velocity more than that of sound.
4. Human audible range is 20 Hz to 20 KHz.
5. Below 20 Hz are Infrasonic & above 20 KHz are Ultrasonic.
6. Sound propagation is an adiabatic process.
7. Unlike sight, hearing is Omni-directional.
8. Unlike light, sound needs medium for propagation.

D. Light:

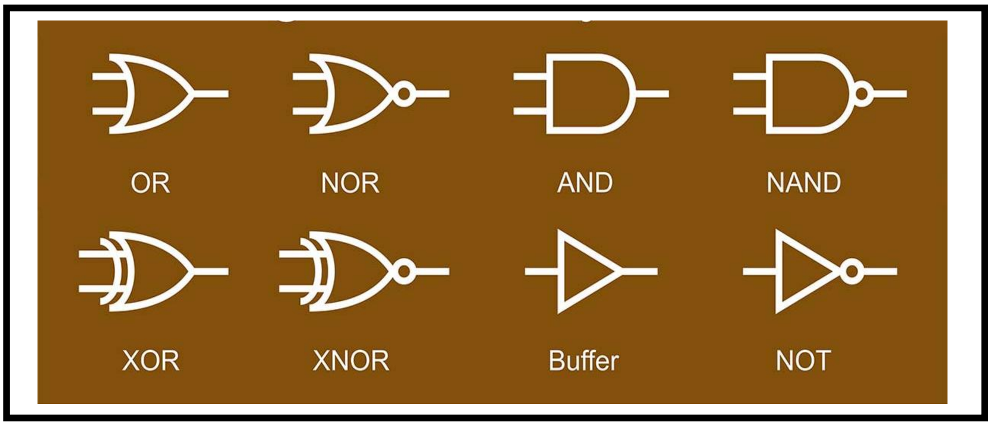
1. Human visible range is from Violet to Red. Wavelength above red is Infrared while below violet is Ultraviolet.
2. When light encounters small obstacle or opening (of the order of the wavelength of light used) the light waves bends from its direction of motion i.e. light undergoes the phenomena of diffraction.
3. Unlike interference, the bands in the diffraction are non-uniform.
4. Interference is a particular case of superposition of waves when the waves meet either in phase (phase difference is zero or even multiple of π) or out of phase (phase difference is odd multiple of π) respectively produces a bright band or a dark band.
5. Refractive index of a medium is the ratio of velocity of light in vacuum to that in the medium.
6. Whenever light ray reaches an interface, it gets partially reflected & partially refracted (absorption is neglected); but when a ray enters from a denser medium to rarer medium & angle of incidence is more than the critical angle (angle of incidence for which angle of refraction is equal to $\pi/2$), the phenomena of refraction does not take place & whole light gets reflected back in the denser medium; is defined as total internal reflection (TIR).

E. Electricity & Magnetism:

1. Electric and Magnetic fields; both are because of charged particle.
2. Charge at rest produces electric field, a moving charge produces magnetic field.
3. Force on a charge in electric field is $F_E = qE$ and in a magnetic field is $F_M = q(v \times B)$, charge should be moving to experience force in a magnetic field; because moving charge only can produce magnetic field.

F. Digital Electronics:

1. Gates summarized: OR, AND, XOR, NOT, NAND & NOR gates; individually may not be much effective but their appropriate combination results into amazing logic circuits.



2. Counters are nothing but cascaded flip-flops used to divide the frequency by two or multiply the time period by two & hence can be used for binary counting. Four flip-flops cascaded can count up to 2^4 =16 (0000-1111) and so on.
3. 74190/74193 are extended version of 7490/7493 (Decade and Mod-16 counters) & are called as pre-settable counters.
4. D/A & A/D converters are available in the form of IC's now-a-days and can be easily interfaced with µP & µC.
5. Number Systems & Equivalence: Refer the table below, numbers in different number systems and their equivalence. Decimal system used by all of us in daily life, binary system is one used by computers. Hexadecimal system makes assembly language programming easy compared to dealing with long strings of binary numbers, difficult to remember & more difficult to deal with. Assembler and compilers are the interfaces, actually does the needful to convert assembly language & high-level languages into machine languages.

NUMBER SYSTEM

D	H	O
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	10
9	9	11
10	A	12
11	B	13
12	C	14
13	D	15
14	E	16
15	F	17

6. Weight-age: Value of 1111 differs with each BASE.

$(1111)_2 = 2^3+2^2+2^1+2^0 = 15$

$(1111)_8 = 8^3+8^2+8^1+8^0 = 585$

$(1111)_{10} = 10^3+10^2+10^1+10^0 = 1111$

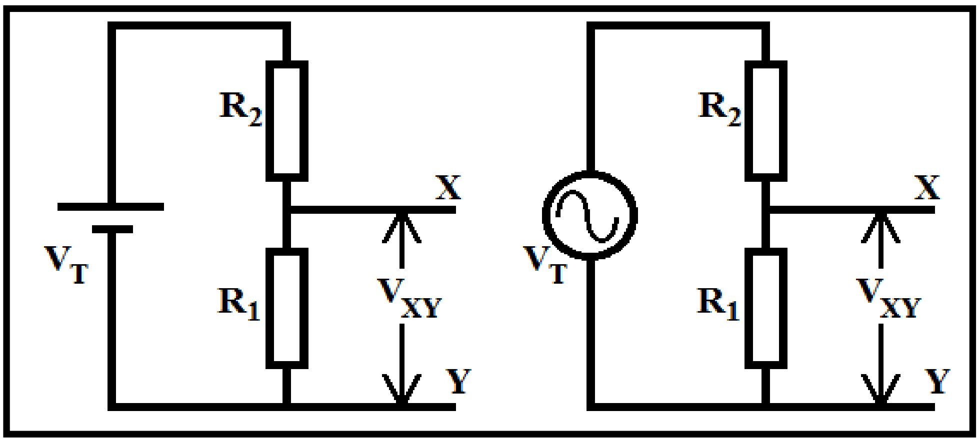
$(1111)_{16} = 16^3+16^2+16^1+16^0 = 4369$

The number 10 has different weightage in each number system. In Binary, Octal, Decimal and Hexadecimal, it is exactly equal 2, 8, 10 & 16 respectively. The value of any number is actually decided by its base.

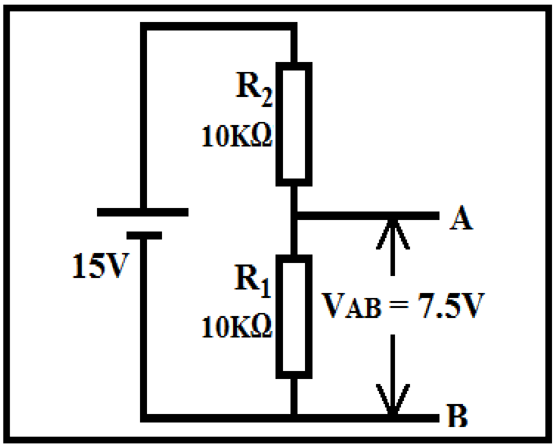
$(111)_2 \neq (111)_8 \neq (111)_{10} \neq (111)_{16}$

G. **<u>Electronics:</u>**

1. Resistors, Inductors, Capacitors & Diodes are defined as passive components.
2. Transistors (bipolar, FET, MOS-FET etc.) & Op-Amps comes under active components.
3. Characteristics of Op-Amp & their significance:
   a. High Gain: Are useful to amplify very small signals (micro to milli volts)
   b. Infinite Bandwidth: Amplify all signals by same amplification factor irrespective of their frequency.
   c. Infinite Input Impedance: Does not load the previous stage.
   d. Zero Output Impedance: Does not get loaded by the next stage.
   e. Reduces impedance mismatch between two interfacing stages.
4. Two or more resistances in parallel, the smaller resistance dominates.
5. Two or more resistances in series the largest resistance dominates.
6. Unlike resistance of resistor, the reactance of capacitor and inductor, not only opposes the flow of charge but also introduces a phase difference (reacts) between the current & voltage, they offer reactance (<u>Reac</u>tion + Resis<u>tance</u>).
7. Unlike resistance of resistor, the reactance of the inductor $X_L = 2\pi f L$ & the reactance of capacitor $X_C = 1/(2\pi f C)$ depends on the frequency of the applied AC. Therefore, the reactance varies with frequency; the reactance of C & L depends on frequency. Dependence of reactance on frequency is the basic principle behind the working of filters.
8. In LCR series (parallel) whenever applied frequency is equal to circuit frequency i.e. $1/2\pi\sqrt{LC}$; there is a resonance. In a series circuit, the current is maximum (selector circuit) & in parallel circuit current is minimum (rejecter circuit). Concept is used in tuning circuits. Quality factor of a LCR circuit is an important factor and decides the selectivity of any LCR based tuning circuit.
9. If you need a voltage lesser than the battery voltage, use potential divider arrangement. This concept is valid for AC as well as DC.

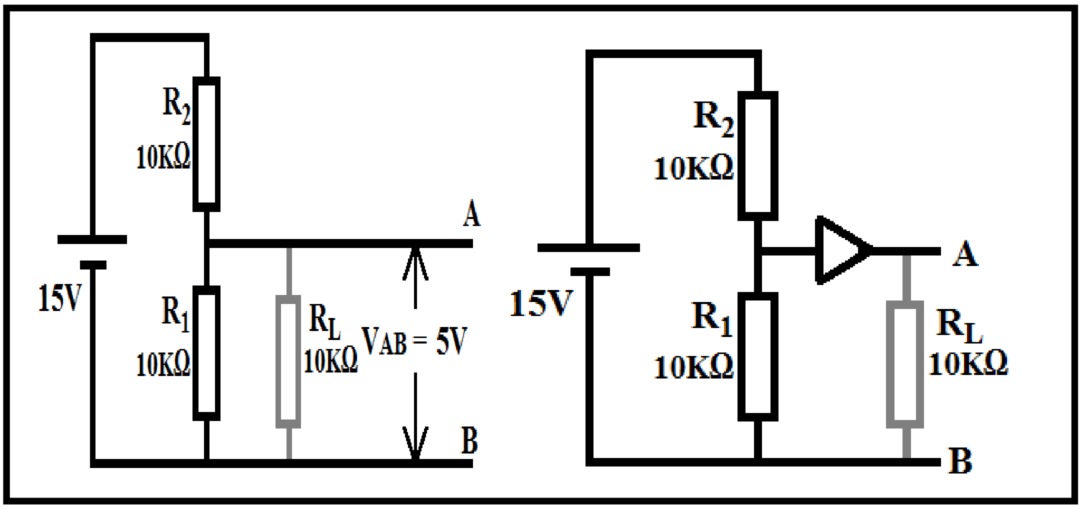


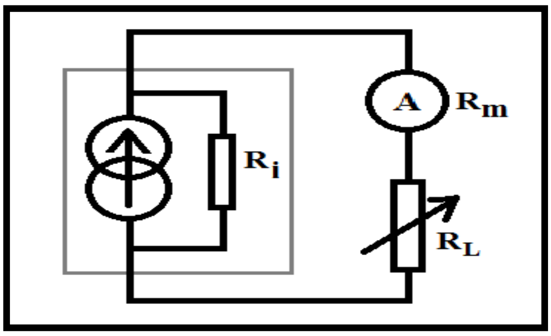
10. **<u>Loading Problem & Impedance Match</u>:** Consider the potential divider circuit as shown above, where a 15V source is divided into 7.5V using a potential divider arrangement as below.



Assume a situation where a 10KΩ load resistance or a device of resistance value 10KΩ is connected across AB i.e. two 10KΩ resistors are parallel to each other, hence the resultant resistance is 5KΩ. Therefore, the voltage across the load is 5V; 7.5V drops to 5V, this is loading problem. The problem can be easily solved by using a 10Ω resistances instead of 10KΩ resistances in the potential divider arrangement. This means that the source should have low output resistance /impedance. The second option is to connect a buffer as shown instead of changing any resistance.

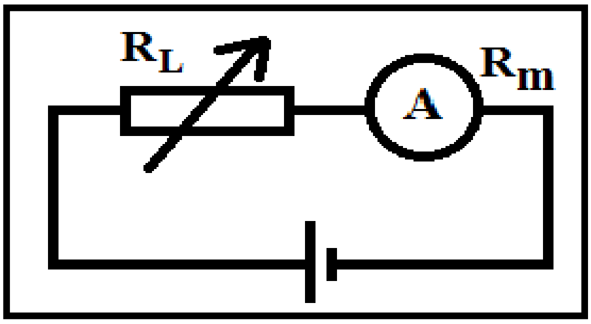
Due to the use of buffer the input impedance of the load is infinite and not 10KΩ. Thus, the buffer helps in impedance match.





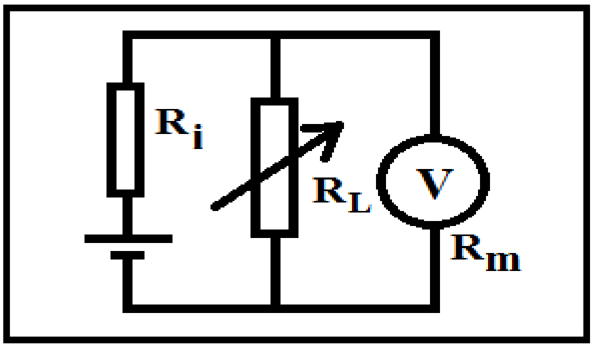
H. CCS & Ammeter:

A constant current source (C.C.S) is one, which provides same current for all load values. It is possible only when $R_L \ll R_i$. The source degrades when $R_L \to R_i$.

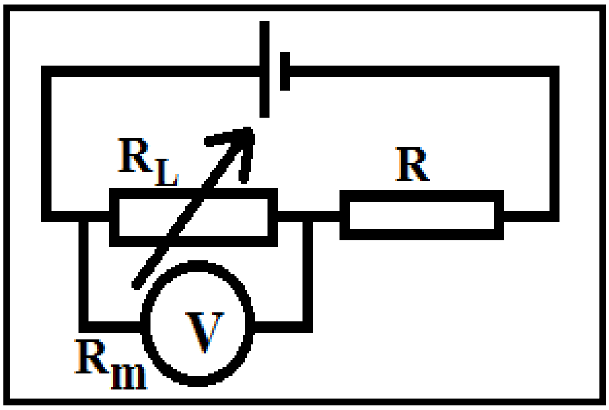


In contrast, for an ammeter to measure correct value of current $R_m <<< R_L$ so that the resistance of the ammeter should not perturb or disturb the circuit resistance. Hence to get proper current measurement, $R_m + R_L \approx R_L$

I. CVS & Voltmeter:



A constant voltage source (C.V.S) is one, which provides same P.D. for all load values. It is possible only when $R_L \gg R_i$. The source degrades when $R_L \to R_i$.

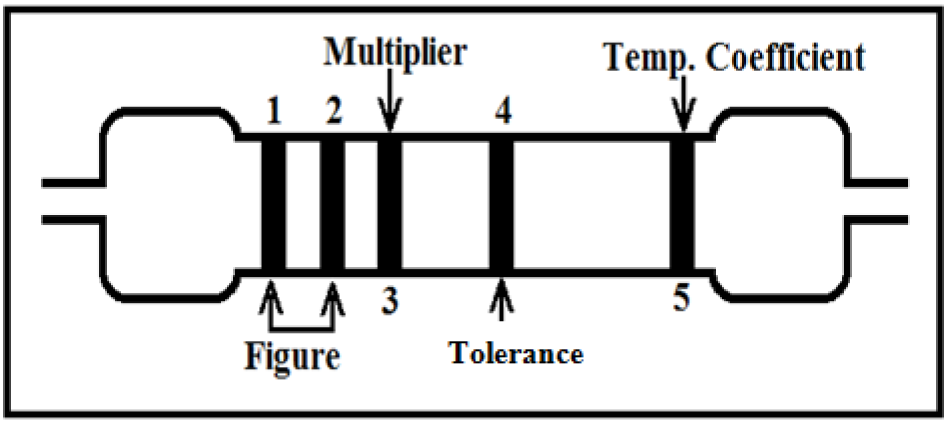


In contrast, for a voltmeter to measure correct voltage, $R_m >> R_L$ so that $R_m \parallel R_L \approx R_L$.Thus, the connection of voltmeter does not perturb the load resistor and hence the voltage value.

J. Important Constants

1. Acceleration due to gravity on earth, g =9.81 m/s^2
2. Velocity of sound in air at N.T. P = 331 m/s
3. Velocity of light in vacuum, c =3 $\times$ $10^8 m/s$
4. Charge on an electron, e = $-1.6 \times 10^{-19} C$
5. Mass of an electron, m_e =9.1 $\times$ $10^{-31} kg$
6. Joule's constant, J = 4.18 J/cal
7. Plank's constant, h = 6.626 $\times$ $10^{-34} Js$
8. Universal gas constant, R= 8.314 $JK^{-1}mole^{-1}$

K. Color Code of Carbon Resistors:



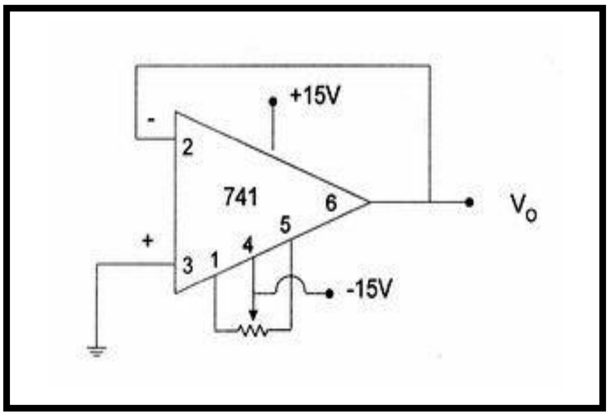
Figures (1st & 2nd Ring)		Multiplier (3rd Ring)		Tolerance % (4th Ring)	
0	Black	10^{-2}	Silver	10	Silver
1	Brown	10^{-1}	Gold	5	Gold
2	Red	10^0	Black	1	Brown
3	Orange	10^1	Brown	2	Red
4	Yellow	10^2	Red	0.5	Green
5	Green	10^3	Orange	0.25	Blue
6	Blue	10^4	Yellow	0.1	Violet
7	Violet	10^5	Green		
8	Grey	10^6	Blue	20	No Colour
9	White	10^7	Violet		

L. Various Parameters & Application of Op-Amp 741

a. Offset Voltage: Ideally the output of the Op-Amp should be zero at zero volts when the inputs are grounded. In reality, the input terminals are at slightly different DC potentials & when both the terminals are grounded, the output is $\pm V_{sat}$, hence the best method to find offset voltage is to configure Op-Amp in voltage follower mode & ground the non-inverting terminal. The cause of input offset voltage is due to the inherent mismatch of the input transistors & components during fabrication of the Op-Amp. It has been reduced with modern manufacturing processes through increased matching and improved package materials and assembly.

b. **Finding Offset Voltage & it's Nullification:** Assemble the circuit as below, paying attention to carefully match the ± 15V power supply values. Measure and record the output voltage (Do not connect a voltage offset adjustment potentiometer). Record the magnitude and polarity of V_{os}. Compare to the specification sheet values.

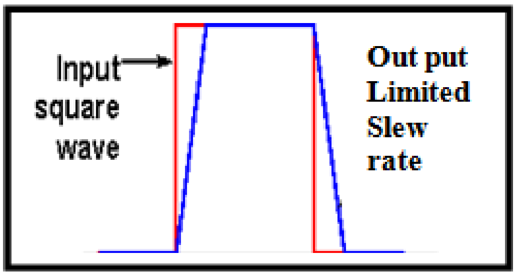
c. **Voltage Offset Adjustment Range:**



Voltage Offset Adjustment Range

Construct the circuit as shown above. Measure and record the range in value of V_o as the 10kΩ potentiometer is varied from the full counter clockwise to the full clockwise position. Note the value of V_o at full counter clock wise rotation and V_o at full clockwise rotation. Vary the potentiometer till $V_o = V_{os} = 0.0V$.

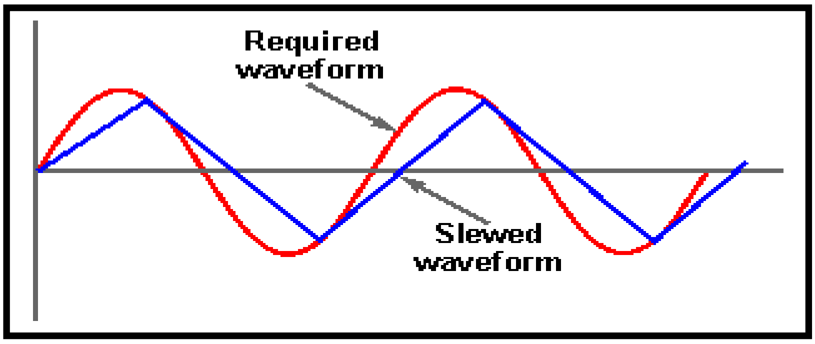
d. **Op-Amp Slew Rate:** The Op-Amp slew rate is particularly an important parameter in applications where the output is required to switch from one level to another quickly. The slew rate of any amplifier is the rate of change in the output voltage caused by a step change on the input, expressed as V/µs or V/ms.



Op-Amp Slew Rate Illustration

In a typical device the value of slew rate of the order of 10V/ microsecond. The values for a slew rate are dependent upon this type of operational amplifier being used. Low power Op-Amps may only have values of a volt per microsecond, whereas there are fast operational amplifiers capable to providing rates of 1000 V/ microsecond.

e. **<u>Slewing Distortion</u>:** If an Op-Amp is operated above its slew rate limit, signals will become distorted. The easiest way to see this is to look at the example of a sine wave. The maximum rate of voltage change occurs at the zero-crossing point. Maximum rate of change of sine wave occurs at zero crossing point.



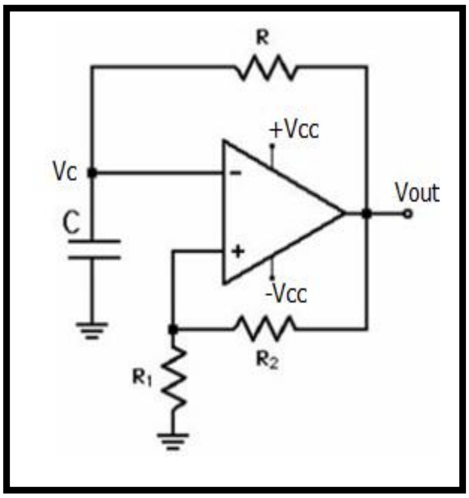
As can be seen in the diagram, in the limit, the Op-Amp slewing distortion will result in the creation of a triangular waveform. If the frequency is increased, the Op-Amp will be even less able to keep up and therefore the amplitude of the output waveform will also decrease.

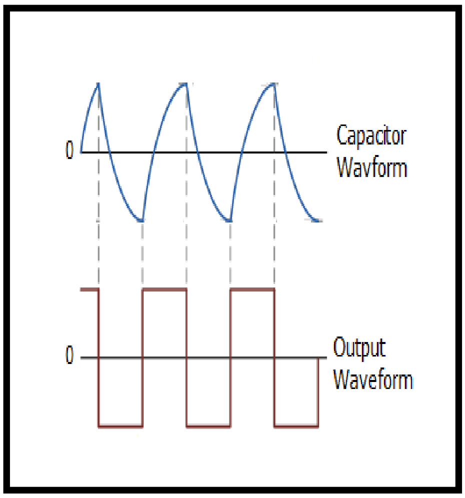
f. **<u>Slew Rate & Formula</u>:** It is relatively easy to calculate the slew rate of an amplifier that is required for a given application from knowledge of the maximum voltage and frequency required. To give distortion free operation, the slew rate of the amplifier, the simple formula below can be used.

Slew Rate: $2\pi fV$

Where, slew rate is measured in volts/second, although actual measurements are often given in V/µs, f = the highest signal frequency, V = maximum peak voltage of the signal. As an example, take the scenario where an Op Amp is required to amplify a signal with a peak amplitude of 5 volts at a frequency of 25kHz. An Op-Amp with a slew rate of at least $2\ \pi \times 25000 \times 5 = 0.785$V/µs would be required.

g. Op-Amp as Astable Multivibrator: Circuit Diagram & Waveform





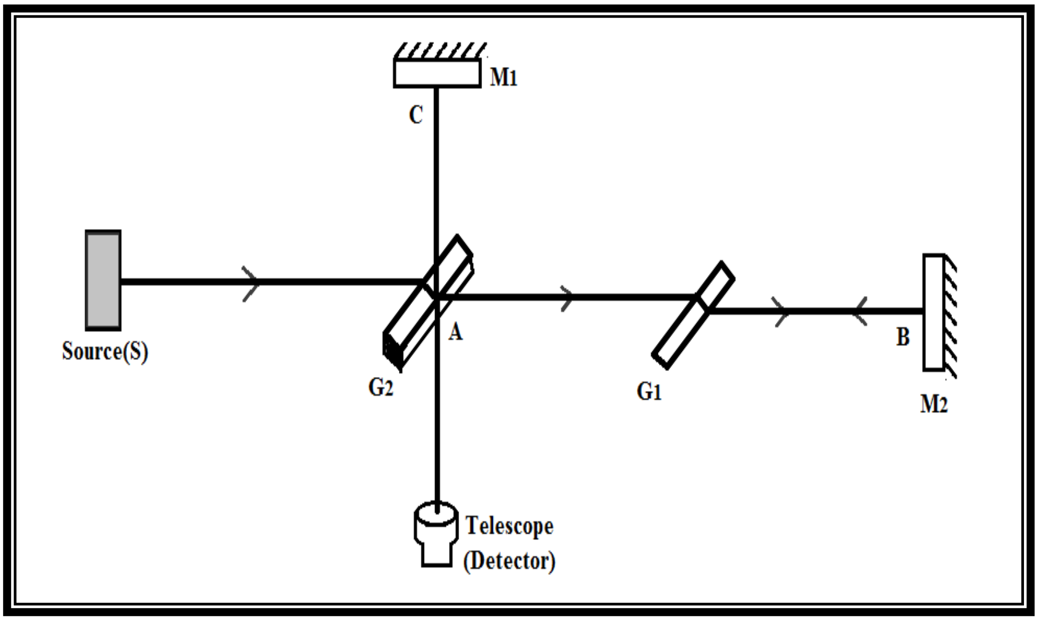
Experiment 1

Michelson Interferometer

Aim: To determine the λ of a monochromatic light source using Michelson Interferometer.

Apparatus: Michelson Interferometer, convex lens, telescope, a source of monochromatic light, plain white board etc.

Ray Diagram:



Theory: When light waves superimpose, then the resultant intensity of light in the region of superposition is different than the intensity of individual waves. The modification in the distribution of intensity due to enhancement & annulment of intensity in the region of superposition is known as Interference. A device that makes effective use of interference is called Interferometer.

The theory of interference has been classified into two:

a. **Based on division of Wave-front**
b. **Based on division of Amplitude**

When the waves interfere in phase, according to the principle of superposition, the resultant amplitude is maximum & is known as constructive interference. But, if the waves are out of phase, the interference is destructive, in such a case, the resultant amplitude is minimum. The interference pattern consists of equally spaced, bright and dark bands.

MI is based on the principle of 'division of amplitude'. In this experiment, two coherent beams of equal intensity are obtained by amplitude division of an extended monochromatic source. They are sent in the directions perpendicular to each other such that, one ray is reflected and another ray is refracted by means of a plane mirror. These two beams are brought together after reflection from the plane mirror to interfere with each other.

Construction: Two highly silver polished, plane mirrors are placed mutually perpendicular to each other. Two plane parallel plates of glass G_1 and G_2, made from the same material, cut from the same glass plate and having equal thickness is used. The plate G_1 is partially silvered at the back. As a result, the incident beam from the monochromatic source S, get divided equally into reflected and refracted beam.

Both the plates are held parallel to each other. Both the mirrors are provided with leveling screws at the back. The mirrors can be made perfectly perpendicular to the direction of beams. By means of achromatic lens, the light from the monochromatic source S is rendered parallel and is allowed to be incident on the first glass plate G_1. The plate G_1 is kept at an angle of 45^o with respect to the horizontal and is mounted on the arm carrying mirror M_2. Light is partially reflected at the back surface of G_1 towards M_1 and also partially transmitted along mirror M_2.

The ray AC is incident normally on M_1; hence it is reflected normally along the same path and emerges out along AT. Mirror M_2 receives ray AB normally and reflects normally along the same path and then moves along AT after the reflection at the back surface of G_1. Thus, two beams along AT interfere with each other under favorable conditions to produce interference pattern. The pattern shows alternate maximum and minimum depending upon their phase difference, i.e. odd or even multiple of π.

Adjustments: To obtain the fringes following adjustments are required:

1. By means of leveling screws of mirrors M_1 and M_2, one can have slow and accurately controlled motion between the two beams (distance of mirrors M_1 and M_2 from the back surface of the glass plate G_1, is nearly the same to each other, in the order of milli-meter) to be interfered.
2. Mirrors M_1 and M_2 should be perfectly perpendicular to each other.
3. A thin sheet with a fine pinhole is introduced and the images are made to overlap. This is possible only if the mirrors M_1 and M_2 are made perfectly perpendicular to each other.

By doing all these Adjustments one can see the interference fringes.

Applications:

1. To find the refractive index of glass plate.
2. To find the thickness of the transparent sheet.
3. To measure the wavelength of light.

Observations:
Least count =
Number of fringes collapsing (or emerging) = n =

No.	I.R. (div)	F.R. (div)	T D= [(F.R.- I.R.) x LC] (cm)	$\lambda = \frac{2d}{n}$
1.				
2.				

Mean wavelength =________________

Calculation:

Result: The observed value of wavelength ___________A° is comparable to the expected value.

Probable error = $d\lambda = \sqrt{\frac{\sum(\lambda_i - \lambda')^2}{n(n-1)}}$

Experiment 2

Refractive Index of Liquid using Laser

Aim: To determine the refractive index of a liquid by using laser.

Apparatus: Laser, water container, sample of liquid, plane mirror etc.

Theory: The main concept behind the experiment is that, when light travels from a denser medium to a rarer medium, it bends away from the normal. Let the ray of light travel from a denser medium to a rarer medium, the angle of refraction (r) keeps on increasing as the angle of incidence (i) is increased. At a particular angle of incidence, there is no refracted ray i.e. the refracted ray grazes the surface of the liquid. This angle of incidence is known as the 'critical angle of incidence' (i_c). At this particular angle of incidence, the refracted ray is at an angle of 90°. Beyond this angle of incidence, no light is refracted, i.e. only reflection takes place. Since reflection happens internally into the same medium as the medium of incident ray, it is known as 'total internal reflection'. This results in the formation of dark and bright region. If 'd' is the depth of the liquid then,

$$\theta_c = tan^{-1}\left(\frac{R}{2d}\right)$$

R.I. of liquid = $\mu = \frac{sin\ 90}{sin\ \theta_c} = \frac{1}{sin\ \theta_c}$

Observation: For Water

No.	Depth d (cm)	Diameter D (cm)	Radius R (cm)	θ_c	μ

Mean μ = _________

**** Repeat the experiment for appropriate molarity of salt water**

Experiment 3

Measurement of Wavelength using Laser

Aim: To determine the wavelength of the He-Ne laser using diffraction grating and scale.

Apparatus: He-Ne laser source, diffraction grating, meter scale etc.

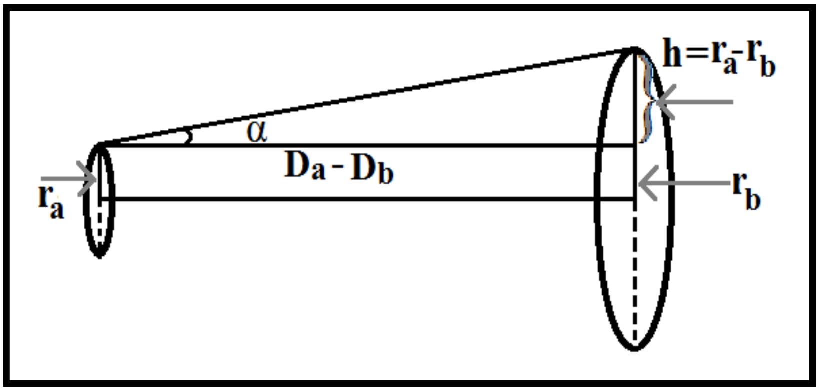
Theory: Lasers are devices that increase the intensity of light to produce a highly directional, high intensity beam that typically has a single frequency. The word LASER is an acronym for 'Light Amplification by Stimulated Emission of Radiation'. Laser requires an active medium for amplification between pair of mirrors. The amplification of waves will occur as it passes through the active medium. The amplification is coherent i.e. phase of the waves is preserved and it remains the same for all waves as it passes through the medium. He-Ne laser consist of a Pyrex tube, which is 35 cm long and 20 mm in diameter with electrodes on the sides and fused silica windows on both the ends. The windows are sided at Brewster's angle usually. This setting eliminates unwanted reflections on this surface for even polarization of light. The laser is first evacuated and filled with helium at 2.5 atmosphere and then neon (active medium). The electrodes in the tube are connected to high voltage source of about 10V.

1. Measurement of Wavelength of Laser Light:

For this purpose, we use a steel scale and use the marking on the scale to deflect the laser light. A clear diffraction pattern is produced on the screen (or wall). Note the distance of the brightest point in the pattern from the direct point of the laser 'y_0'. Taking this a reference point, we measure the distance of the consecutive brightest point with respect to the direct point.

$$\boldsymbol{\lambda} = \frac{\boldsymbol{d}}{\boldsymbol{2(D)^2}} \times \frac{\boldsymbol{y_m^2 - y_0^2}}{\boldsymbol{m}}$$

D → distance from the scale to the screen
d → smallest distance of the scale (least count of the scale)
y_m → distance of m^{th} brightest point from the reference point
y_0 → distance of the 0^{th} brightest point from the reference point (distance of the brightest point from the direct point)



2. **Measurement of Divergence of the Laser Beam:**

He-Ne laser is a very intense and sharp beam. When the light falls on the screen only a single spot is seen. But if we keep increasing the distance of the source from the screen, the divergence of the spot goes on increasing. Hence the beam is a conical beam here 'α' is the divergence angle and can be calculated from the formula as $\alpha = tan^{-1}\left[\frac{r_a - r_b}{D_a - D_b}\right]$

3. **To Find the Grating Element:**

A diffraction grating being equivalent to a large number of equidistant slits of equal width, each slit forms its diffraction maxima and minima. These maxima and minima interfere (overlap) resulting in an intensity at the maxima, proportional to the square of number of slits. The intensity of minima is zero. The grating equation for normal incidence is $d\,sin\,\theta = n\lambda$. Where d, is the grating constant or grating element for known value of λ.

Observation:

1. **For Diffraction Using Scale for D = ________ cm**

Spot No.	d = 0.05 cm		d = 0.079 cm	
	y_i(cm)	λ(A°)	y_i(cm)	λ (A°)

Mean λ = _______ A°

Calculation: $\lambda = \frac{d}{2D^2} \times \frac{y_m^2 - y_0^2}{m}$

2. For Grating:

Grating element = G = _________ L.P.I

Distance between consecutive lines in grating = d = 1/G = ______ inch = ______ cm

$d\,sin\,\theta = n\lambda$, Where n is the order number

No.	D (cm)	y (cm)	$\theta = tan^{-1}(y/D)$	(cm)	λ (A°)
1	D_1 =	y_1 = y_2 =	θ_1 = θ_2 =		
2	D_2 =	y_1 = y_2 =	θ_1 = θ_2 =		
3	D_3 =	y_1 = y_2 =	θ_1 = θ_2 =		

D, distance of the grating from the screen & y_n, distance of n^{th} spot from the central maxima.

Calculation:
If 'λ' is known 'd' can be found out or if 'd' is known 'λ' can be found out using

$$d \sin\theta = n\lambda, \quad \theta = \tan^{-1}(y/D)$$

2. **For Divergence:**

No.	'D' (cm)	Radius of Spot 'r' (cm)	Difference(cm)	'α'°
1	D_1 =	r_1 =	$r_1 - r_2$ =	
2	D_2 =	r_2 =	$r_1 - r_3$ =	
3	D_3 =	r_3 =	$r_2 - r_3$ =	

Calculation: $\alpha = \tan^{-1}\left[\frac{r_a - r_b}{D_a - D_b}\right]$

Results:

1. **The wavelength of the laser when measured using**
   a) **Scale = __________ A°**
   b) **Grating = __________ A°**

2. **The grating element using laser measurement:**
   d = _________ cm = _________ L.P.I

3. **The divergence of laser beam is _______**

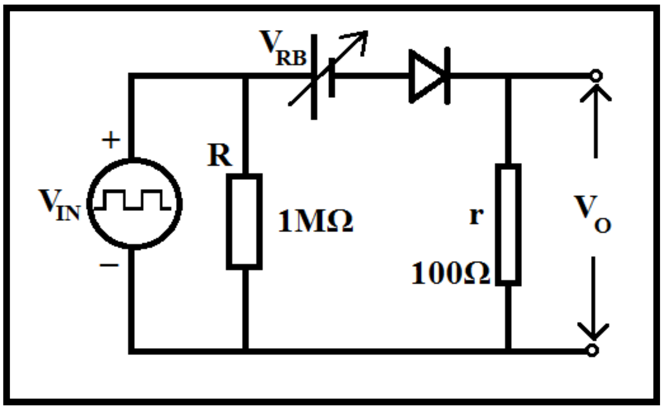
Experiment 4

Carrier Life-Time: Pulse Reverse Method

Aim: To determine the life-time of charge carriers in the given semiconductor by pulse reverse method.

Apparatus: Diodes (IN4007 and BY127), DC power supply (0-5V), signal generator, resistance, CRO, bread board, connecting wires etc.

Circuit Diagram



Theory: When a diode is switched from forward bias to reverse bias mode suddenly, a reverse current which is much larger than the normal reverse saturation current flow through the junction during the time required for the decay of stored charges.

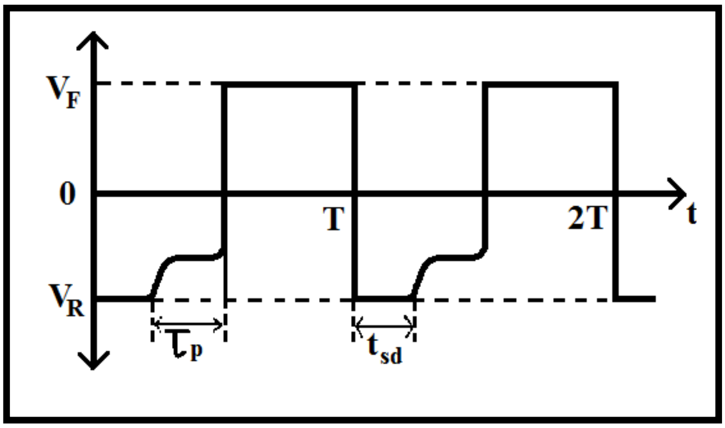
When the diode is forward biased, the potential barrier at the junction is lowered and a very large number of carriers are injected to both sides of the junction. The injected minority carriers eventually recombine with the majority carries as they diffuse further into the electrically neutral region. The characteristic decay length is called the "minority carrier diffusion length". Carrier density gradients on either side of the junction are supported by a forward current I_F (flowing from p side to n side). When diode is reversed biased, reverse voltage adds to the height of the potential barrier. The electric field strength at the junction and the width of the space change region also increases. This gradient in minority carrier density causes a small flux of minority carriers to defuse towards the depletion layer where they are swept immediately by the large electric field into the electrical neutral region of the opposite side. This will constitute a small leakage current across the junction from the n side to the p side. There will also be a contribution to the leakage current by the electron hole pairs generated in the space change layer by the thermal ionization process. These two components of current together is called the "reverse saturation current I_s "of the diode.

Assume p-n junction is driven by a square wave generator, that periodically switches the diode from forward to reverse state and vice-versa. When the diode is forward biased and in steady state the forward current I_F flows through the junction. The source voltage appears entirely across the resistor.

If the diode is suddenly reversed biased then because of stored minority carriers, the voltage across the p-n junction depletion region cannot be changed instantaneously. Due to large number of minority carriers on both the sides of the diode, current will simply reverse the direction and stay at this measurable level for the period t_{sd} (storage time) required for the minority carriers to return to their majority-carrier state in the opposite material. Thus, the diode will remain in the short-circuit state with a reverse current $I = -I_F$. Eventually, when this storage phase has passed, the current will reduce in level to that associated with the non-conduction state. This second period is denoted by t_{sd} (transition interval). The reverse recovery time is the sum of these two intervals.

$$\tau_p = \frac{t_{sd}}{ln\left[1 + \frac{V_F}{V_R}\right]}$$

τ_p → life time of minority charge carriers
V_F → Forward voltage
V_R → Reverse voltage



Procedure:

1. Connect the circuit as shown in the diagram.
2. Keep the reverse voltage V_{RB} = 0V and measure V_F, V_r, t_{sd} on CRO.
3. Change the V_{RB} and measure V_F, V_r, t_{sd}.
4. Calculate τ_p.
5. Repeat the procedure for one more diode.

Observation:

1) **For Diode (BY127); At f = 20 KHz**

Obs. No.	V_{RB} (V)	V_R (V)	V_F (V)	t_{sd} (μs)	τ_p (μs)

****Repeat the above steps for two more diodes and draw the waveforms.**

Result:

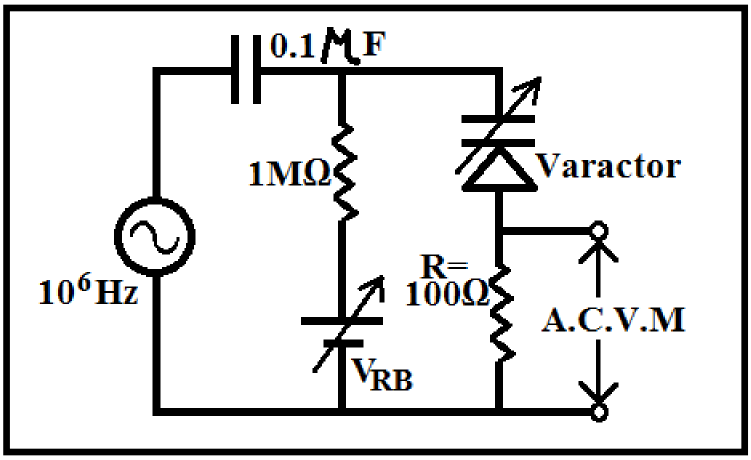
Experiment 5

Barrier Capacitance of a Junction Diode

Aim: To study the junction capacitance i.e. the capacitive effect of p-n junction under reverse bias condition.

Apparatus: Signal generator, diode BY127, p-n-p transistor, 30 V variable power supply, capacitor, resistor, A.C.V.M., connecting wires, bread board, etc.

Circuit Diagram:



Theory: Depletion region of p-n junction of a semiconductor diode is like two plates of a capacitor, with depletion region acting as a dielectric medium of the capacitor. When the diode is reverse biased the width of the depletion region increases with increase in the applied reverse bias voltage. This capacitance produced by a diode in reverse bias condition is known as 'Junction Capacitance' or 'Depletion Layer Capacitance' and such a diode is named as 'Varactor' i.e. variable capacitor. The depletion capacitance per unit area is

$$C_j = \frac{dQ}{dV}$$

Where dQ is the incremental change in charge per unit area caused by incremental change in voltage, dV. dQ causes a change in the electric field dE

$$dE = \frac{dQ}{\epsilon_S}$$

The corresponding change in the applied voltage dV is approximately (WdE) which equal to $\left({}^{WdQ}/_{\epsilon_S}\right)$. Therefore, the depletion capacitance per unit area is given by

$$C_j = \frac{dQ}{dV} = \frac{dQ}{W\frac{dQ}{\epsilon_S}} = \frac{\epsilon_S}{W}$$

Above equation for the depletion capacitance per unit area is the same as the standard expression for a parallel-plate capacitor where the spacing between the two plates represents the depletion-layer width. The equation is valid for any arbitrary impurity distribution.

For abrupt junction, the width of the depletion layer is given by

$$W = \sqrt{\frac{2\epsilon_S(V_{bi} - V)(N_A + N_D)}{qN_A N_D}}$$

$$C_j = \frac{\epsilon_S}{W} = \epsilon_S\sqrt{\frac{qN_A N_D}{2\epsilon_S(V_{bi} - V)(N_A + N_D)}}$$

Where

V_{bi} →Barrier potential

V → Applied voltage

ϵ_S → Dielectric constant of the medium

N_d, N_a → Donor and acceptor concentrations

Considering all other factors constant, we have

$$C_j \propto (V_{bi} - V)^{-1/2}$$

$$\frac{1}{C_j^2} \propto (V_{bi} - V)$$

For linearly graded junction, the width of the depletion layer is given by

$$W = \left(\frac{12\epsilon_S(V_{bi} - V)}{qa}\right)^{1/3}$$

Where, qa is impurity gradient.

$$C_j = \frac{\epsilon_S}{W} = \epsilon_S\left(\frac{qa}{12\epsilon_S(V_{bi} - V)}\right)^{1/3}$$

Considering all other factors constant, we have

$$C_j \propto (V_{bi} - V)^{-1/3}$$

$$\frac{1}{C_j^3} \propto (V_{bi} - V)$$

As per the circuit diagram the varactor and the 100 Ω resistance acts as a potential divider arrangement, dividing the 50 0mV A.C. input voltage. Reactance X_C of a capacitor varies inversely to its capacitance i.e. $X_C = {}^{1}/_{2\pi f C_j}$

Since the reactance of the capacitor (varactor) varies with reverse bias voltage, the voltage across 100 Ω resistance (V_0) also varies with the reverse bias voltage.

$$\frac{V_O}{V_{IN}} = \frac{R}{Z}, where,\ Z = \sqrt{R^2 + X_C^2} = R\sqrt{1 + \frac{1}{\omega^2 C^2 R^2}}$$

$$Z = {}^{1}/_{\omega C}\left(1 \ll {}^{1}/_{\omega^2 C^2 R^2}\right)$$

$$\frac{V_O}{V_{IN}} = \omega CR, \qquad C = \frac{V_O}{2\pi f R V_{IN}}$$

$$C_j = \frac{V_O}{2\pi f R V_{IN}}$$

Procedure:

1. Connect the circuit as shown in circuit diagram.
2. Set input voltage $V_{IN} = 500mV$ at 1 MHz.
3. Apply V_{RB}.
4. Note V_0 with the variation of V_{RB}.
5. Calculate C_j.
6. Perform the experiment for another diode.
7. Draw graph of $\left({}^{1}/_{C_j}\right)^2 \times 10^{19}$ versus V_{RB} and $\left({}^{1}/_{C_j}\right)^3 \times 10^{28}$ versus V_{RB}.

Observation:

For Diode BY127

No.	V_{RB} (V)	V_O (mV)	C_j (pF)	$\left({}^{1}/_{C_j}\right)^2 \times 10^{19}$	$\left({}^{1}/_{C_j}\right)^3 \times 10^{28}$

Graph: Draw graph of $\left({}^{1}/_{C_j}\right)^2 \times 10^{19}$ v/s V_{RB} and $\left({}^{1}/_{C_j}\right)^3 \times 10^{28}$ v/s V_{RB}

**** Repeat the observation and draw the graphs for two more junctions.**

Result

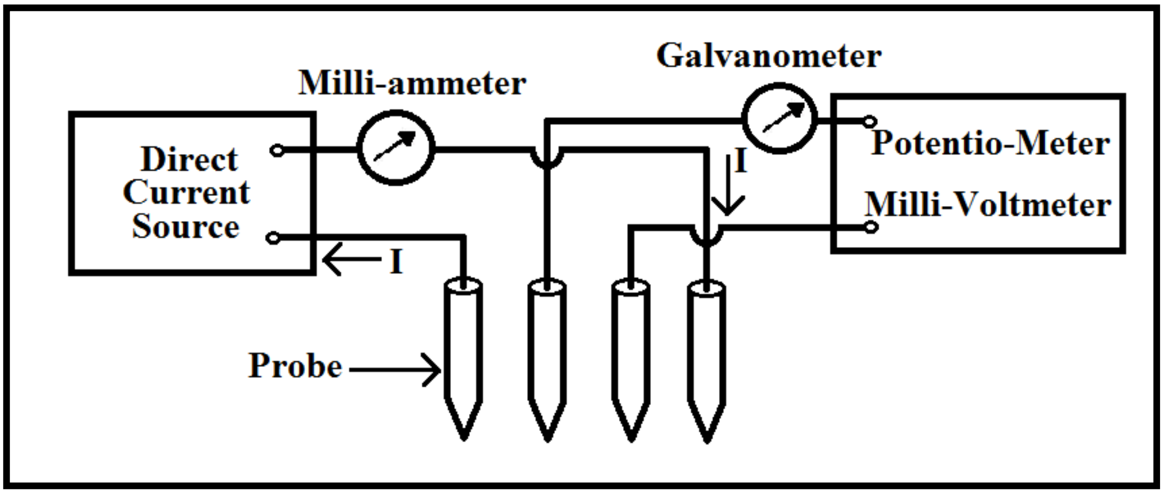
Experiment 6

Resistivity: Four-Probe Method

Aim: To find the resistivity of a given semi-conductor material using Four Probe method.

Apparatus: Four probe kit, oven, CCS, voltmeter, etc.

Circuit Diagram:



Theory: In the semiconductor industry, the most generally used technique for the measurement of resistivity is by using Four-Probe. The usual geometry is to place all the probes in a line and equal probe spacing current is passed though the outer two probes and the potential developed between the inner two probes is measured. Instead of four probes, any other number of probes can be used and any other combination of probe current and voltage can be used. Instead of equal amount of spacing between probes, unequal distance can also be considered.

For probes resin on semi-infinite medium, the resistivity is $\rho = 2\pi s \, V/I$ where 's' is the spacing in centimeter. If the probes spaced $s_1 = s_2 = s_3 = \ldots = s$

There is a limitation for accurate measurement of current because generally it is in small fraction of amperes. It is often convenient to preset the current to 2πs milli-amperes or micro-amperes, so that the resistivity in Ωcm, is numerically equal to measured voltage in milli or micro volts respectively. Alternately the probe spacing can be 0.159 cm so that 2πs = 1, in this case, ρ is given numerically by V/ I.

Normally, a large enough sample to be considered infinite is not available and that in above case is not directly applicable. However, since the four probe offers the most convenient mode of resistivity measurement, a variety of corrections have been developed. For an electrically isolated slice, ρ approaches 0.73 (W/S) ρ, where (W/S) becomes less than 1. Where 'W' is the slice thickness. If the back of the slice is covered with a conducting layer (e.g.: a metal layer) dependable results are possible only when (W/S) > 0.5. Thus in-order to measure layers few micrometers thick accurately; very close probe spacing is required.

If a slice has a finite extent, two set of corrections are required. They are usually considered to be independent to each other and are given in terms of measured V/I i.e.

$$\rho = F_1 F_2 \rho_{mean}$$

Where F_1 is the correction for the edge effects and F_2 takes into account the slice thickness. For thickness greater than the probe spacing, interaction between thickness and edge effect does not allow a simple set of independent corrections. Sheet resistance R_s is used in evaluating thin conducting layers. R_s = V/I when the contacts extend the full length of the opposite side of square material and independent of the side of the square. For four-point probes

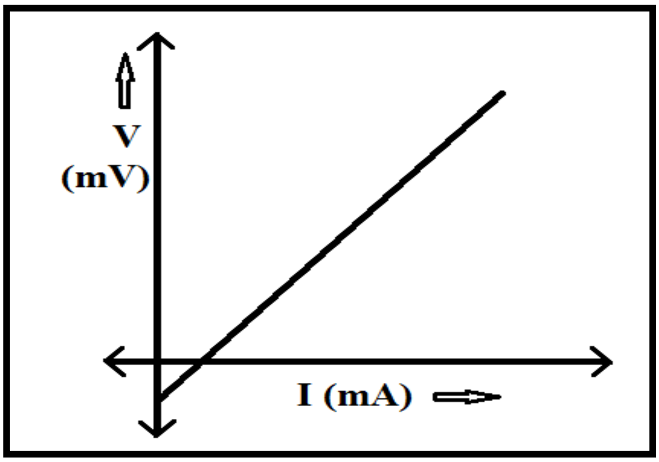
$R_s = F^*(V/I)$, Where F* is all possible combination of current and voltage.

Observation:

1) To Study the Ohmic Characteristics:

No.	Probe Current (mA)	Probe Voltage (mV)

Graph:



Result:

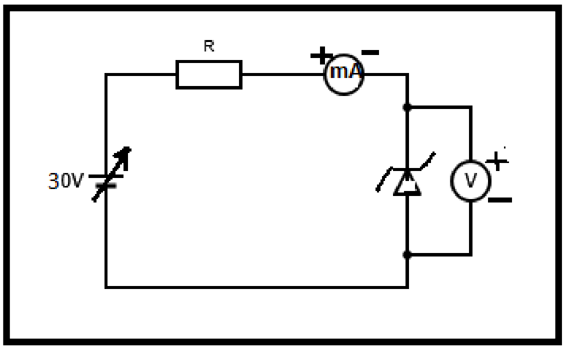
Experiment 7

Temperature Dependence
Avalanche & Zener Breakdown Voltages

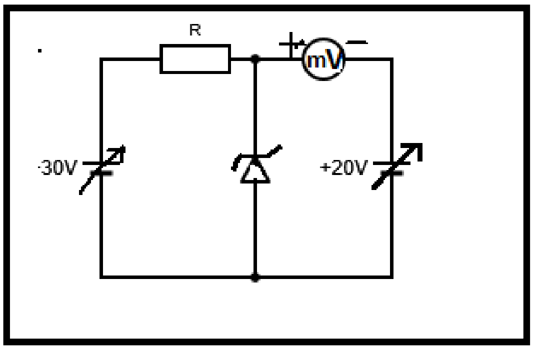
<u>Aim:</u> To study the Temperature Dependence of Avalanche and Zener Breakdown diodes.

<u>Apparatus</u>: Zener Diodes (9.2V, 2.8V), Variable power supply, voltmeter, milliammeter, etc.

<u>Circuit Diagram:</u>

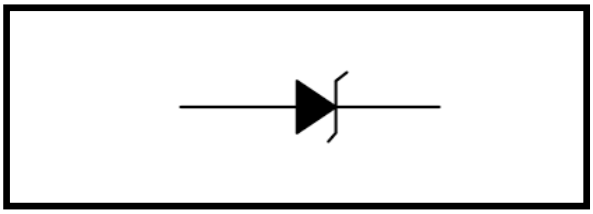


Reverse bias V-I Characteristics



Thermal Characteristics

<u>Theory</u>: A Zener diode is a special type of diode designed to operate in the Zener breakdown region. It is named after the American physicist Clarence Melvin Zener who discovered the Zener effect. Zener diode is heavily doped p-n junction diode. Hence, it has very thin depletion region. It is generally operated in the reverse breakdown region. The breakdown voltage of a Zener diode is carefully set by controlling the doping level during manufacture.



Zener Diode Symbol

<u>Zener Breakdown:</u>

Forward biased Zener diode works like a normal diode. When reverse biased voltage is applied to a Zener diode, it allows only a small amount of leakage current until the voltage is less than Zener voltage. When reverse biased voltage applied to the Zener diode reaches Zener breakdown voltage, it starts allowing large amount of electric current. At this point, a small increase in reverse voltage will rapidly increase the electric current.

The Zener breakdown voltage of the Zener diode depends on doping level. If the diode is heavily doped, Zener breakdown occurs at low reverse voltages. On the other hand, if the diode is lightly doped, the Zener breakdown occurs at high reverse voltages. Zener diodes are available with Zener voltages in the range of 1.8V to 400V.

Avalanche Breakdown:

When high reverse voltage is applied to the p-n junction diode, the free electrons (minority carriers) gains large amount of energy and accelerated to greater velocities. The free electrons moving at high speed will collide with the atoms and knock off more electrons. These electrons are again accelerated and collide with other atoms. Because of this continuous collision with the atoms, a large number of free electrons are generated. As a result, electric current in the diode increases rapidly. This sudden increase in electric current may permanently destroy the normal diode. However, avalanche diodes do not get destroyed because they are carefully designed to operate in avalanche breakdown region. Avalanche breakdown occurs at greater than 6V.

Applications of Zener Diode:

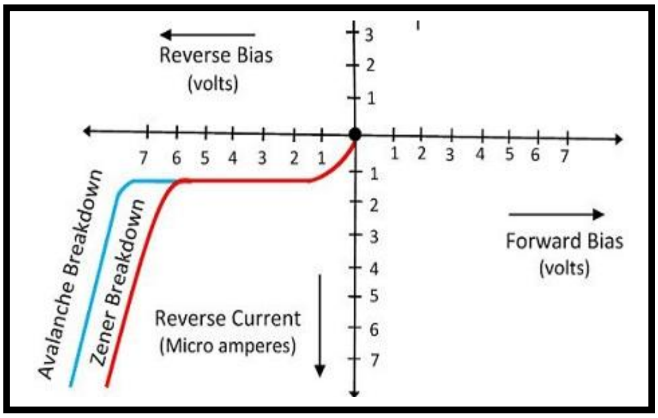
- Used as voltage reference.
- Zener diodes are used in voltage stabilizers or shunt regulators.
- Zener diodes are used in switching operations
- Zener diodes are used in clipping and clamping circuits.
- Zener diodes are used in various protection circuits

Zener Breakdown & Temperature Effect:

As temperature increases, band gap decreases so less electric field is required to pull electrons from valence band to conduction band. So, Zener breakdown voltage decreases as the temperature increases. Hence, temperature coefficient is negative.

Avalanche Breakdown & Temperature Effect:

Due to increase in temperature, vibrations of atoms increase and thus reduce the mean free path for electrons. Hence in avalanche breakdown, breakdown voltage increases with increase in temperature. So, temperature coefficient is positive.



Observations:

i) **Reverse bias V-I Characteristics of Zener Diode:**

Obs. No.	V in Volts	I in mA

ii) **Reverse bias V-I Characteristics of Avalanche Diode:**

Obs. No.	V in Volts	I in mA

iii) **Thermal Characteristics for Zener Diode:**

Temp ^{0} C	Output Voltage mV	Mean Voltage

iv) **Thermal Characteristics for Avalanche Diode:**

Temp ^{0}C	Output Voltage mV	Mean Voltage

Result:

Temperature coefficient of Zener Diode is --------------------mV/^{o}C.
Temperature coefficient of Avalanche Diode is --------------------mV/^{o}C.

Experiment 8

Linear Variable Differential Transducer

Aim: Study of Linear Variable Differential Transducer.

Apparatus: Dual trace CRO, Patch cords, LVDT trainer kit, etc.

Theory: The most widely used inductive transducer to translate the linear motion into electric signals is the Linear Variable Differential Transducer (LVDT).

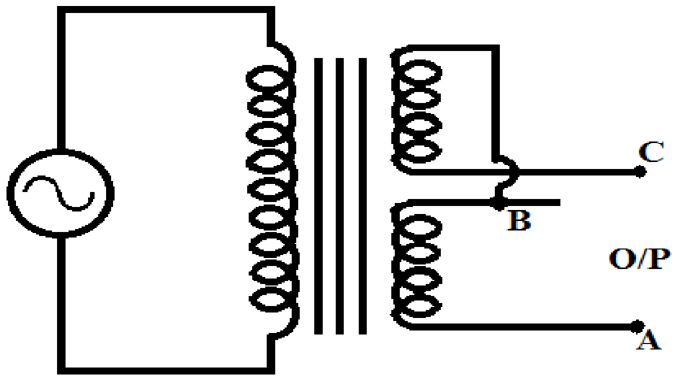


Fig (1): Connection Diagram For Observing 180^0 Phase Shifted Output

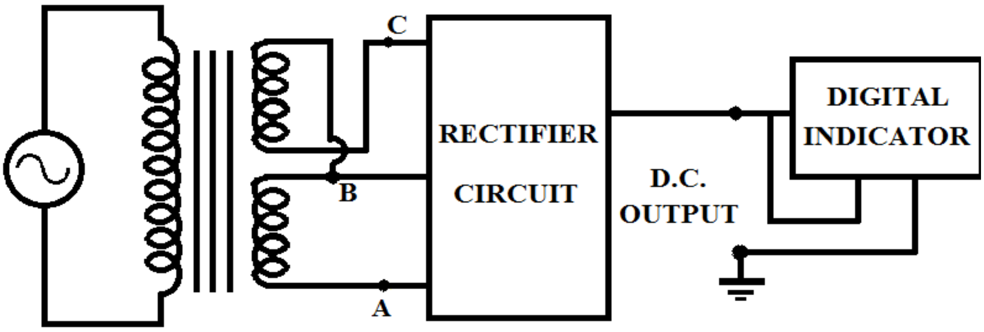


Fig (2): Connection Diagram For Observing The D.C. Output For The Corresponding L.V.D.T. Displacement

The basic construction of the LVDT is given in Fig (1). The transformer consists of a single primary winding P_1 and two secondary windings S_1 and S_2 wound on a cylindrical former. The secondary windings have equal number of turns and are identically placed on either side of the primary winding. The primary winding is connected to an A.C. source. A movable soft iron core is placed inside the former. The displacement to be measured is applied to an arm attached to the soft iron core. In practice the core is made from nickel iron alloy, which is slotted longitudinally to reduce eddy current losses. When the core is in the normal position (NULL position), equal voltages are introduced in two secondary windings. The frequency of the A.C. applied to primary winding may be between 50 Hz to 20 KHz.

The output voltage of secondary winding S_1 is ES_1 and that of the secondary winding S_2 is ES_2. In order to convert outputs from S_1 and S_2 into a single voltage signal, the two secondary windings S_1 and S_2 are connected in series opposition as shown in Fig (2). Thus, the output voltage of the transducer is the difference of the two voltages. Differential output voltage $E_O = ES1 - ES2$

When the soft iron core is at the normal position, the flux linking with both the secondary windings is equal and hence equal emfs are introduced in them. Thus, at null position ES1 = ES2. Since the output voltage of the transducer is the difference of the two voltages, the output voltage E_O is equal to zero at null position.

Now if the soft iron core is moved to the left of the null position, number of turns will change in S_1 and S_2. Accordingly output voltage of S_1 is more than ES_2 and it is the output voltage of S_2. The magnitude of output voltage is thus $ES_1 - ES_2$, and the output voltage is in phase with ES_1 i.e. output voltage of S_1. The reverse of above happens when the soft iron core moved to the right of null position.

The amount of voltage change in either of the secondary winding is proportional to the amount of movement of the soft iron core. Hence, we have an indication of amount of linear motion. By noting which output voltage is increasing or decreasing, we can determine the direction of motion. In other words, any physical displacement of the soft iron core causes the voltage of one secondary winding to increase while simultaneously decreasing the voltage in the other secondary winding. The difference of the two voltage appear across the output terminal of the transducer gives a measure of the physical position of the core and hence the displacement.

As the core is moved in one direction from the null position, differential voltage i.e. the difference of the two secondary voltages while maintaining the phase relationship with the null position, the difference voltage will also increase, but will be 180° out of phase with the voltage from the source. By comparing the magnitude and the phase of the output (differential) voltage with that of the source, the amount and direction of the movement of the soft iron core and hence of the displacement may be determined.

The amount of the output voltage may be measured to determine the displacement. The output signal may also be applied to a recorder or to a controller that can restore the moving system to its normal positions.

Uses of LVDT:

1. The LVDT can be used in all applications where displacement ranging from fractions of milli-meter to few centi-meters has to be measured. LVDT converts the displacement into an electrical output proportional to displacement. This is a fundamental conversion i.e. mechanical variable (displacement) is directly converted into an analogous signal (voltage).

2. Acting as a secondary transducer, it can be used as a device to measure force, weight and pressure, etc. the force measurement can be done by using a load cell as the primary transducer while fluid pressure can be measured by using Bourdon tube, which acts as a primary transducer. The force or the pressure is converted into a voltage. In these applications the high resistivity of LVDT is a major attraction.

Disadvantages of LVDT:

1. Relatively large displacements are required for appreciably different output.
2. Many a times, the transducer performance is affected by vibrations.

Observations:

1. **A.C. Characteristics of LVDT**

No.	Displacement (mm)	Output Voltage (V)

2. **D.C. Characteristics of LVDT**

No.	Displacement (mm)	Output Voltage (V)

3. **Phase of the Secondary Coils with Displacement:**

Obs. No.	Displacement (mm)	t (μs)	$\theta^\circ = \frac{t}{T} \times 360^\circ$	Comments

Graph:

Result:

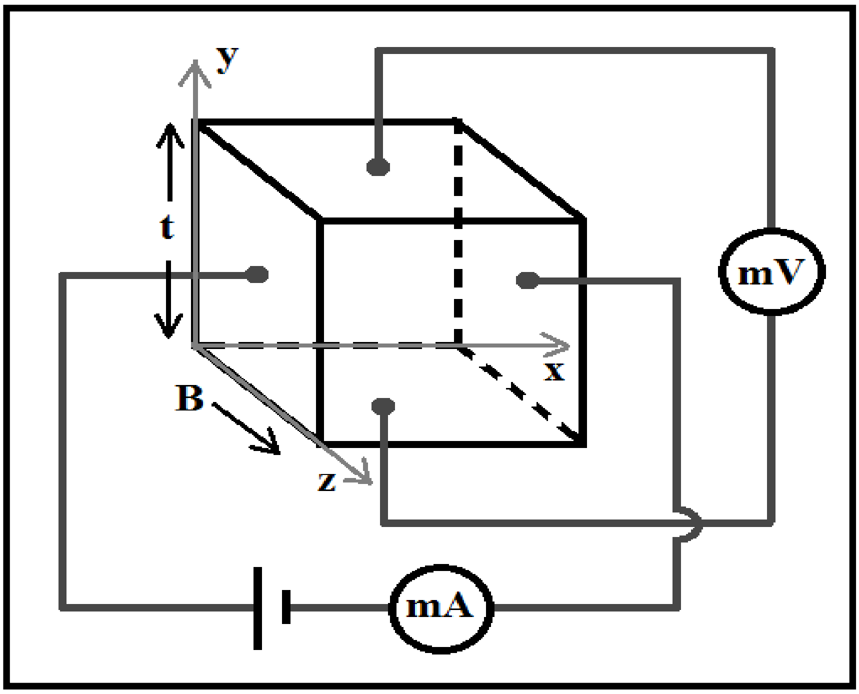
Experiment 9

DC Hall Effect

Aim: To study DC Hall Effect using the given semiconductor sample and to calculate the Hall coefficient.

Apparatus: Semiconductor sample, electromagnets (Hall kit), bread board, connecting wires, ammeter, DMM, resistance, etc.

Theory: If a piece of conductor (metal or semi-conductor) carrying current is placed in a transverse magnetic field, an electric field is produced inside the conductor in a direction perpendicular to both the current and the magnetic field. This phenomenon is called Hall Effect and the voltage developed is called Hall Voltage.



With reference to the diagram, the battery connected to the specimen is responsible for current to flow in x-direction. Magnetic field is applied along z-direction. So, Hall Voltage develops along y-direction and this voltage is in milli-volts.

The whole concept moves around the expression $\vec{F} = e(\vec{v} \times \vec{B})$ i.e. the force on the electron or hole will be in a direction perpendicular to both electric and magnetic field and the process of charge accumulation of charges continues till the equilibrium stage is reached i.e.

$$eE_H = eBv \qquad \Rightarrow E_H = Bv$$

If J_x is the current density in the x-direction, then $J_x = nev \quad \Rightarrow \quad E_H = \frac{BJ_x}{ne}$

The Hall Effect is described by means of Hall Coefficient R_H, defined in terms of the current density J_x

$$E_H = R_H J_x B \quad or \quad R_H = {}^{E_H}\!/_{J_x B} \qquad \therefore\ R_H = \frac{1}{ne}$$

If 't' is the thickness of the specimen across which voltage is developed

$$V_H = E_H t \quad \Rightarrow \quad V_H = B_t R_H J_x$$

If 'b' is the width of the sample, then its cross section will be 'bt' and the current density is given by $J_x = \frac{I_x}{bt}$ $\therefore\ V_H = \frac{R_H I_x B t}{bt}$ $\therefore\ R_H = \frac{V_H b}{I_x B}$; R_H can be determined.

Observation:

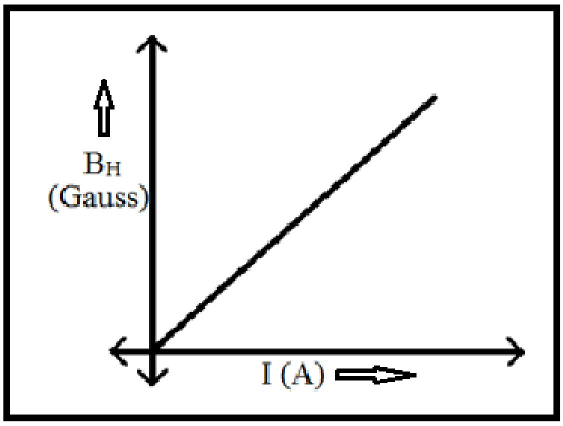
No.	I_S (mA)	I_{H1} =		I_{H2} =		I_{H3} =	
		V_H (mV)		V_H (mV)		V_H (mV)	
		Forward	Reverse	Forward	Reverse	Forward	Reverse

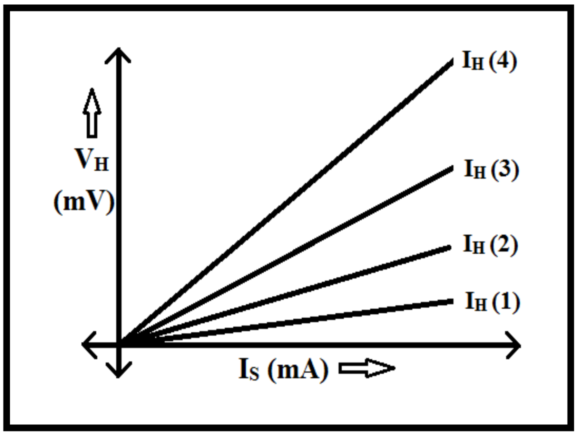
Calibration Chart:

I (A)	B_H (Gauss)

Graph:

Calculation:





1) Slope of V_H v/s I_S graph at, I_H = ________ m A = ___________

2) To calculate Hall Coefficient

$$R_H = \frac{V_H}{I_S} \times \frac{W}{B_y} \times 10^8 = (Slope) \times \frac{W}{B_y} \times 10^8$$

Result:

Experiment 10

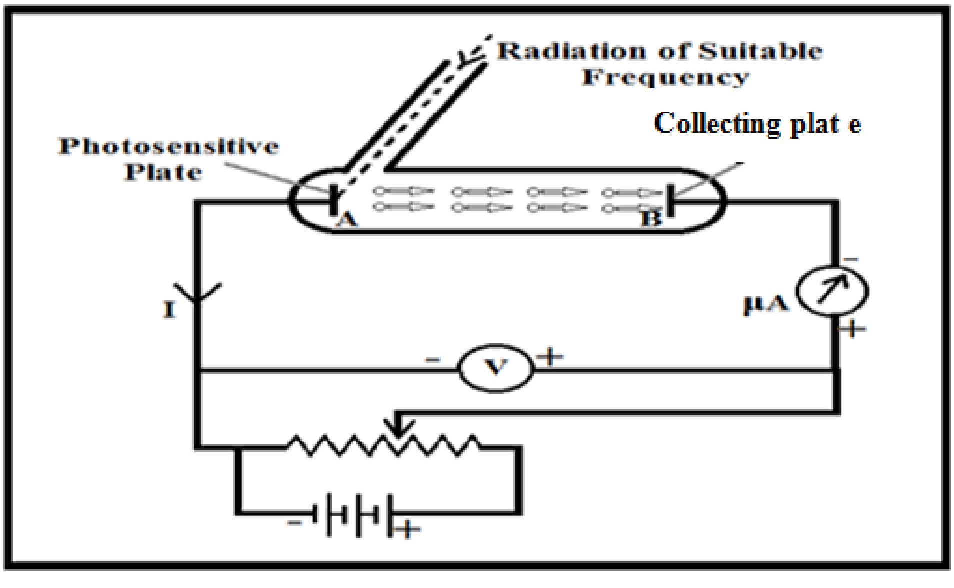
h/e using Vacuum Photo-cell

<u>Aim</u>: To study h/e using vacuum photo-cell.

<u>Apparatus</u>: Experimental set up for h/e.

<u>Theory</u>: Max Planck's Quantum Theory was formulated to explain the distribution of energy in the spectrum of black body; it is assumed that atoms in the walls of the black body behave like a simple harmonic oscillator and each one has a characteristic frequency of oscillation. These oscillators cannot have any arbitrary values of energy, rather is expressed as E = hυ. (n = 0, 1, 2, 3 and so on) E = energy of the oscillator; h = Planks constant; υ = frequency of oscillation. When an oscillator jumps from higher state n_2 to lower state n_1, it emits energy in the form of electro-magnetic radiation; $E = (n_2 - n_1)h\upsilon$

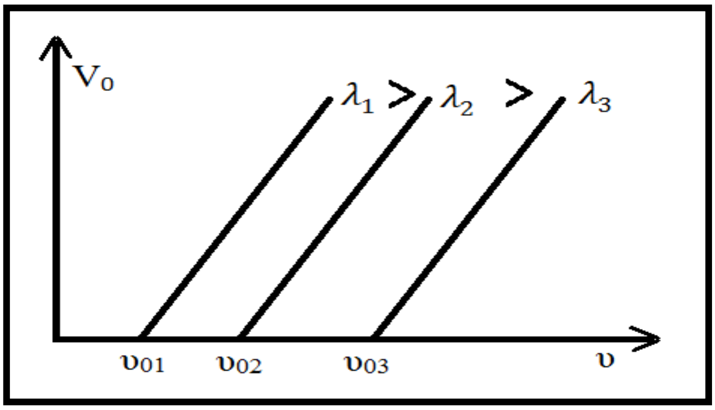
<u>Photoelectric Effect</u>: Photoelectric Effect was discovered by Heinrich Hertz in 1887 and studied in detail by Lenard. When a light of suitable frequency falls on a metal surface, electrons are emitted from metal surface. This phenomenon is known as Photo electric Effect. This effect cannot be described by Maxwell's wave theory of light.



<u>Einstein's Explanation of PEE</u>: Einstein applied Planck's Quantum theory of light to explain photoelectric effect. He assumed that light is made up of a stream of particles called 'Photons'. Photons have zero rest mass and they travel through space with the speed of light. Energy of each photon is E = hυ. The minimum amount of energy required for electron at the surface to come out from the surface is called the 'Work Function = ϕ'. When a photon of energy hυ is incident on the metal surface, entire energy of photon is absorbed by an electron of metal if $h\upsilon \geq \phi$, otherwise it is reflected. Electron absorbs energy of a single photon only. If the photon is absorbed its energy is used by electron to come out from the metal surface.

$$h\upsilon = \phi + K.E_{max} = \phi + {}^{1}/_{2}\, mv_{max}^{2}$$

It means, if photon has energy greater than ϕ, electrons are emitted with some kinetic energy i.e. they contribute to the current. When a potential difference (V), is applied to the emitted electrons, they acquire energy eV. If a positive potential is applied to plate B, then the motion of electron is opposed by applied field. To stop the electrons from being emitted by metal surface, the applied negative voltage should be atleast equal to the stopping potential given by V_0,



Electrostatic Energy = K.E. $_{max}$

$$\therefore eV_0 = {}^{1}/_{2}\, mv_{max}^{2} = hv - \phi$$
$$\therefore V_0 = \frac{h}{e}v - \frac{\phi}{e}$$

From the above equation, we know that if we plot a graph of V (voltage) against υ (frequency), then we get a straight line with slope h/e we can plot this graph for different values of wavelength and determine h/e more accurately.

<u>Observation</u>:

No.	**V_R (V)**	**I(μA)**			
		Yellow λ_y = _____A° f_y = ______Hz	**Green** λ_g = ______A° f_g = ______Hz	**Blue** λ_b = ______A° f_b = ______Hz	**Violet** λ_v = ______A° f_v = ______Hz

Colour	**Yellow**	**Green**	**Blue**	**Violet**
Stopping Potential (V_0)				
Frequency (Hz)				

Calculation: $(V_{0A} - V_{0B}) = \frac{h}{e}\left(\frac{1}{\lambda_A} - \frac{1}{\lambda_B}\right) c \therefore \frac{h}{e} = \frac{(V_{0A} - V_{0B})}{\left(\frac{1}{\lambda_A} - \frac{1}{\lambda_B}\right) c}$

Error in calculation = $\Delta \frac{h}{e} = \sqrt{\frac{\sum (x_i - x')^2}{n\ (n-1)}}$

Where x = $\frac{h}{e}$ and x′= mean $\frac{h}{e}$

Graph:

Result:

1) **h/e (by calculation) = __________Js / Coulomb**
2) **h/e (by graph) = __________Js / Coulomb**

Experiment 11

Ultrasonic Interferometer

Aim: To study the velocity of ultrasonic waves in a liquid medium using Ultrasonic Interferometer.

Apparatus: Ultrasonic Interferometer kit, sample liquid.

Theory: An Ultrasonic Interferometer is a simple and direct device to determine the ultrasonic velocity in liquid with a high degree of accuracy. The principle used in the measurement of velocity (v), is based on the accurate determination of wavelength (λ) in the medium. Ultrasonic waves of known frequency (f) are produced by a quartz crystal fixed at the bottom of the cell. The waves are reflected by a movable metallic plate kept parallel to quartz crystal. If the separation between these two plates is exactly a whole multiple of the sound wavelength, a standing wave is formed in the medium. This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz crystal and the anode current to the generator becomes maximum. If the distance is now increased or decreased and the variation is exactly one half of the wavelength or multiple of it, anode current becomes maximum. From the knowledge of wavelength (λ) and frequency (f), the velocity (v) can be obtained by the relation; $v = f \times \lambda$

The Ultrasonic Interferometer consists of following parts

a. The high frequency generator: 1, 3 and 5 MHz
b. The measuring cell: 1 MHz
c. Base to hold the cell
d. Co-axial cable

1. The High Frequency Generator: It is designed to excite the quartz crystal fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic waves in the experimental liquid filled in the 'Measuring Cell'. A micrometer is provided to observe the changes in the current and two controls for the purpose of sensitivity regulation and initial adjustment of the micro-meter are provided on the panel of high frequency generator.

2. Measuring Cell: It is specially designed double walled cell for maintaining the temperature of the liquid constant during experiment. A fine micrometer screw has been provided at the top, which can lower or raise the reflector plate in the liquid in the cell through a known distance. It has a quartz crystal fixed at the bottom. In multi-frequency Ultrasonic Interferometer, frequency selector knob should be positioned at desired frequency.

Adjustments: For initial adjustment two knobs are provided on high frequency generator, one is marked with 'ADJ' to adjust the position of the needle on the ammeter and the knob marked 'GAIN' is used to increase the sensitivity of the instrument for greater deflection, if desired. The ammeter is used to notice the number of maximum deflections while micrometer is moved up and down in liquid as described.

Precautions:

1. Do not switch ON the generator without filling the experimental fluid.
2. Do not tilt the cell after filling the liquid to avoid flow of liquid towards micro-meter which may rust/jam the threads of the micro-meter head.
3. Keep micrometer open at 25 mm after use.
4. Remove experimental liquid out of the cell after use.
5. Avoid sudden rise or fall in temperature of the liquid used to prevent thermal shock to the crystal.
6. Give generator 15 minutes warming up time.

Observations:

Smallest division on the main scale = x = ______ mm
Number of divisions on the circular scale = N = _______
Least count = L= x/N = _______ mm

No.	Distance x_i (mm)			Difference d (mm)
	M.S.R	C.S.R	T.R	
			x_1 =	$\lvert x_2 - x_1 \rvert$ =
			x_2 =	$\lvert x_3 - x_2 \rvert$ =
			x_3 =	$\lvert x_4 - x_3 \rvert$ =
			x_4 =	$\lvert x_5 - x_4 \rvert$ =
			x =	

Calculation:

Mean difference = $\lambda/2$ = ________ mm

$\therefore \lambda$ = _________ mm

$\therefore$ v = $\lambda \times f$ = _______ m/s

Result:

The velocity of ultrasonic waves in the given liquid is __________ m/s.

Experiment 12

Characteristics of Geiger-Muller Counter

Aim:To study the characteristics of G.M. counter and to calculate its dead time.

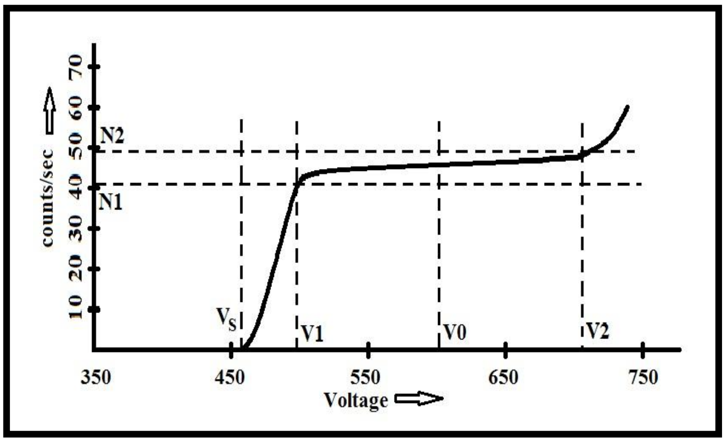
Apparatus: G.M. counters kit, radioactive sample.

Theory: G.M. radiation tubes are intended to detect alpha particles, beta-particles, gamma or X-radiations. A G.M. tube is a gas filled device, which reacts to individual ionizing events, thus enabling them to be counted. A G.M. tube consist of basically an electrode at positive potential (anode) surrounded by a metal cylinder at a negative potential (cathode). The cathode forms part of the envelope or is enclosed in a glass envelope. Ionizing events are initiated by quanta or particle entering the tube either through the window or through the cathode and colliding with the gas molecule.

Operating Characteristics:

Starting Voltage: This is the lowest voltage applied to a G.M. tube at which pulse of 1V amplitude appears across the anode resistor.

Plateau: This is the section of the counting rate versus voltage characteristics (with constant irradiation) over which the counting rate is substantially independent of the applied voltage. Unless otherwise stated the plateau is measured at a counting rate of approximately 100 counts.



Plateau Threshold Voltage: This is the lowest voltage applied which corresponds to the start of the plateau for the stated sensitivity of the measuring circuit.

Plateau Length: This is the range of applied voltage over which the plateau extends.
Plateau Slope: This is the change in counting rate over the plateau length, in % per volume.

Recommended Supply Voltage: This is the supply voltage (V_0) at which the G.M. tube should be preferably used. This voltage is normally chosen to be in the middle of the plateau region.

Background: This is the counting rate of the surrounding in the absence of the radiation which the G.M. tube is intended to measure.

Dead Time: This is the time interval, after the initiation of a discharge resulting in a normal pulse during which the G.M. tube is insensitive to further ionizing events.

Characteristics of The G.M. Tube: To study the characteristics of a G.M. tube, the variation of the count-rate with change in applied voltage is studied. For this an α, β or γ source is used and counting of radiations is noted for different values of applied voltage. At a particular voltage, the count-rate suddenly increases; this region is called the 'Discharge Region'. A graph of applied voltage versus the corrected count-rate gives a graph as shown in the above figure.

Where,

$V_1 \Rightarrow$ starting voltage of the plateau
$V_2 \Rightarrow$ upper threshold of the plateau
$V_{PL} = V_2 - V_1 \Rightarrow$ plateau length
$V_0 = (V_2 - V_1)/2 \Rightarrow$ operating voltage

Slope of plateau is given by, slope = $\frac{(N2-N1)}{N1} \times \frac{100}{(V_2 - V_1)}$

(Where N1 and N2 are the count-rate at the lower and upper limits of the plateau)
If the slope is less than 10% then the tube is defined to be good.

Dead Time using Double Source:

The G.M. counter is a slow device. In a G.M. counter, the negative ions formed (mostly free electrons) reach the wire very quickly, in about 5×10^{-7} sec, however the sheath of positive ions that now surrounds the wire reduces the voltage gradient below the value necessary for ion multiplication and the counter cannot record anything until the positive ions reaches the cathode in about 100-500 µsec. This time is known as 'Dead Time' and it limits the use of G.M. counter to counting-rates below a few tens of thousands per minute. The two-source method is based on observing the counting rates from the source individually and in combination. Because the counting-rates are non-linear, the observed rates due to combined source will be less than the sum of the rates due to the two sources counted individually and the dead time can be calculated from this discrepancy.

If n= true count rate, m= recorded count rate, T= system dead time

Then $n = \frac{m}{1-mT}$ counts/min

Extending this for two-source method, let n_1, n_2 and n_{12} be the true counting rates with source 1, source 2 and combined sources respectively. Then we have $n_{12} = n_1 + n_2$

$$\therefore \frac{m_{12}}{1-m_{12}T} = \frac{m_1}{1-m_1T} + \frac{m_2}{1-m_2T}$$

$$\therefore deadtime\ T = \frac{m_1 + m_2 - m_{12}}{2\,m_1 m_2}$$

Observation:

1) To Study the Characteristics of G.M. Tube

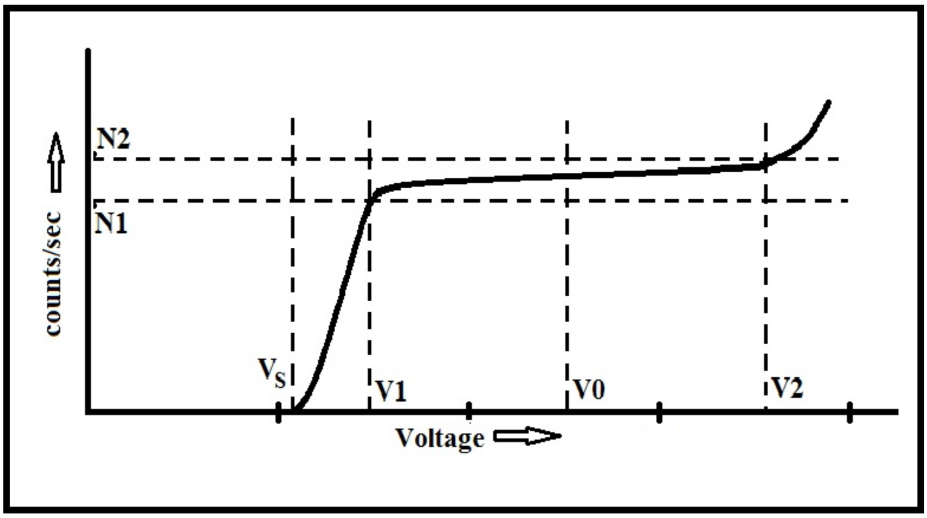
Source 1				
Obs. No.	**Voltage (V)**	**Counts**	**Background counts**	**Corrected counts**

Source 2				
Obs. No.	**Voltage (V)**	**Counts**	**Background counts**	**Corrected counts**

2) Dead Time Using Double Source Method

Obs. No.	**Counts / 10 sec**			
	Source 1	**Source 2**	**Source 1 & 2**	**Background**
Mean				
Corrected	**m_1 =**	**m_2 =**	**m_{12} =**	

Graph:



Calculation:

1) The dead time of the G.M. tube is given by $T = \frac{m_1 + m_2 - m_{12}}{2\, m_1 m_2}$ = ___________ ms
2) True count rate = $n = \frac{m}{1-mT}$= __________ /s
   Where 'm' is count per second of source 1 and source 2 combination.
3) Expected count rate = n′ = (m_1 / 10) + (m_2 / 10) = _____________ /s

Result:

1) **Plateau slope of source 1 = s_1 = ________%**
2) **Plateau slope of source 2 = s_2 = ________%**
3) **Dead time of the counting spectrum = T = ________s**
4) **True count rate**
   a. **Expected = n = __________/sec**
   b. **Observed = n = ___________/sec**

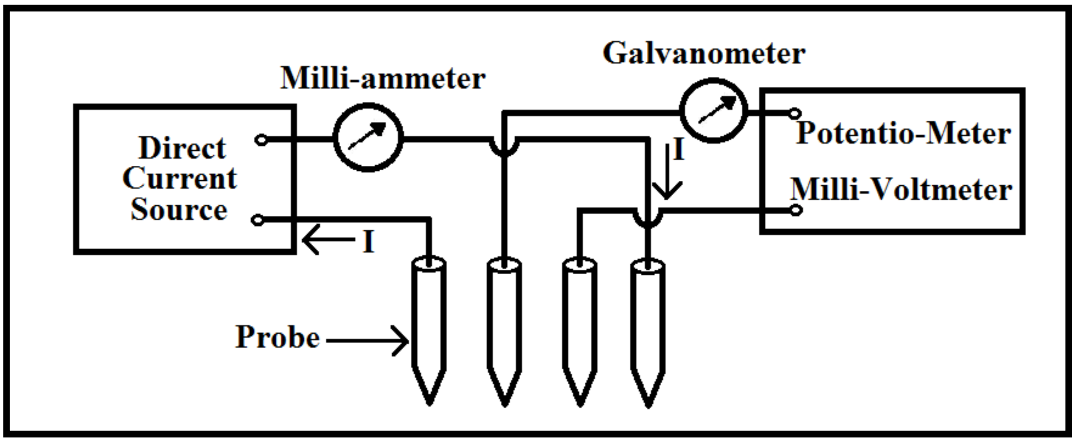
Experiment 13

Energy Band Gap: Four Probe Method

Aim: To find the energy band gap of a given material using four probe method.

Apparatus: Four probe kit, oven, constant current source, voltmeter, etc.

Circuit Diagram:



Theory: In the semiconductor industry, the most generally used technique for the measurement of resistivity is by using four-probe. The usual geometry is to place all the probes in a line with equal probe spacing, current is passed through the outer two probes and the potential developed between the inner two probes is measured. Instead of four probes, any other number of probes can be used and any other combination of probe current and voltage can be used. Instead of equal amount of spacing between probes, unequal distance can also be considered.

There is a limitation for accurate measurement of current because generally it is in small fraction of amperes. It is often convenient to preset the current to 2πs milli-amperes or microamperes, so that the resistivity in Ωcm, is numerically equal to measured voltage in milli or micro volts respectively. Alternately the probe spacing can be 0. 159 cm so that $2\pi s = 1$, in this case ρ is numerically expressed as V/I.

Normally, a large enough sample to be considered infinite is not available and that in above case is not directly applicable. However, since the four probe offers the most convenient mode of resistivity measurement, a variety of corrections have been developed. For an electrically isolated slice, ρ approaches 0.73(W/S) ρ, where (W/S) becomes less than 1. Where 'W' is the slice thickness. If the back of the slice is covered with a conducting layer (e.g.: a metal layer) dependable results are possible only when $(W/S) > 0.5$. Thus, in order to measure layers with few micrometers thick, accurately; very close probe spacing is required.

If a slice has a finite extent, two set of corrections are required. They are usually considered to be independent to each other and are given in terms of measured V/I i.e.

$$\rho = F_1 F_2 \rho_{mean}$$

Where F_1 is the correction for the edge effects and F_2 takes into account the slice thickness. For thickness greater than the probe spacing, interaction between thickness and edge effect does not allow a set of independent corrections. Sheet resistance R_s is used in evaluating thin conducting layers. R_s = V/I when the contacts extend the full length of the opposite side of square material and independent of the side of the square. For four-point probes

$R_s = F^*(V/_I)$, Where F* is all possible combination of current and voltage.

Observation:

For I = __________ mA

No.	Temp T°C	Voltage V (mV)		T °K	$^1/_T$	ρ Ω cm	$log_e \rho$
		Heating	Cooling				

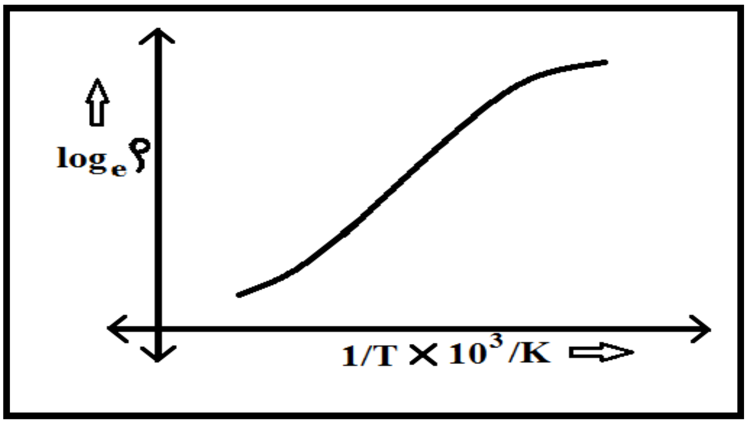
(Repeat the above steps for one more value of current)

Calculation:

$$\frac{Eg}{2K} = \frac{\log_e \rho}{\frac{1}{T}}$$

$$Eg = \frac{2.3026 \times K \times 2 \times \log_{10} \rho}{\frac{1}{T}}$$

Graph:



Result: The energy band gap of the given specimen is calculated and studied by four-probe method and is __________eV.

Experiment 14

TTL Characteristics

Aim: To determine the various current and voltage parameters of a given TTL device.

Apparatus: IC 7400, IC 7402, +5V power supply, milli-ammeter, resistance boxes, connecting wires, DMM, bread-board, etc.

Theory: IC's are identified by a decoding number of codes stamped on the top. The prefix is the manufacture's code. The next two numbers denote the family of IC's such as TTL or CMOS. If letters follow, they indicate the sub-family of the IC. The next numbers indicate the function of the IC, and the last letters indicate the package style.

***Noise Immunity*:**
It is defined as the ability of the gate or circuit to tolerate the noise at input side. If noise spikes are greater than the noise margin may drive the gate into the intermediate range. This gives rise to ambiguity.

***Noise Margin*:**
Noise margin is the quantitative measure of noise immunity of the circuit.

1. **High level Noise Margin (V_{NH})**
   $V_{NH} = [V_{OH}]_{min} - [V_{IH}]_{min} = 2.4 - 2$
   $V_{NH} = 0.4V$

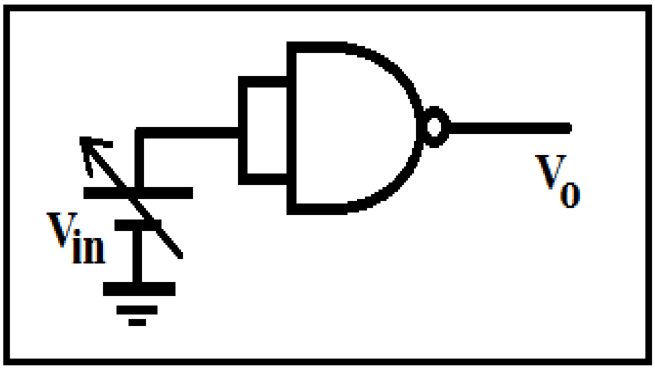
2. **Low level Noise Margin (V_{NL})**
   $V_{NL} = [V_{IL}]_{max} - [V_{OL}]_{max}$
   $= 0.8 - 0.4; V_{NL} = 0.4V$

Tristate Logic Output: Tristate logic output combines the advantages of the totem-pole and open collector outputs. The three output states are high, low and high impedance (Hi-Z). In high-impedance (Hi-Z), both transistor of the totem-pole arrangement is turned off. This means that in Hi-Z state, the circuit appears to be disconnected (open circuit).

General Parameters for TTL:

Parameter	Min(V)	Typical(V)	Max(V)
V_{OH}	2.4	3.5	---
V_{OL}	---	0.2	0.4
V_{IH}	2.0	---	---
V_{IL}	---	---	0.8

Observation: For IC 7400 (NAND Gate)



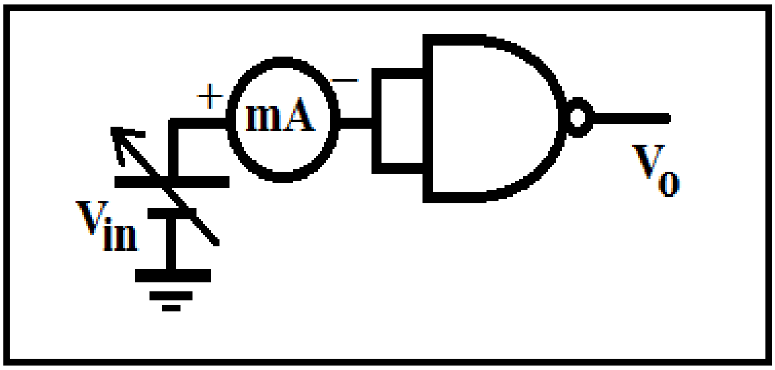
1. **Input – Output Voltage Characteristics: (without load)**

No.	Input (V)	Output (V)	Reverse O/P (V)

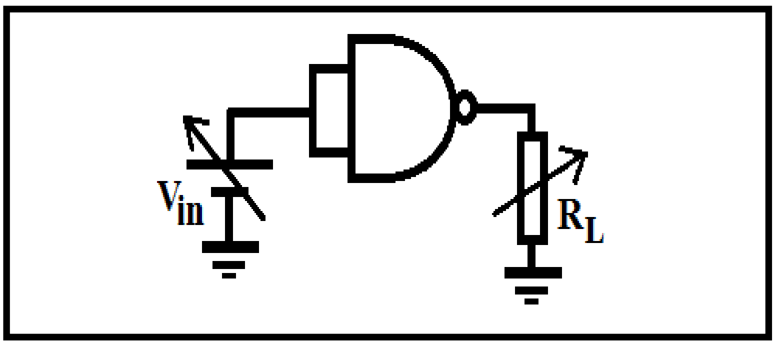
V_{IH} = ____V; V_{IL} = ____ V; V_{OH} = ____ V; V_{OL} = ____ V

2. **Input Current for High and Low Levels:**

I_{IH} = ____mA, I_{IL} = ____mA

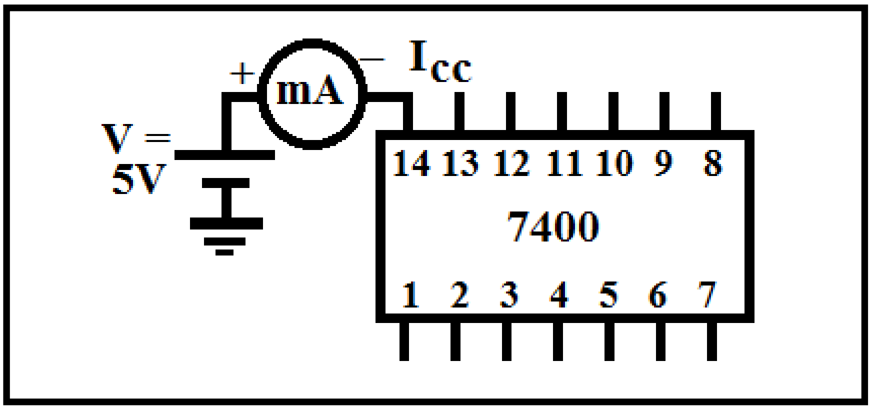


3. **Effect of Loading on Output Voltage:**



No.	V_{IN} = ____ V (High)			No.	V_{IN} = ____ V (Low)	
	R_L (Ω)	V_O (mV)			R_L (Ω)	V_O (mV)

4. **Supply Current for High and Low Levels:**



$I_{CC(1)} = I_{CC(0)}$ = _________ mA
<u>Result:</u> **TTL characteristics are studied.**

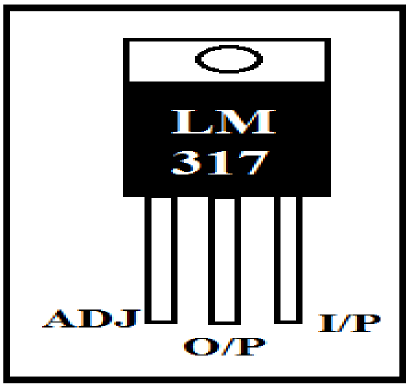
Experiment 15

Regulated Power Supply using LM 317

Aim: To design a regulated power supply using IC LM 317 and to study its line and load regulation.

Apparatus: LM 317, resistor, capacitor, resistance box, connecting wires, DMM, step-down transformer, bridge rectifier, etc.

Theory: The LM 317 is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%.



The device requires up to 3V headroom (V_I – V_O) to operate in regulation.
In operation, the LM 317 develops a nominal 1.25 V reference voltage, V_{REF}, between the outputs and adjust terminal. The reference voltage is impressed across the program resistor. Since this voltage is constant, a constant current I_1 flows through the output set resistor R_2 giving an output voltage,

$$V_0 = I_1 R_1 + R_2(I_1 + I_{adj})$$

Where, $I_1 = \frac{V_{REF}}{R_1}$.

The output voltage, $V_0 = V_{REF}\left(1 + \frac{R_2}{R_1}\right) + I_{adj} R_2$

Since I_{adj} is very small

$$V_0 = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$

Protection diodes one between input and output pin and second across R_1 is necessary to prevent the capacitors from discharging through low current points into the regulator. The I/P voltage should be at least 1.5V to 3V greater than the desired O/P.

Load Regulation: It is a measure of the circuit's ability to maintain the prescribed output voltage under changing current level through the load resistance.

$$load\ regulation = \left(\frac{V_{NL} - V_{FL}}{V_{NL}}\right) \times 100\%$$

where V_{NL} = load voltage with no load current
V_{FL}= load voltage with full load current

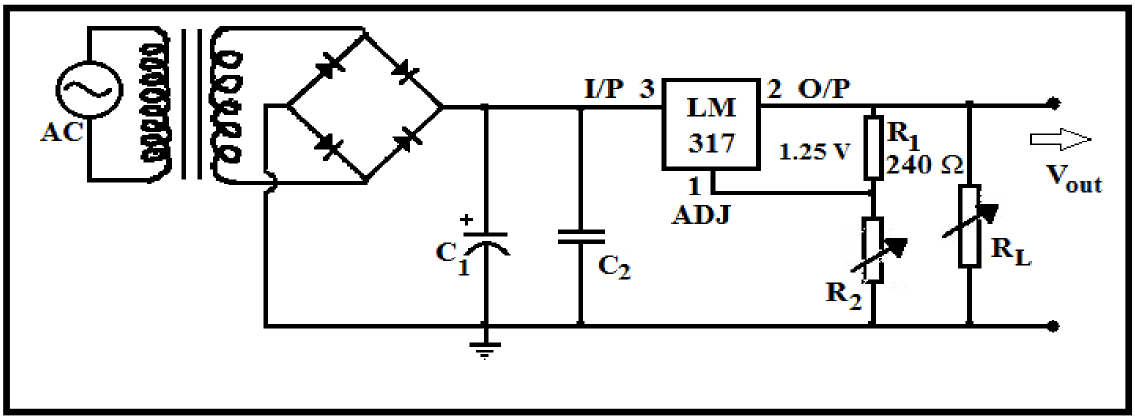
Line Regulation: It is the measure of circuit's ability to maintain the output under varying input voltage. It is the change in regulated load voltage for a specified range of line voltage, typically 220 V±10%

$$line\ regulation = \frac{V_{HL} - V_{LL}}{V_{nom}} \times 100\%$$

Where V_{HL}= load voltage with high line, V_{LL} = load voltage with low line

V_{nom} = nominal load voltage under typical operating conditions

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in the diagram.
2. Also measure V_{REF}. Calculate the value of R_2 for a desired value of output voltage V_0.
3. Connect the load resistance across the output and obtain the load regulation characteristics for the given range of load current.
4. Calculate percentage of load regulation.
5. Study line regulation by varying the line voltage [220 ± 10% of 220] V and note the output voltage.
6. Calculate percentage of load regulation.
7. Measure the input ripple V_{ir} (peak-to-peak) by connecting load.
8. Calculate the output ripple which is given by.

$$\text{Ripple rejection in dB} = 20\ \log_{10}\frac{V_{ir\ (p-p)}}{V_{0r\ (p-p)}}$$

The ripple rejection is 90 dB.

Observations:

$V_i =$ ______ $, V_{REF} =$ _____ , $R_2 =$ _______Ω, $R_1 =$ ________Ω

$$V_o = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$

Obs No.	R_L (Ω)	V_L (V)	I (mA)

Graph:

Result:

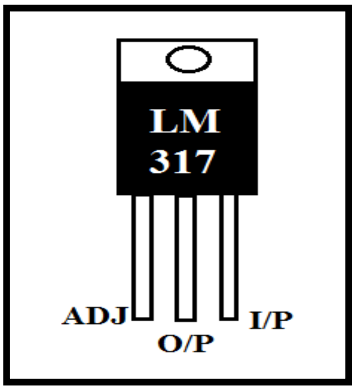
Experiment 16

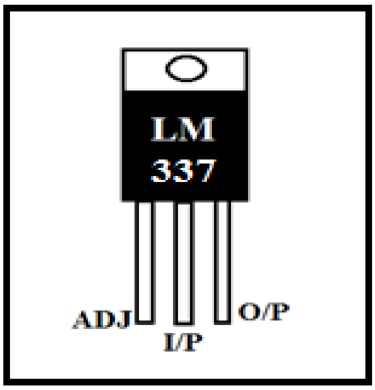
Regulated Dual Power Supply LM 317 & LM 337

<u>Aim:</u> To study LM317 and LM337 as a variable voltage source, use it as a dual supply and to study its line and load regulation.

<u>Apparatus</u>: IC's (LM 317 and LM 337), resistor, capacitor, resistance box, connecting wires, DMM, step-down transformer, bridge rectifier, etc.

<u>Theory</u>: LM 317 and LM 337 are standard part number of an integrated, three terminal, adjustable, floating (regulator that has no direct ground connection i.e. all connections will have some voltage above or below earth or ground voltage) linear voltage regulator. LM 317 is a positive voltage regulator capable of supplying an excess current of 1.5 A and support an input voltage of 3 V to 40 V and output voltage between 1.25V and 37V. LM 337 has the same properties, the difference being, it is*





a negative voltage regulator.

LM 317 and LM 337 offers full overload protection with current limiting, thermal overload protection and safe area protection, besides having a high performance as compared to fixed regulator. The adjustment terminal can be bypassed with a capacitor to ground, to achieve very high ripple rejection ratio. This is difficult to achieve in standard 3-terminal regulators. In operation LM 317 and LM 337 develops and maintain a reference voltage, V_{ref} = 1.25V, between its adjustment pin and O/P terminal. This reference voltage is converted to current by resistance R_1, and its constant current flows through R_2 to ground.

Since LM 317 and LM 337 are floating regulators, it is only the voltage difference between the circuits which is important for performance. Thus, operation at high voltage with respect to ground is possible.

The AC supply is fed into a step-down transformer, whose O/P goes into the bridge, which is the rectifier circuit for full-wave rectification. The electrolytic capacitor C_1 of value 1000μF/50V helps in filtering this rectified wave to produce a DC current with unwanted AC ripple. The necessity of LM 317 and LM 337 is to remove this unwanted AC ripple from the DC and for line and load regulation. A capacitor C_2 is used for minimizing the problems caused by long leads and wires.
R_1 = 120Ω, R_2 = 10KΩ, C_1 and C_2 are electrolytic capacitors, C_2 = C_4 = 0. 1μF. The input voltage should be atleast 1.5V to 3V greater than the desired output. The output of this circuit will be regulated dual supply. The measure of voltage from ground to output pin of LM 317 will give $+V_{out}$ and measure of output voltage from ground to output pin of LM 337 will give $-V_{out}$. If voltage is measured between output pins of LM 317 and LM 337, it will provide a voltage value equal to 2Vout. The total O/P voltage is given by

$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right)$$

The O/P of this circuit is a regulated supply. This circuit also helps in line and load regulation.

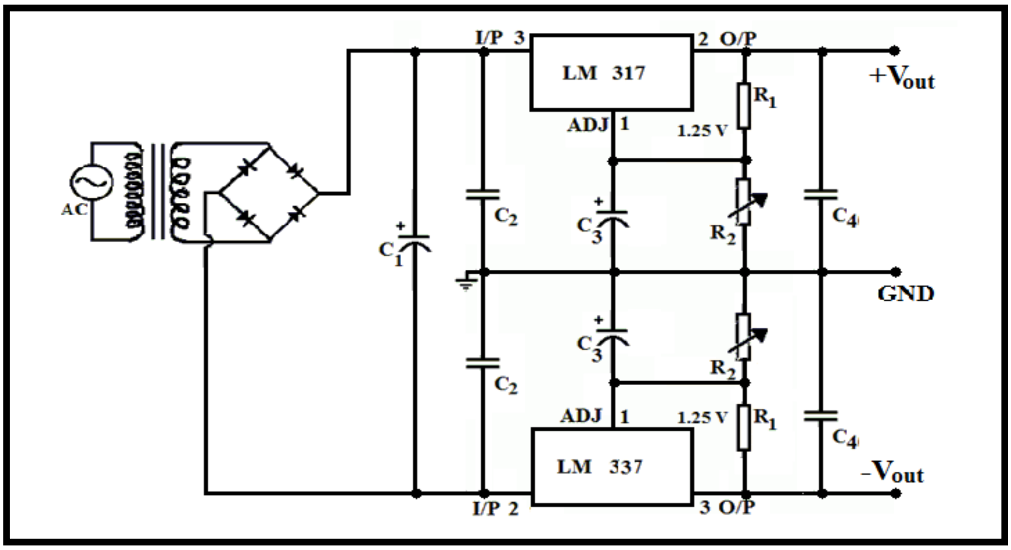
Line Regulation: It is the capacity to maintain a constant O/P voltage level on the O/P channel of a power supply, despite the changes to the I/P voltage level. Line regulation is expressed as percentage of change in O/P voltage to per unit change in I/P voltage

$$\text{line regulation} = \frac{\Delta V_{out}}{\Delta V_{in}}$$

Load Regulation: It is the capacity of the power supply to maintain a constant current level on the O/P channel of a power supply, despite the changes in the load value; $load\ regulation = \left(\frac{V_{NL} - V_{FL}}{V_{NL}}\right) \times 100\%$

Where V_{NL} and V_{FL} are the voltages when no load is applied and maximum value of load is applied.

Circuit Diagram:



Observations:

(Take readings for two different values of ±V_{out})

$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right)$ ∴ **For V_{out} = ±_______ V, R_2 = _______Ω**

No.	R_L (Ω)	V_L (V)	I (mA)

For, I_{FL} = 200 mA, Load regulation = ____________ %

Graph:

Result:

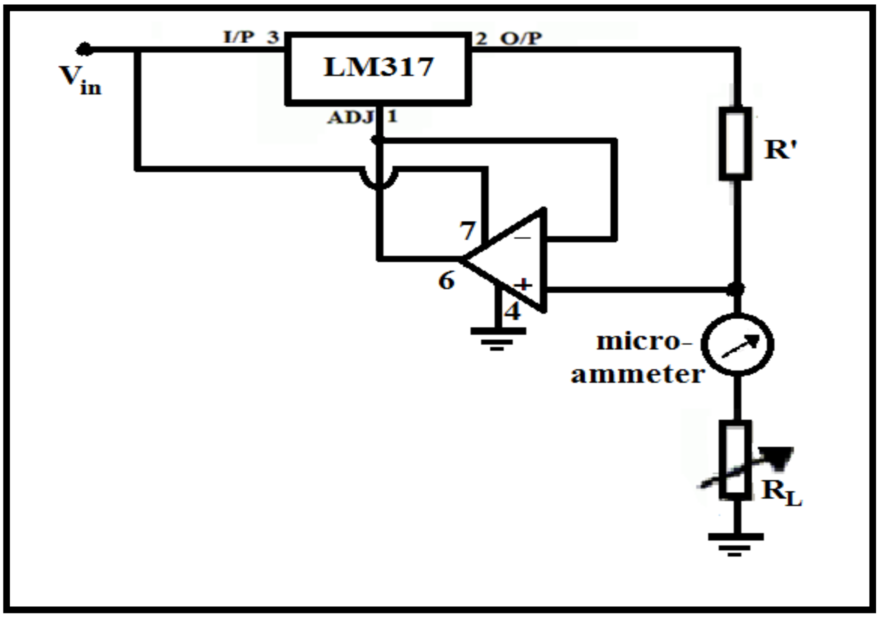
Experiment 17

Constant Current Source: LM 317 & Op-Amp 741

Aim: To design a constant current source using LM 317 and IC 741.

Apparatus: IC 741, LM 317, power supply, dc milli-ammeter, resistance, connecting wires, bread board, resistance box, etc.

Circuit Diagram:



Theory: A constant current source should ideally provide a current independent of the change in load resistance. An ideal constant current source should have infinite internal resistance.

LM 317 is a three terminal variable voltage regulator. It can supply an excess of 1.5A current over a voltage of 1.25V to 37V. The voltage (v_{ref}) across $R^{'}$ is constant at 1.25V and is called reference voltage. Hence the current through $R^{'}$ remains constant, and its value can be given by $I = \frac{v_{ref}}{R^{''}}$. The same current also flows through R_L. This constant current is independent on R_L. The voltage drop across R_L is given by

$$V_L = \left(\frac{V_{ref}}{R'}\right) R_L.$$

If we design circuit for small current using LM 317 only then I_{adj} is comparable with I, hence I_{adj} cannot be neglected. When we use Op-Amp in circuit due to high input impedance I does not enter back in adjust terminal and we can neglect I_{adj}. The circuit is designed for very small value (μA) of current. Cascading of Op-Amp to LM 317 is to increase the internal resistance of the CCS, more is the internal resistance of constant current source smaller the current value the CCS can be designed for.

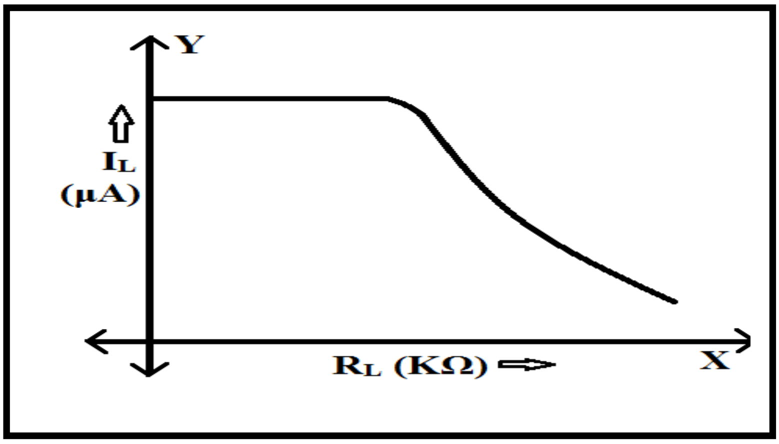
Observation:

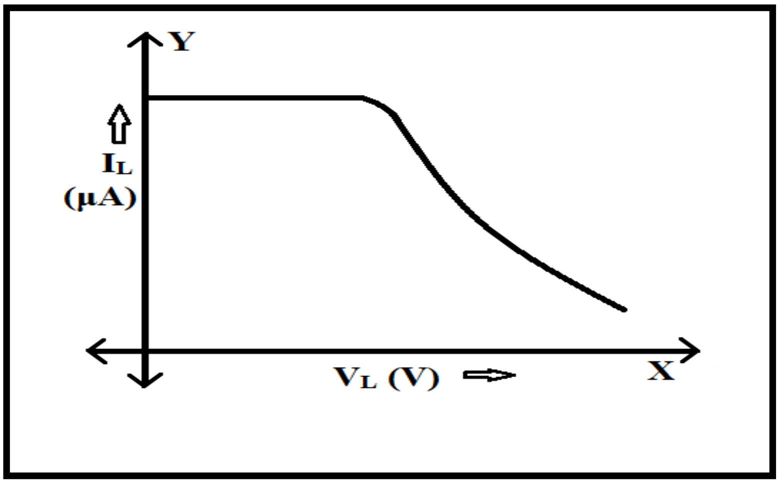
V_{in} = ______V, R' = _______KΩ, Vref = _______ V

I = _______ μA.

Obs. No.	R_L (KΩ)	I (μA)	V_L (V)

Graph:





Result:

Experiment 18

Active Filters

Aim: To study first order and second order active high pass, low pass, band pass and notch filter.

Apparatus: Signal generator, CRO, Op-Amp, resistance, capacitors, bread board, connecting wires

Theory: A filter is a circuit that is designed to pass a specified band of frequencies while attenuating the frequencies outside this band. Filter networks may be either active or passive. Passive filter networks contain only resistors, inductors and capacitors. Active filters employ transistors or Op-Amps along with resistors and capacitors.

There are five types of filters:

1. **Low-pass filter**
2. **High-pass filter**
3. **Band-pass filter**
4. **Band reject filter**
5. **All pass filters**

With RC components the configuration is called passive in addition with the use of transistor / Op-Amps the configuration becomes active. The order of an active filter depends on the number of RC networks it contains. Frequency response rolls off at a rate of 20n dB per decade where n is the order of filter.

Low-Pass Filter: A low pass filter is a circuit that has a constant output voltage up to cut-off frequency f_C and attenuates signals of frequency above f_C

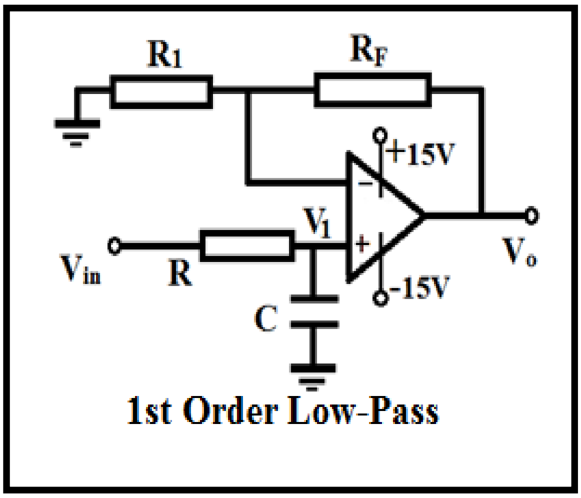
$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_1 = \left(1 + \frac{R_F}{R_1}\right) \frac{1/j\omega C}{(R + 1/j\omega C)} V_{in}$$

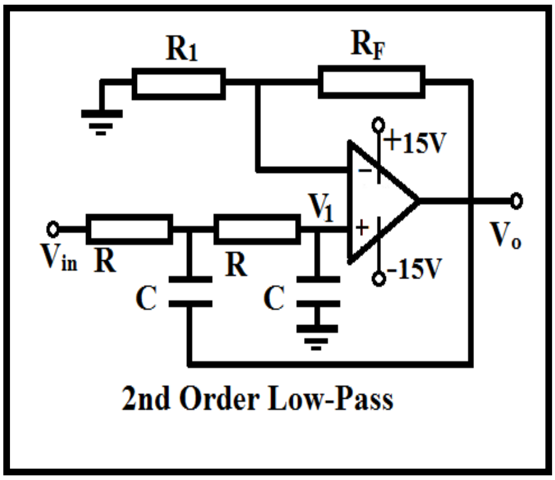
Where, ω is the angular frequency of V_{in}

$$\frac{V_0}{V_{in}} = \left(1 + \frac{R_F}{R_1}\right) \frac{1}{1 + j\omega RC} = \frac{A_F}{1 + j\left(\frac{f}{fc}\right)}$$

$$\left| \frac{V_o}{V_{in}} \right| = \frac{A_F(f/f_c)}{\sqrt{\left(\frac{f}{f_c}\right)^2 + 1}}$$

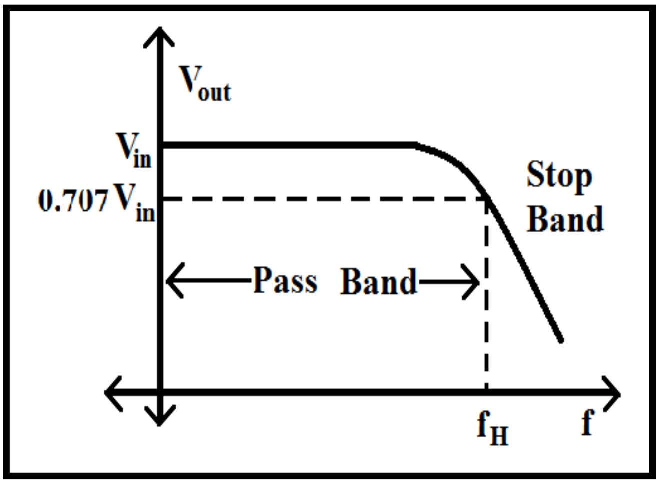
Where $A_F = 1+\frac{R_F}{R_1}$: the pass band gain of the filter





The cut-off frequency, f_c is defined as the frequency of V_{in} where voltage gain is reduced to 0.707 times pass band voltage gain.

$$f_c = \frac{1}{2\pi RC}$$



Voltage gain in dB = 20 $\log_{10} \frac{V_o}{V_{in}}$

At cut-off frequency voltage gain is -3dB. For the frequencies greater than f_c, voltage gain decreases at a rate of 20 dB/decade.

Procedure:

1. Design a first order active low pass filter with a desired value of cut-off frequency. Let the pass band gain be 1.586. Select the value of R_F and R_1.
2. Choose the value of C less than or equal to 0.1 µf.
3. Calculate the value of R using the equation R = $\frac{1}{2\pi fc}$.

4. Bread board the circuit as shown in the diagram.
5. Keep $V_{in(p-p)} = 2V$. Vary the frequency of the input and note the output on CRO.
6. Find the phase shift at cut off frequency, below and above the cut off frequency.
7. Plot the graph of voltage gain in dB against frequency.
8. Find the cut off frequency and roll-off from the graph.
9. Repeat the steps 1 to 7 for second order low pass filter.

<u>High-Pass Filter</u>: The high pass filter attenuates all signals which are below cut off frequencyf_c and passes signals above the cut-off frequency.For the first order high pass filter, the output voltage is

$$V_o = \left(1 + \frac{R_F}{R_1}\right)\left(\frac{j2\pi fRC}{1 + j2\pi fRC}\right)V_{in}$$

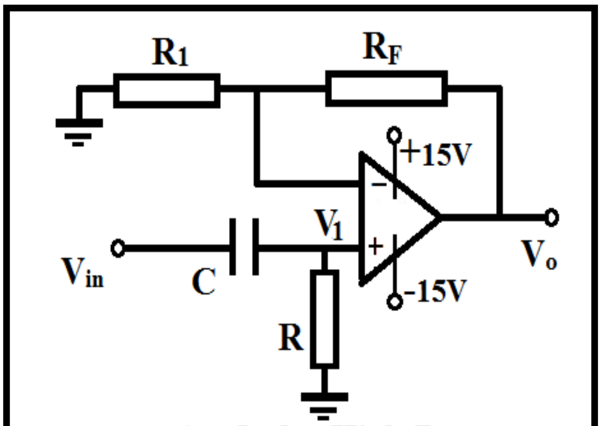
$$V_o = A_F\left(\frac{j2\pi fRC}{1 + j2\pi fRC}\right)V_{in}$$

where $A_F = \left(1 + \frac{R_F}{R_1}\right)$ pass band gain of filter

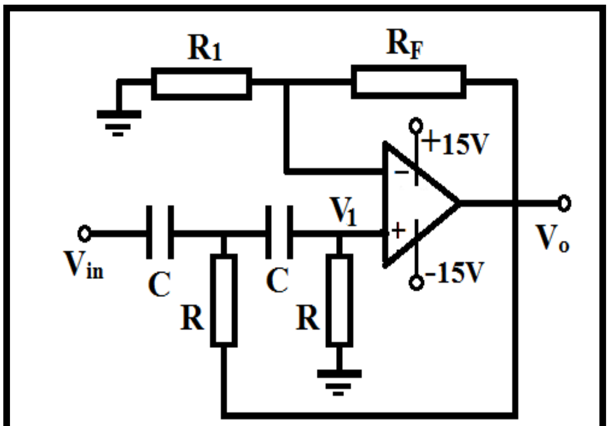
f = frequency of the input signal

$f_c = \frac{1}{2\pi RC}$ cut off frequency

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{A_F(f/f_c)}{\sqrt{\left(\frac{f}{f_c}\right)^2 + 1}}$$



1st Order High-Pass



2nd Order High-Pass

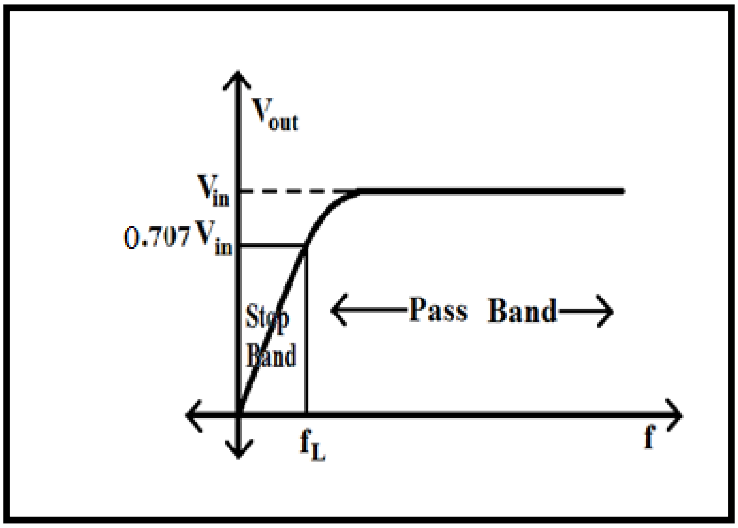
At cut-off frequency, f=f_c

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{A_F}{\sqrt{2}}$$

Therefore, at cut-off frequency, the voltage gain is 0.707 of pass band gain.

Procedure:

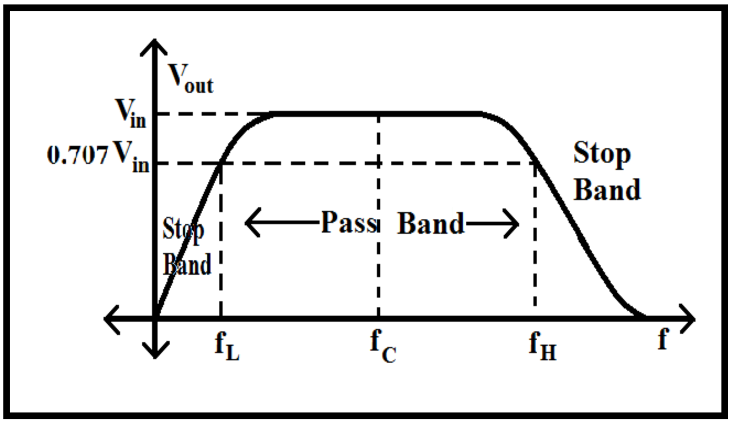
1. Design a first order active high pass filter with the suitable cut-off frequency, let the pass band gain be 1.586.
2. Bread board the circuit as shown in the diagram
3. Keep input signal 2V (p-p).
4. Vary the frequency of input signal keeping input voltage fixed and note the corresponding output on CRO.
5. Plot the graph of voltage gain in dB versus frequency and calculate the cut-off frequency from the graph and calculate roll on.



Band-Pass Filter:

Band pass filters allows a band of frequencies between a lower cut-off frequency f_L and a higher cut-off frequency f_H. The frequency at the center of the band is known as 'center frequency'. The magnitude of output voltage at the cut-off frequency is 0.707 of the magnitude of center frequency. The bandwidth (B.W.) is defined as the difference between the high and low cut-off frequency.

BW = f_H - f_L.



A band-pass filter is designed by connecting low-pass and high-pass filter in series. A band pass filter is defined as a wide band pass if its figure of merit or quality factor Q < 10. And if quality factor is Q > 10, the filter is narrow band pass filter. Hence Q is a measure of selectivity.

$$Q = \frac{f_c}{B.W.} = \frac{f_c}{f_H - f_L}$$

For wide band pass filter the center frequency is defined as

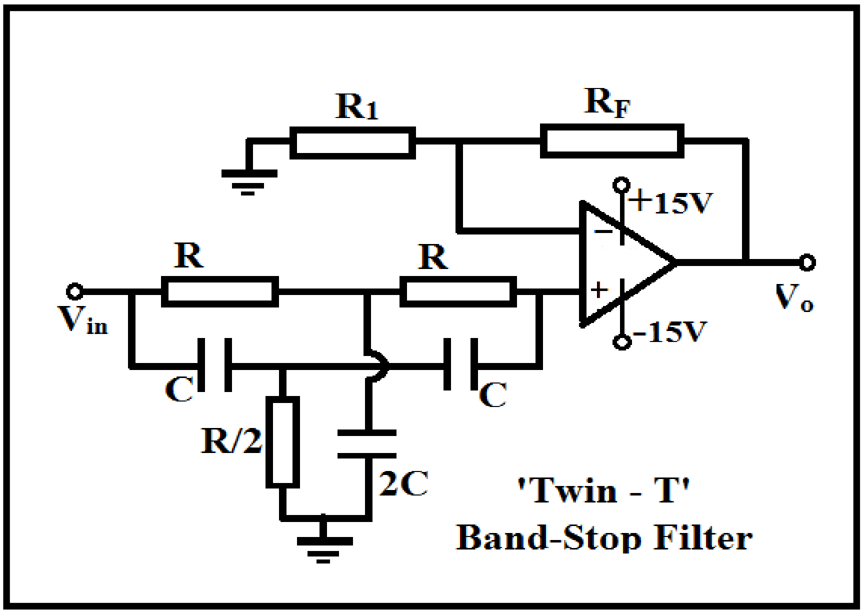
$$f_c = \sqrt{f_H f_L}$$

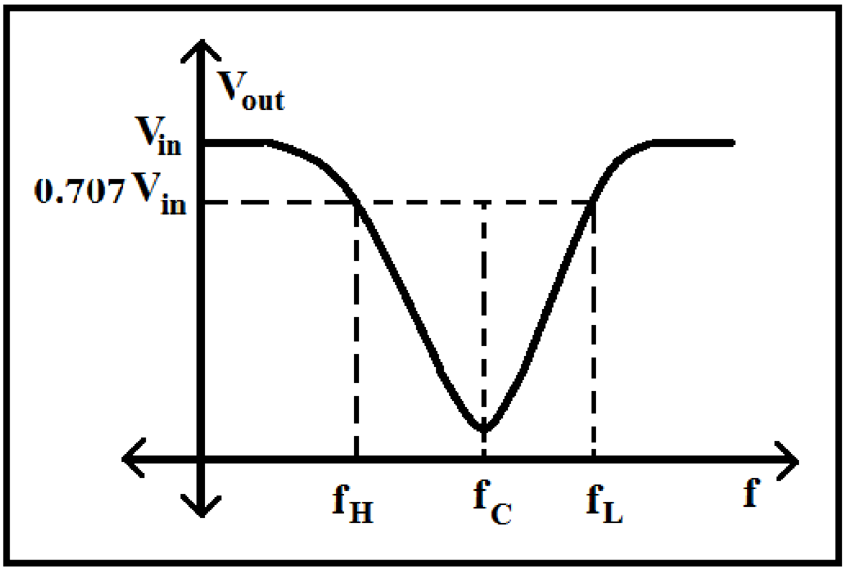
The order of the band pass filter depends on the order of the high pass and low pass filter sections.

<u>Notch Filter:</u>

The narrow band reject filter often called the notch filter. It is commonly used for attenuation of a single frequency. The most commonly used notch filter is Twin T network. The frequency at which maximum attenuation occurs is called notch-out frequency and is given as,

$$f = \frac{1}{2\pi RC}$$





<u>Observations</u>:

1) 1st and 2nd Order Low-Pass Filter

For f_c = __________ **Hz,** **C = 0.1μF**

R = $\frac{1}{2\pi fc}$ = ___________ **Ω,** R_F = _____ **and** R_1 = _____ **Ω**

V_{in} = ________ **V**

Obs.No.	f (Hz)	V_o(V)	Gain	Gain in dB = 20 $log\ {}^{V_o}/_{V_{in}}$

Roll-off = __________ **dB/decade**

<u>High Pass Filter:</u>

f_c = __________ **Hz,** **C = 0.1μF**

R= ${}^{1}/_{2\pi fc}$= ___________ **Ω,** R_F = __________, R_1 = __________ **Ω**

$gain\ A_F = 1 + \frac{R_F}{R_1}$___________ V_{in} = ________ **V**

No.	f_{in}(Hz)	V_o(V)	V_o/V_{in}	$20\ log\ V_o/V_{in}$	$log\ f_{in}$

Roll-on = ___________ dB/decade

Notch Filter:

For V_{in} = _________ V

Obs. No.	f_{in} (Hz)	V_o (V)	V_o/V_{in}	$20\ log\ V_o/V_{in}$

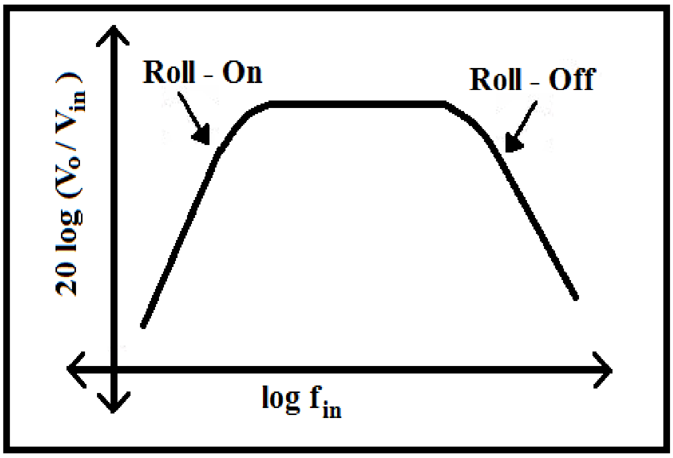
Graph:

Band Pass Filter:

For V_{in} = _________ V

No.	f_{in} (Hz)	V_o (V)	V_o/V_{in}	$20\ log\ V_o/V_{in}$

Graph:



Result: The frequency response of 1st and 2ndorder active filters is studied.

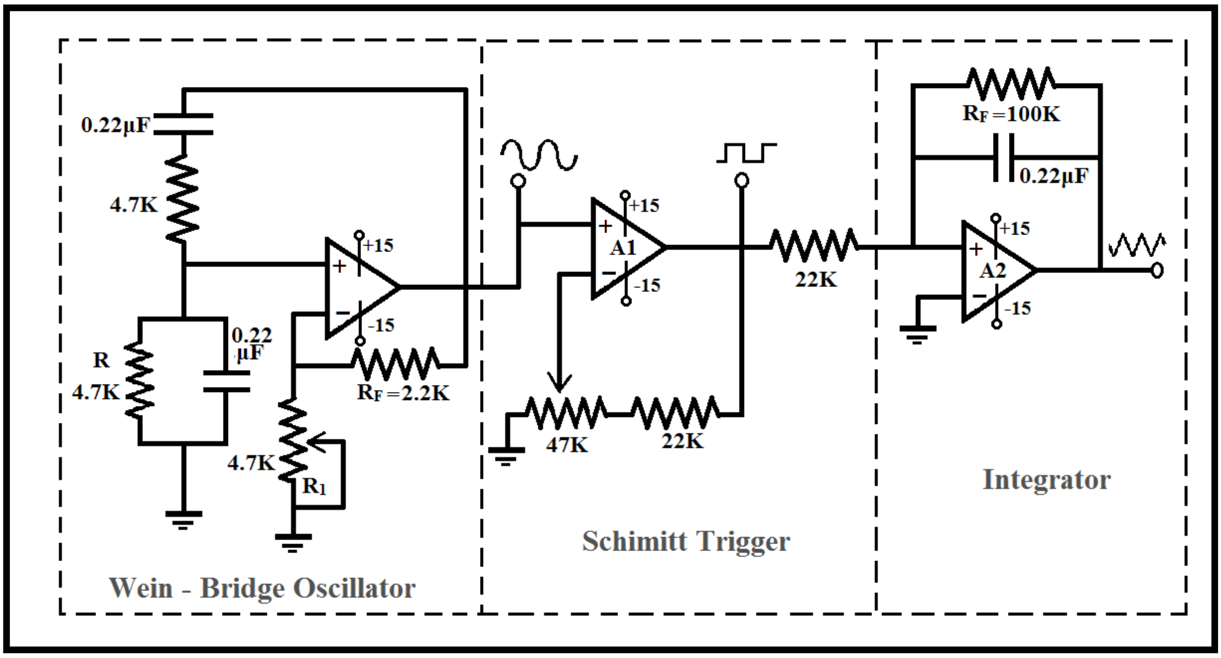
Experiment 19

Waveform Generation

Aim: To study waveform generation using Op-Amps.

Apparatus: IC 741, capacitors, resistances, regulated power supply, CRO, bread board, connecting wires, etc.

Circuit Diagram:



Theory: Sine wave is obtained with the help of Wein bridge oscillator. This sine wave is converted into square wave with the help of Schmitt trigger. The square is then converted to triangular wave using integrator circuit.

Wein bridge oscillator: Wien bridge oscillator uses Op-Amp as an amplifier and a resonant feedback circuit called a lead-lag circuit. At very low frequencies, the series capacitor appears open to the input signal and there is no output signal. At very high frequencies, the shunt capacitor is shorted, and there is no output. In between these extremes, the output voltage reaches a maximum, called resonant frequency. At this frequency the feedback factor is $^1/_3$.

For the circuit to produce sustained oscillations, it must satisfy Barkhausen criteria.

1. The total phase shift around loop is zero
2. The loop gain $A\beta \geq 1$

The network produces zero phase shift around the loop only when the bridge is balanced. Frequency of oscillation, $f = \frac{1}{2\pi RC}$

A negative feedback is applied to amplifier through resistors R_1 and R_F to reduce the loop gain $A\beta$ to unity.

Voltage gain of the amplifier $A = 1 + \frac{R_F}{R_1}$

$$A\beta \geq 1$$

At resonant frequency, $\beta = \frac{1}{3}$

$$A = 3$$

$$\frac{R_F}{R_1} \geq 2$$

Schmitt Trigger: This sine wave is converted into square waveform with the help of Schmitt trigger. The output trips between the two values of input voltage called upper and lower threshold voltage. In this circuit, positive feedback is used. The feedback fraction is

$$\beta = \frac{R_2}{R_1 + R_2}$$

Upper threshold UTP = $\beta\,(+V_{sat})$ and lower threshold LTP = $\beta\,(-V_{sat})$

Integrator: It converts square wave to triangular. Square wave generated by Schmitt trigger is given to integrator as input. The output of the integrator is the negative going ramp during the positive half cycle of the input voltage and positive going ramp during the negative half cycle. Therefore, the output is a triangular wave with the same frequency as the input. The peak-to-peak output voltage of triangular waveform is

$$V_{o(p\text{-}p)} = \frac{V_{i(p-p)}}{4RCf}$$

Where, $V_{i(p\text{-}p)}$ is the peak-to- peak input voltage and *f* is the input frequency.

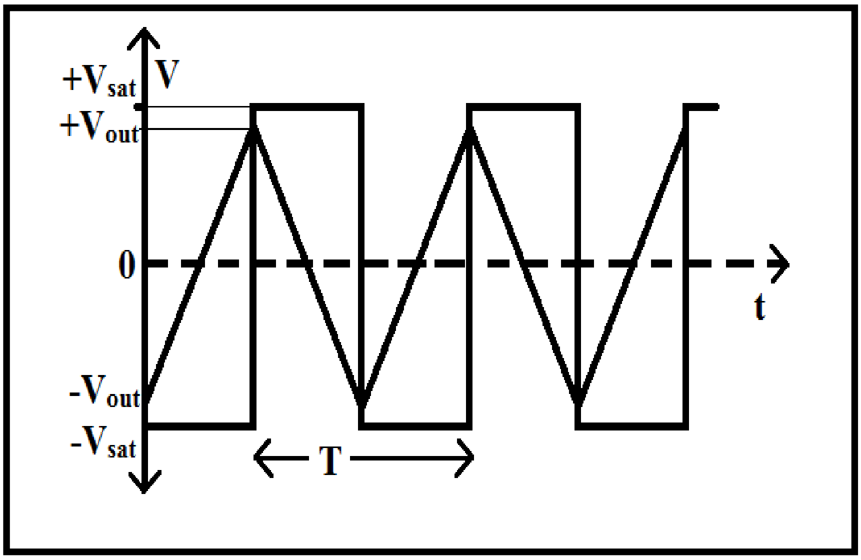
Since capacitor is open to dc signals, there is no negative feedback at lower frequencies. Therefore, the capacitor charges due to any input offset voltage and the output goes into positive and negative saturation. To reduce the effect of input offset voltage, a resistor (R_F) is connected in parallel to the capacitor which reduces the gain at lower frequencies. This resistor should be at least 10 times larger than the input resistor.

Procedure:

1. Choose a suitable frequency of sine wave to be generated.

2. Calculate R using the equation $R = \frac{1}{2\pi fc}$. Take C = 0.1 μf.

3. Take a value of R_1 and calculate R_F using $\frac{R_F}{R_1} = 2$
4. Select the values of R_1 and R_2 such that β is in between 0.2 to 0.5.



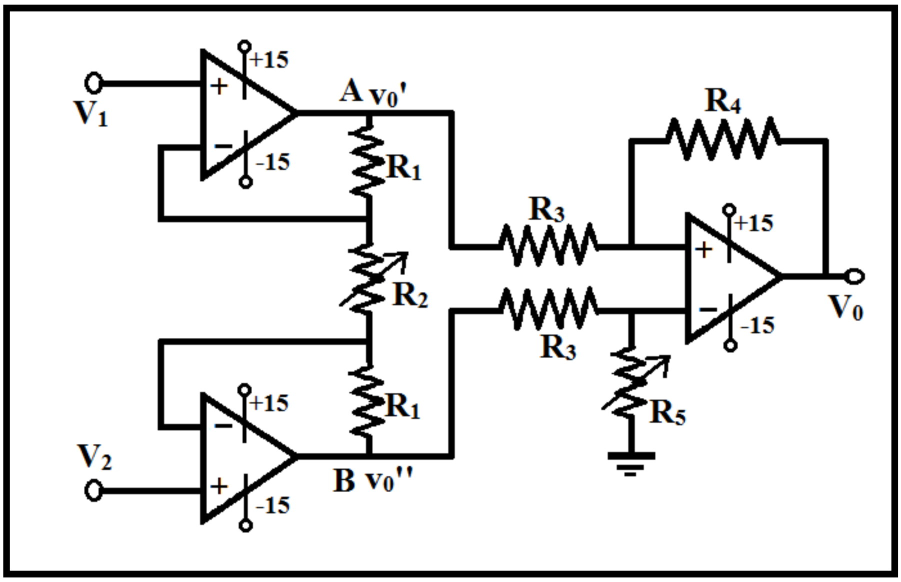
Experiment 20

Instrumentation Amplifier

Aim: To study the working of instrumentation amplifier & its application.

Apparatus: Bread-board, resistors, Op-Amp IC 741, dual power supply, DMM, connecting wires, etc.

Circuit Diagram:



Theory: An instrumentation amplifier is a differential amplifier optimized for its dc performance. It has large voltage gain, high CMRR, low input offsets, low temperature drift and high input impedance. It has adjustable gain with high gain accuracy and gain linearity. It is used to amplify the weak signals, such as output of transducers.

The basic instrumentation amplifier uses three Op-Amps. The differential input stage formed by two voltage followers produces a differential input signal. Assuming that, the amplifiers at the input stage draws no current at their input terminals, the same current must flow through the three resistors R_1, R_2 and R_1. If we make further assumption that there is negligible voltage drop between the amplifier input terminals and $R_2 = aR_1$, then the current I is,

$$I = \frac{V_1' - V_1}{R_2} = \frac{V_1 - V_2}{aR_1} = \frac{V_2 - V_2'}{R_2}$$

$$\frac{V_1' - V_1}{R_2} = \frac{V_1 - V_2}{aR_1}$$

$$V_1' = \left(1 + \frac{R}{aR}\right)V_1 - \left(\frac{R}{aR}\right)V_2$$

Similarly, we have

$$\frac{V_1 - V_2}{aR_2} = \frac{V_2 - V_2'}{R_2}$$

$$V_2' = \left(1 + \frac{aR}{R}\right) V_2 - \left(\frac{R}{aR}\right) V_1$$

$$V_2' - V_2' = \left(1 + \frac{2R}{aR}\right)(V_1 - V_2)$$

$$A_V = 1 + \frac{2}{a}$$

Procedure:

1. Connect the circuit as shown in the figure
2. Design an instrumentation amplifier for a gain of 10.
3. Offset null the Op-Amps.
4. Apply the differential input. at V_1 and V_2 and note the output.
5. Calculate gain and compare with expected gain.
6. To find common mode gain, $A_{v(cm)}$, give same voltage to both the inputs and vary the CMRR pot to get minimum output and note the output.

$$A_{v(cm)} = \frac{V_{o(cm)}}{V_{in(cm)}}$$

7. Find CMRR

$$\text{CMRR} = \frac{\text{differential gain}}{\text{common mode gain}} = \frac{A_{vd}}{A_{v(dm)}}$$

8. Find CMRR in dB.

Observation:

$\boldsymbol{A_v}$=____________

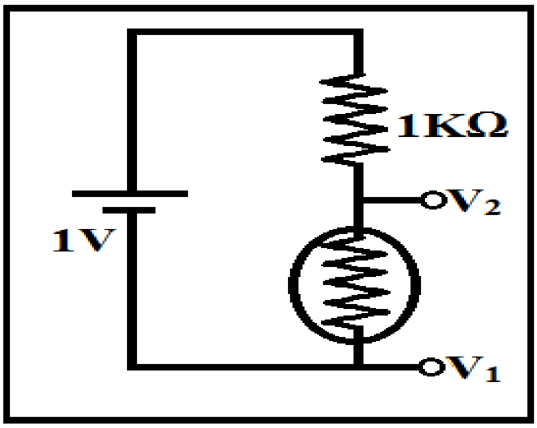
Obs. No.	V1	V2	V2 – V1	Output	A_v

Measurement of CMRR:

$V_{in(cm)}$	V_o	$A_{v(cm)}$	CMRR	CMRR (dB)

Application:

The input of the instrumentation amplifier can be given from the output of an LDR or thermistor to study, measure and amplify its output. For this a resistance of 1KΩ is connected in series with LDR or thermistor and this is connected to a 1V battery. The voltage across LDR or thermistor and ground is given as inputs to the Instrumentation amplifier.



Observation:

Consider a thermistor connected in series with a resistance of 1KΩ. A voltage of 1V is provided to this series arrangement. Here V_2 voltage across the thermistor and V_1= GND

$$A_v = \frac{R_4}{R_3}\left(1 + \frac{2R_1}{R_2}\right)$$

Obs. No.	Temperature T °C	V_2 (V)	V_0 (V)	Gain V_0/V_2

Result:

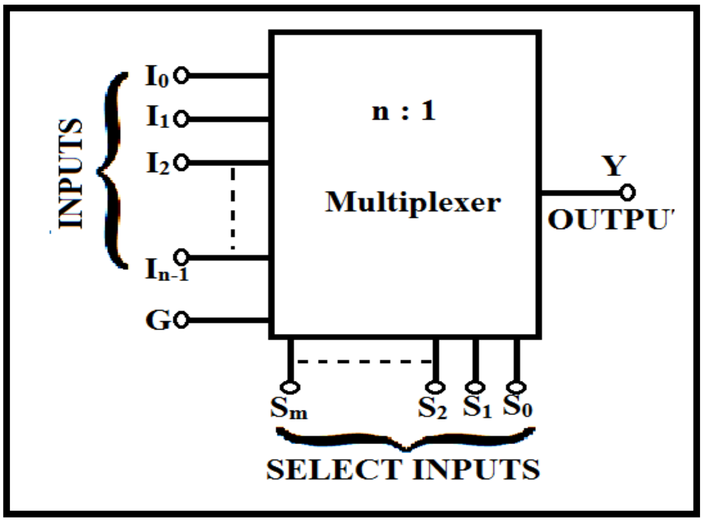
Experiment 21

16-Channel Digital Multiplexer

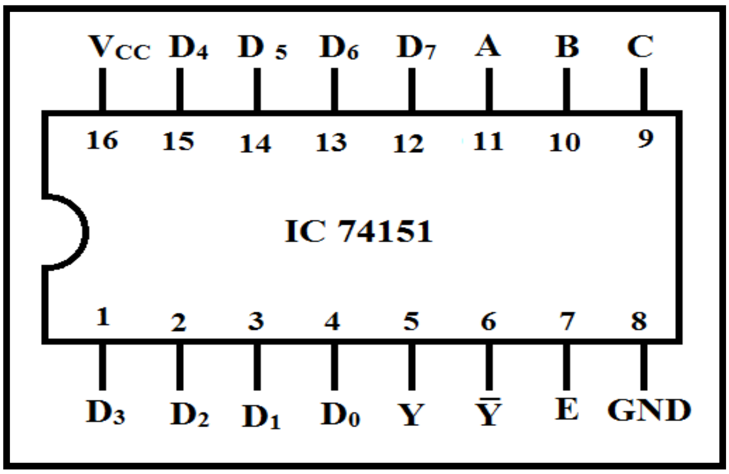
Aim: To study multiplexer using IC 74151 and IC 74150.

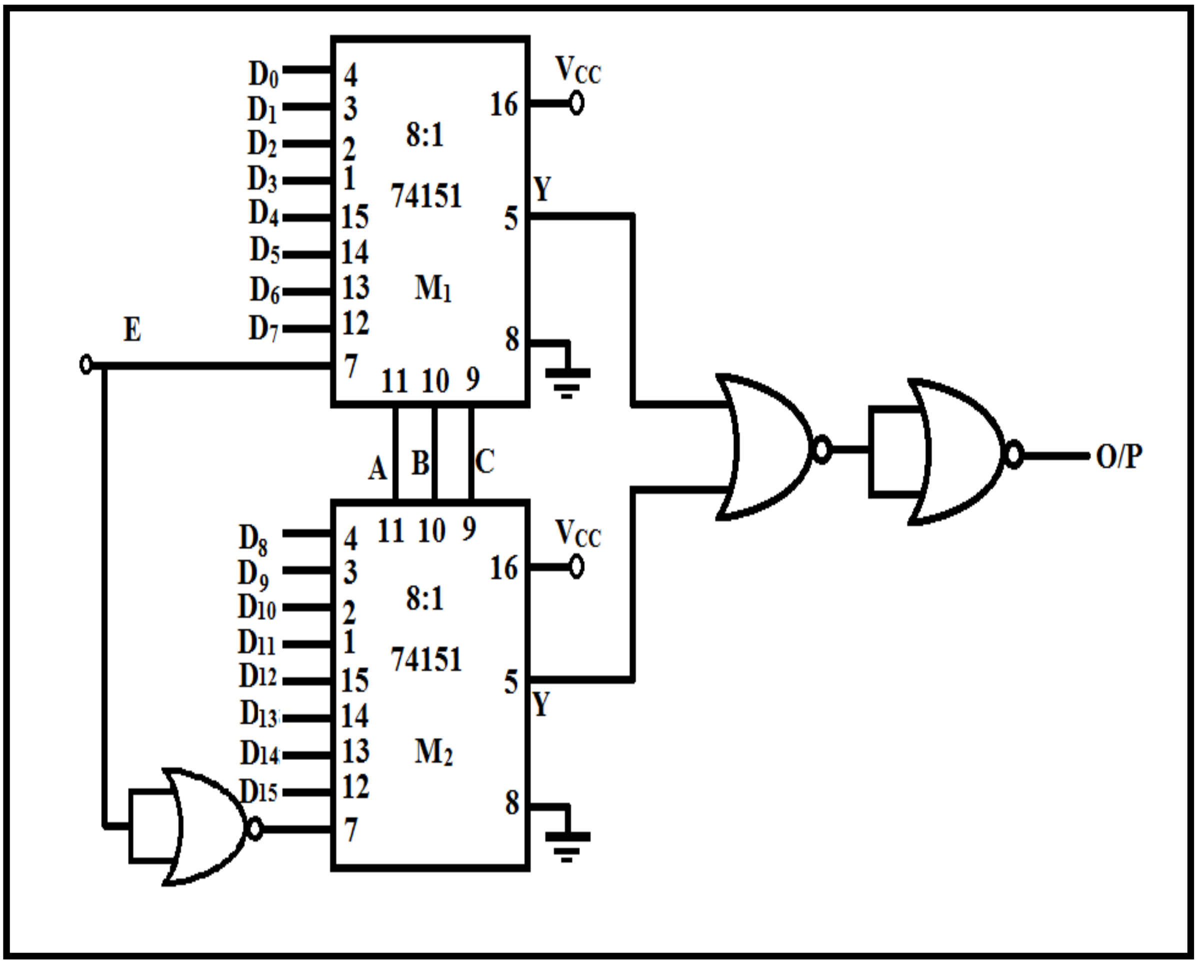
Apparatus: IC 74151, IC 7402, IC 74150, power supply, bread board, LED's, connecting wires etc.

Theory: Multiplexer or data selector is a logic circuit that allows one of the 'n' data in the input to the output. The general block diagram of a multiplexer with n input line and one output line is shown in the figure.



There is 'm' select inputs, which are used for selecting one of the 'n' inputs, to be displayed at the output such that $2^m = n$.





16:1 Multiplexer from two 8:1 Multiplexer

1. 16:1 multiplexer can be constructed using two 8:1 mux (IC 74151) and one IC 7402 consisting of NOR gate to be configured as inverter.
2. It consists of 4 select lines, 16 inputs and one output.
3. The enable of the multiplexer M_1 is complimented and is connected to the enable of the second multiplexer M_2.
4. Fourth select line D is $\overline{EN}$, i.e, enable of the first multiplexer (M_1).
5. The select inputs of both the multiplexers are shorted.
6. When the enable is low, multiplexer M_1 is active and M_2 remains off. When enable is high, multiplexer M_1 is off and M_2 remains active.

<u>**Observation**</u>**:** <u>**8:1 Multiplexer.**</u>

	D7	D6	D5	D4	D3	D2	D1	D0
Input:								

E	C	B	A	I/P	O/P (Y)	O/P ($\bar{Y}$)
1	X	X	X	X	0	1
0	0	0	0	D0 =		
0	0	0	1	D1 =		
0	0	1	0	D2 =		
0	0	1	1	D3 =		
0	1	0	0	D4 =		
0	1	0	1	D5 =		
0	1	1	0	D6 =		
0	1	1	1	D7 =		

16:1 Multiplexer using IC 74150

IC 74150 selects one-of-sixteen data inputs. IC 74150 has a strobe input which must be at a LOW logic level to enable the device. A HIGH level at the strobe forces the output HIGH. The IC 74150 features an inverted output only.

Observation: 16:1 Multiplexer.

i/p	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

A. Using IC 74151

E	C	B	A	I/P	O/P (Y)
0	0	0	0	D0 =	
0	0	0	1	D1 =	
0	0	1	0	D2 =	
0	0	1	1	D3 =	
0	1	0	0	D4 =	
0	1	0	1	D5 =	
0	1	1	0	D6 =	
0	1	1	1	D7 =	
1	0	0	0	D8 =	
1	0	0	1	D9 =	
1	0	1	0	D10 =	
1	0	1	1	D11 =	
1	1	0	0	D12 =	
1	1	0	1	D13 =	
1	1	1	0	D14 =	
1	1	1	1	D15 =	

B. Using IC 74150

E	C	B	A	I/P	O/P (Y)
0	0	0	0	D0 =	
0	0	0	1	D1 =	
0	0	1	0	D2 =	
0	0	1	1	D3 =	
0	1	0	0	D4 =	
0	1	0	1	D5 =	
0	1	1	0	D6 =	
0	1	1	1	D7 =	
1	0	0	0	D8 =	
1	0	0	1	D9 =	
1	0	1	0	D10 =	
1	0	1	1	D11 =	
1	1	0	0	D12 =	
1	1	0	1	D13 =	
1	1	1	0	D14 =	
1	1	1	1	D15 =	

Result:

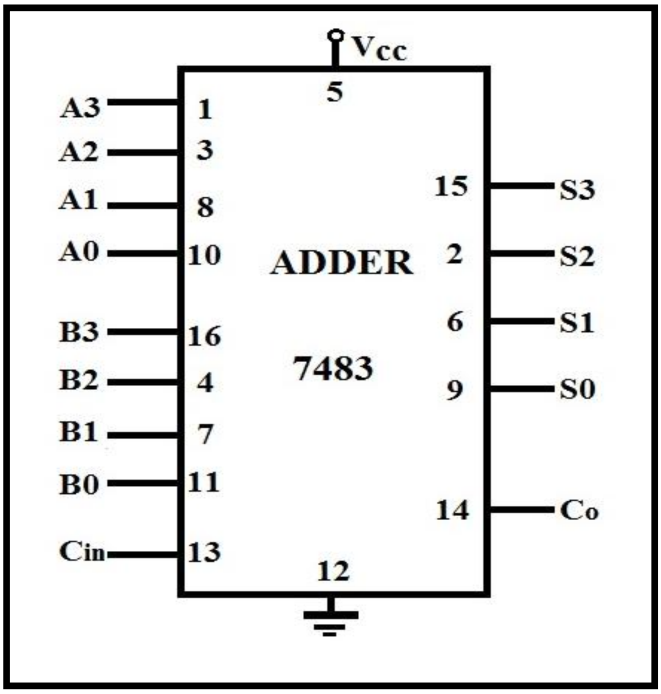
Experiment 22

Adder – Subtractor using IC 7483 & IC 7486

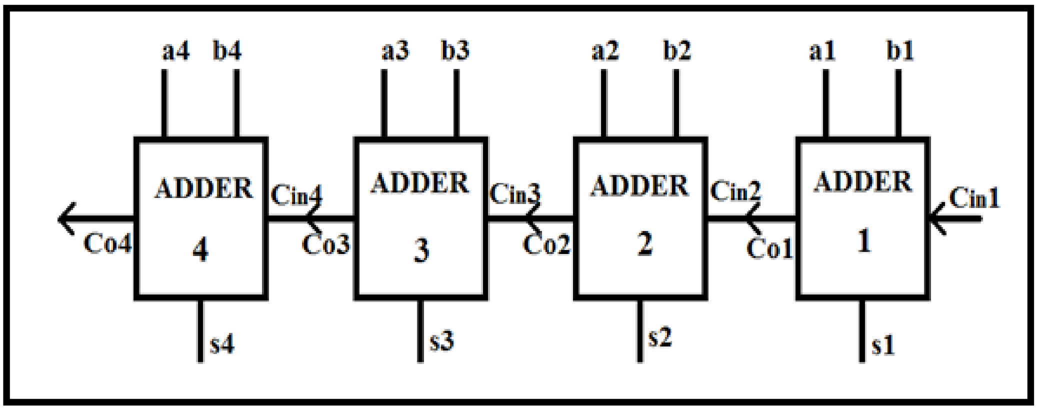
Aim: To construct and study adder-subtractor circuits using IC 7483

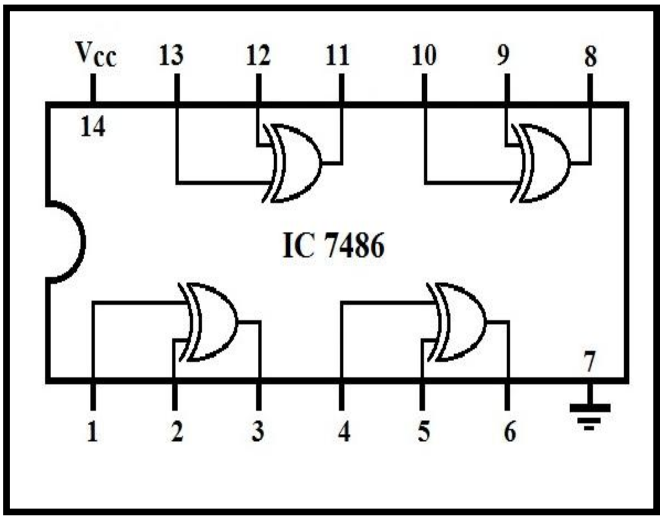
Apparatus: IC 7483, IC 7486 (EX-OR gates), 5V supply, bread-board, DMM, etc.

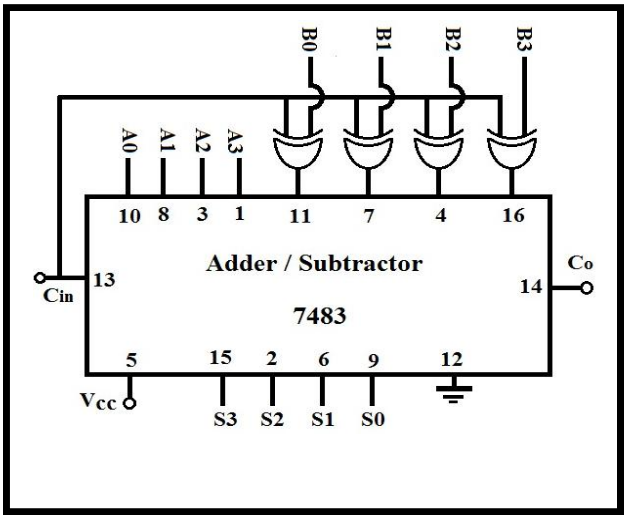
Theory: The largest number that can be obtained from a 4-bit full adder is $(31)_{10}$ i.e. $(1F)_{16}$. Parallel adders can add multiple digit numbers.



IC 7483 has 9 i/p pins. Out of these 4 i/p pins are for 1st data or addend (A), 4 i/p pins are for 2nd data or augend (B) and the 9th i / p pin for the value of i/p carry (C_{in}). IC 7483 has 5 o/p pins. Out of this 4 are for the sum (S) and last pin for o/p carry (C_{out}). For parallel addition i.e. for addition of 'n' digit number, 'n' 7483 IC's should be cascaded such that C_o of one is connected to C_{in} of another.





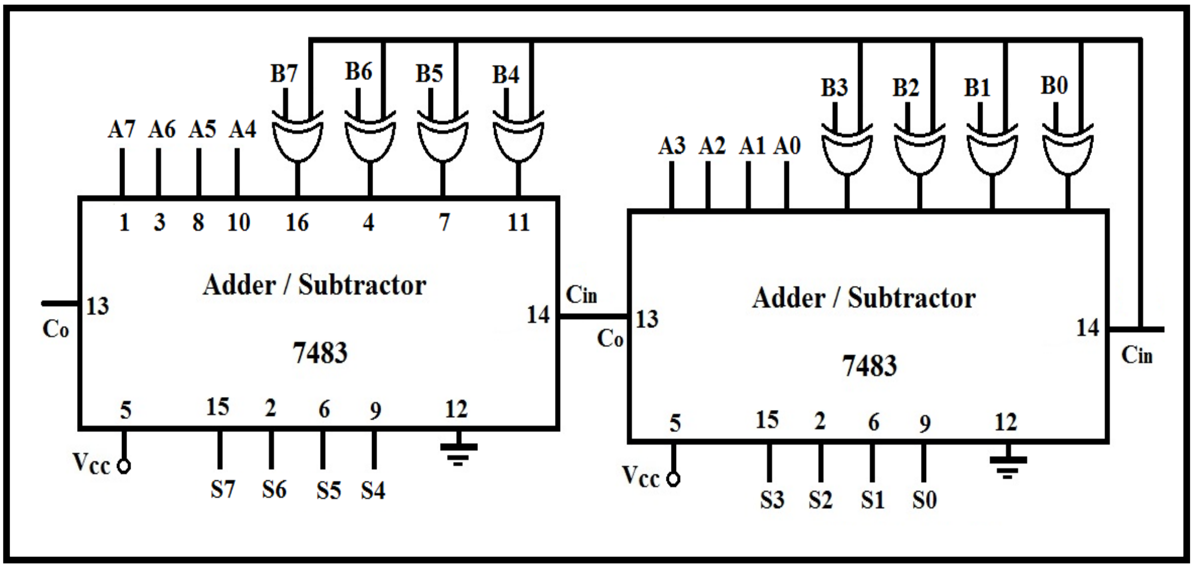


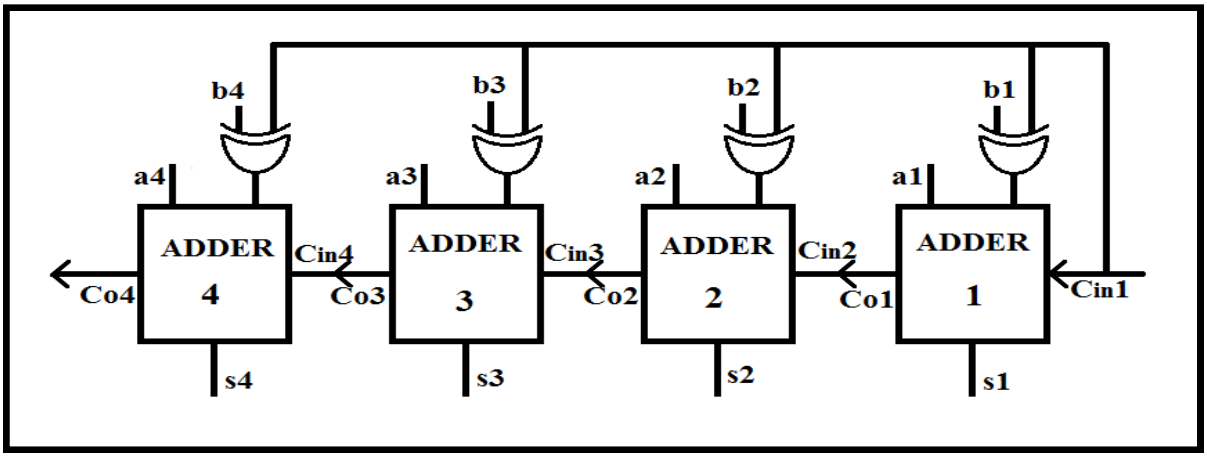
7483 can be made to act as subtractor by using EX-OR gates as shown below.

When C_{in} is '0', the IC acts as a normal full-adder and when it is '1', the same configuration acts as a subtractor. When C_{in} is '0', one of the inputs of each EX-OR gate is '0' and the o/p of the gate is same as the value of other i/p. Thus, the gates give out the same o/p as the i/p and addition takes place. When C_{in} is '1', one of the inputs of each EX-OR gate is '1' and the o/p of the gate is the complement (1's complement) of the value of other i/p. Thus, the data reaching B3, B2, B1 and B0 is the 1's complement of the 2nd data.

What exactly happens is that the 2's complement of the 2nd data is added to the 1st data, which is nothing but subtraction. Thus, the arrangement works as a subtractor. An 8-bit adder/subtractor can be formed by cascading two full – adders.

<u>Observation</u>:





For 4-bit Adder/Subtractor

No.	1st Data		2nd Data		C_{in}	Sum/Difference		C_o
	HEX	BINARY	HEX	BINARY		HEX	BINARY	

For 8-bit Adder/Subtractor

No.	1st Data		2nd Data		C_{in}	Sum/Difference		C_o
	HEX	BINARY	HEX	BINARY		HEX	BINARY	

Experiment 23

Pre-Settable Counters: 74190 / 74193

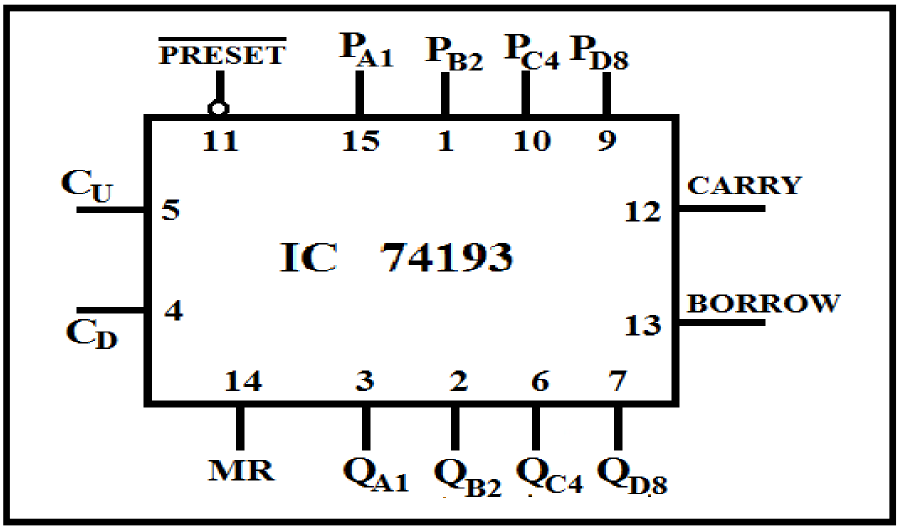
Aim: To study Pre-settable counters using IC 74193.

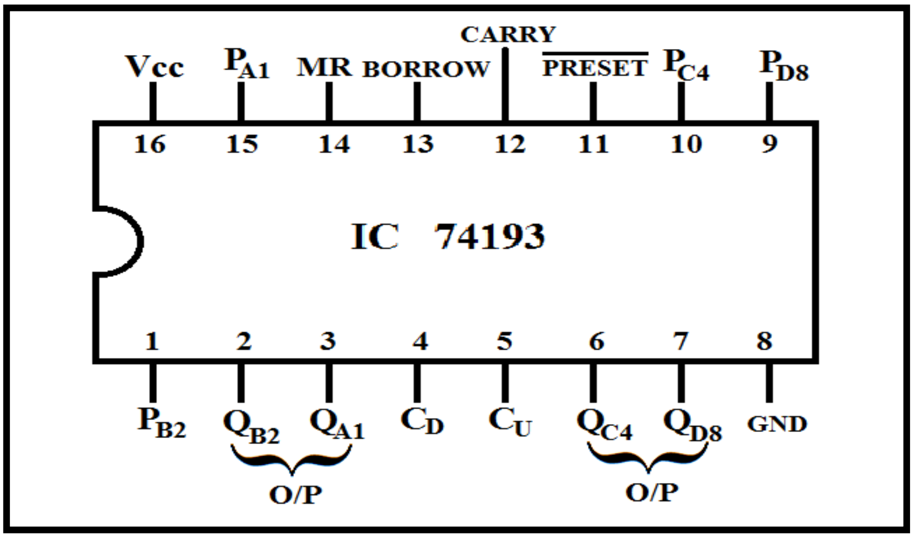
Apparatus: IC 74193, IC 7400, IC 7402, 5V supply, bread board, DMM, connecting wires, resistors, LED's, etc.

Theory:

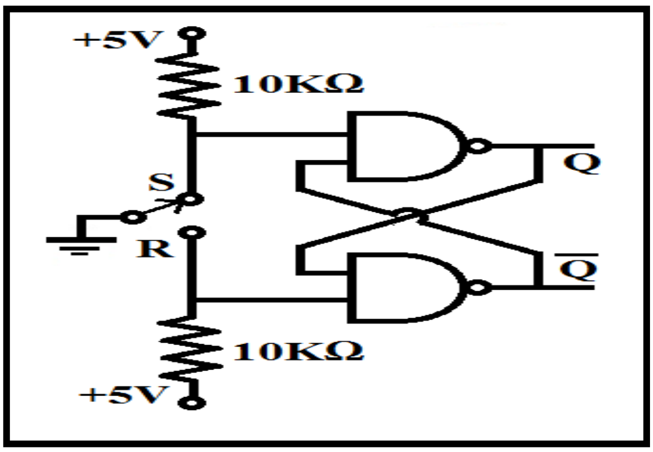
1. IC 74193 is a 4-bit synchronous binary up-down counter.
2. There are 4 master/slave flip-flops in this IC. The outputs of the four master-slave flip-flops are triggered by a low-to-high level transition of either count (clock) input. The direction of counting is determined by which count input is pulsed while the other count input is held high.
3. The counter is fully programmable; that is, each output may be preset to either level by entering the desired data at the inputs while the load input is low. The output will change independently of the count pulses. This feature allows the counters to be used as mod-N dividers by simply modifying the count length with the pre-set inputs.
4. IC 74193 has a parallel-data-entry capability which permits the counter to be pre-set to the number present on the parallel-data-entry inputs (P_A, P_B, P_C, P_D). Whenever the parallel load input $\overline{PRESET}$ is low, the data present on the four inputs are shifted into the counter i.e. the counter is preset to the number held by P_D, P_C, P_B, P_A.
5. A clear input has been provided which, when taken to a high level, forces all outputs to the low level; independent of the count and load inputs.
6. These counters were designed to be cascaded without the need for external circuitry. Both borrow and carry outputs are available to cascade both the up and down counting functions.
7. The pin (CO) goes low when the count reaches the maximum count when used as up counter. The pin (BO) goes low when count reaches the max count (0000) in down counter.
8. To prevent glitches in clock signal switch, a De-bouncing circuit is used.

This ensures a clear transition from a logic 0 to logic 1 (or logic 1 to logic 0) when the switch is thrown. Consider the switch is connected to the S input, as a result, the S input is pulled to a logic 0 and output Q is at logic 1, since the latch is in the set state. When the switch moves towards input R to the SR latch the output Q remains at logic 1 only.





When the switch is connected to R, the R input is pulled to logic 0 and output $\bar{Q}$ is logic 1. Note the two pull-up resistors at the input to the SR latch prevent the latch from entering the intermediate sates where both R = 0 and S = 0, forcing boths Q and $\bar{Q}$ outputs of the latch to be logic 1's.



When the clock pulse from the De-bouncer circuit is given to pin C_U (5) and pins $P_A = P_B = P_C = P_D = 0$ (0V), the output on the output pins Q_A, Q_B, Q_C and Q_D will be dependent on the signals at pins MR (14), $\overline{PRESET}$(11) and the number of clock pulse.

If clock pulse is given to down count pin C_D (4), the counting will be in reverse direction. If the pins P_A, P_B, P_C and P_D are given any value, and $\overline{PRESET}$ pin is made low, the counter is preset to the value given by (P_D, P_C, P_B, P_A) and when $\overline{PRESET}$ is made high and the pulses are provided, the counter will start counting up or down from the value (P_D, P_C, P_B, P_A) depending on the pin to which clock pulse is applied (C_U and C_D).

Observation:

UP Counter

MR	PRESET	C-P No	Outputs				
			Q_D	Q_C	Q_B	Q_A	CARRY

DOWN Counter

MR	PRESET	C-P No	Outputs				
			Q_D	Q_C	Q_B	Q_A	BORROW

Pre-Settable Counter

UP Count

Pre-set Value	CLK No	Q_D	Q_C	Q_B	Q_A

DOWN Count

Pre-set Value	CLK No	Q_D	Q_C	Q_B	Q_A

Result:

Experiment 24

Shift Registers

Aim: To study the working of shift register IC 7495 as a serial shift and parallel-in parallel-out register.

Apparatus: IC 7495, +5V power supply, bread board, LED's, resistance, IC 7400, connecting wires, etc.

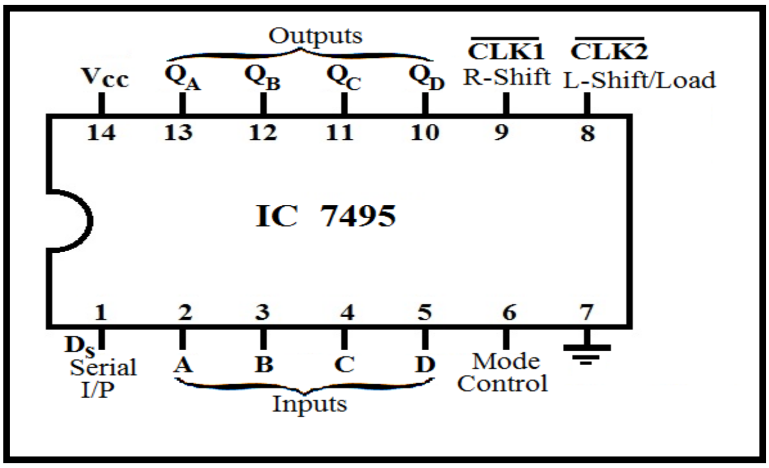
Theory: Shift registers are a type of sequential logic circuit, mainly for storage of digital data. They are a group of flip-flops connected in a chain so that the output from one flip-flop becomes the input of the next flip-flop. All the flip-flops are driven by a common clock, and all are set or reset simultaneously.

There are two ways to shift data into a register (serial or parallel) and similarly two ways to shift the data out of the register. The first method involves shifting the data 1 bit at a time in serial fashion beginning with either MSB or LSB. This technique is referred to as serial shifting. The second method involves shifting all the data bits simultaneously and referred to as parallel shifting. This leads to the construction of four basic register types:

a) **Serial in-serial out**
b) **Serial in-parallel out**
c) **Parallel in-serial out**
d) **Parallel in- parallel out**

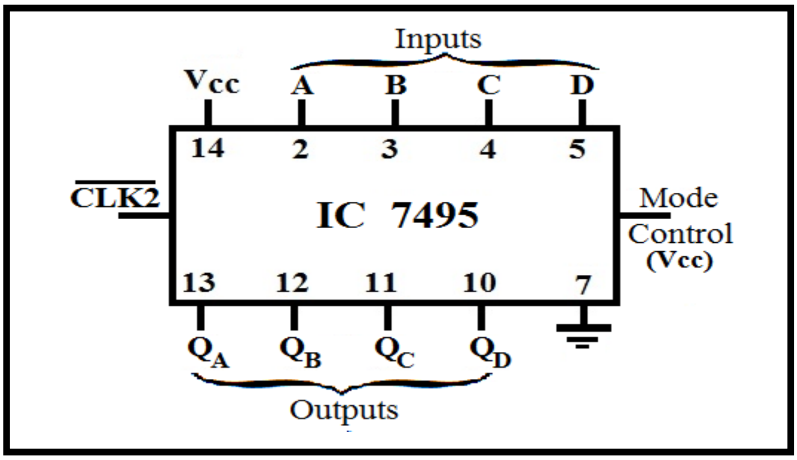
The 74LS95B is a 4-bit Shift register with serial and parallel synchronous operating mode. The serial shift right and parallel load are activated by separate clock inputs which are selected by a mode control pin.

Pin Diagram:



IC 7495 has a serial input data pin D_S (1) and 4 parallel input data pins A, B, C, D (2-5) and 4 parallel data output pins Q_A, Q_B, Q_C, Q_D (13-10). The serial or parallel mode operation is controlled by a Mode Control pin (6) and two clock inputs $\overline{CLK1}$ and $\overline{CLK2}$ (9 and 8).

Parallel-in Parallel Out:

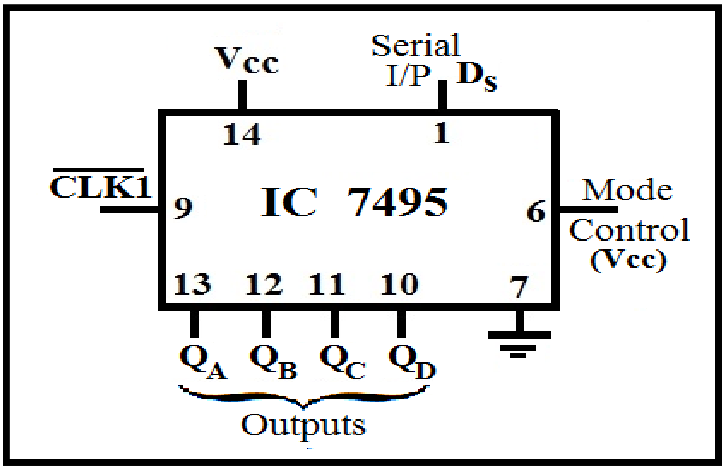


1. Apply four-bit data at A, B, C, D.
2. Apply one clock pulse to CLK 2 (Mode control =1).
3. All the 4 bits of the data from A, B, C, D appear at the corresponding outputs simultaneously during HIGH to LOW transition of the clock.
4. Serial input D_S and $\overline{CLK1}$ which are in don't Care Mode, can either be kept open or connect to ground.

Serial in Serial Out:

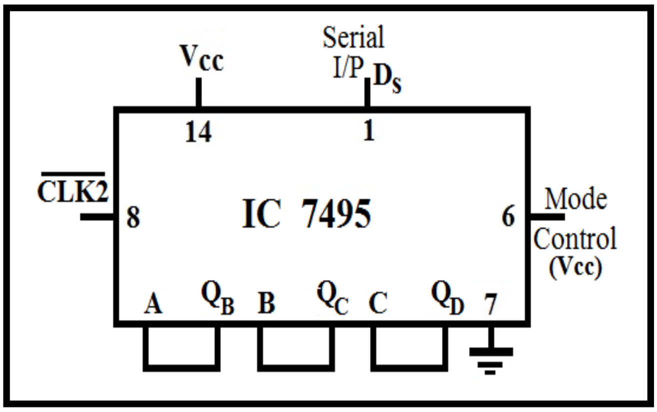
1. Load the shift register with 4 bits of data one by one serially.
2. At the end of 4th clock pulse first data D0 appears at Q_D.
3. With another clock pulse, next data D1 appears at Q_D.
4. Application of another clock pulse, data D2 appears at Q_D.
5. In the next clock pulse, data D3 appears at Q_D. Thus, data applied serially at input will appear serially at Q_D.

Serial Shift Right Operation:



For serial shift right operation, the Mode Control Pin is made LOW. Hence the parallel inputs A, B, C, D are in Don't Care Mode. The input data is given to the Serial Input (D_S) to Q_A and shifts the Q_A to Q_B, Q_B to Q_C, Q_C to Q_D respectively. Thus, a right shift is accomplished. The don't Care Mode pin $\overline{CLK2}$ is grounded or left open.

Serial Shift Left Operation:



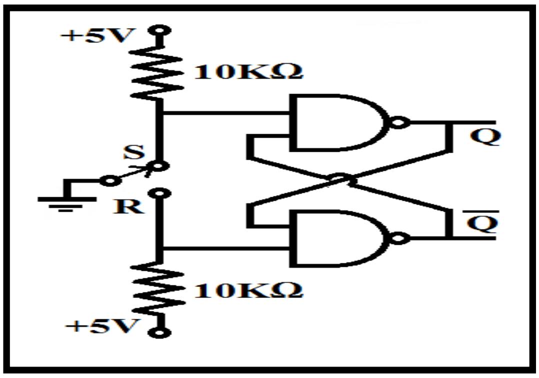
For serial shift left operation, the Mode Control Pin is made HIGH. Thus, the Serial Input data pin D_S (1) and $\overline{CLK1}$ (9) is in Don't Care Mode. The serial input data is applied to D (5). Pins A and Q_A, B and Q_B, C and Q_C are shorted. A HIGH to LOW transition on $\overline{CLK2}$ will transfer data from D_S to Q_D, Q_D to Q_C, Q_C to Q_B, Q_B to Q_A respectively. Thus, a left shift is accomplished.

Parallel in Serial Out:

1. Apply the desired 4-bit data at A, B, C, D.
2. Keeping the mode control M = 1, apply one clock pulse. Data applied at A, B, C and D will appear at Q_A, Q_B, Q_C and Q_D respectively.
3. Now keep mode control M = 0, apply clock pulses one by one and data will come out from Q_D serially.

Serial in Parallel Out:

1. Apply data at serial input.
2. Apply one clock pulse at CLK1 (Right shift). Data will appear at Q_A.
3. With the subsequent clock pulses data will be right shifted and at the end of 4th clock pulse all the data is available at corresponding outputs.



A de-bouncer circuit is used to apply clock pulse to $\overline{CLK1}$ or $\overline{CLK2}$. When the switch (GND) is connected to S1, positive half cycle of the square wave is formed and when switch (GND) is connected to S2, negative half cycle of the square wave is formed.

Observation:

1. **Parallel-in Parallel Out:**

The clock pulse is given to $\overline{CLK2}$. Mode Control → HIGH

$\overline{CLK1}$ & D_S → Don’t Care mode

Obs. No.	Clock Pulse	Inputs				Outputs			
		A	B	C	D	Q_A	Q_B	Q_C	Q_D
1	1								
2	2	D							
3	3	B							
4	4	A							
5	5	C							

2. **Serial Shift Right:**

The clock pulse is given to $\overline{CLK1}$. Mode Control → LOW

$\overline{CLK2}$, A, B, C and D → Don’t Care mode

No.	Clock Pulse	Serial Input D_S	Outputs			
			Q_A	Q_B	Q_C	Q_D
1	0	X				
2	1	a				
3	2	b				
4	3	c				
5	4	d				
6	5	e				

(Where a, b, c, d, e are bits having value 1 or 0)

3. **Serial Shift Left:**

The clock pulse is given to $\overline{CLK2}$. Mode Control → HIGH

$\overline{CLK1}$ and D_S → Don't Care mode

Obs. No.	**Clock Pulse**	**Input D**	**Outputs**			
			Q_A	**Q_B**	**Q_C**	**Q_D**
1	**0**	**X**				
2	**1**	**a**				
3	**2**	**b**				
4	**3**	**c**				
5	**4**	**d**				
6	**5**	**e**				
7	**6**	**f**				

(Where a, b, c, d, e, f are bits having value 1 or 0)

Result: The working of the shift register IC 7495 as serial shift registers and parallel in parallel-out register is checked.

Experiment 25

Study of 8-Bit DAC

MC 1408 is a familiar 8-bit monolithic D/A converter with a current output that can be converted to voltage by using an Op-Amp based current to voltage converter. The reference current should be 2 mA.

In D/A conversion process the possible number of digital inputs are fixed in case of 8-bit DAC and there are 2^8 possible inputs. Hence the whole range of analog voltage required to be represented suitably in 2^8 intervals.

Resolution: It is determined by number of input bits of D/A converter. It defines the smallest increment made by the output voltage. It is given by

Resolution = $\frac{1}{2^n - 1}$; for an 8-bit system, where, n = 8.

Procedure:

1. Connect the circuit as shown in circuit diagram first without connecting Op-Amp, adjust R_{ref} to get reference current 2mA.

2. To check the IC, make all inputs high and check I_O, $I_O \approx$ 2mA.

3. Make all input low and check I_O, $I_O \approx$ 0 Amps.

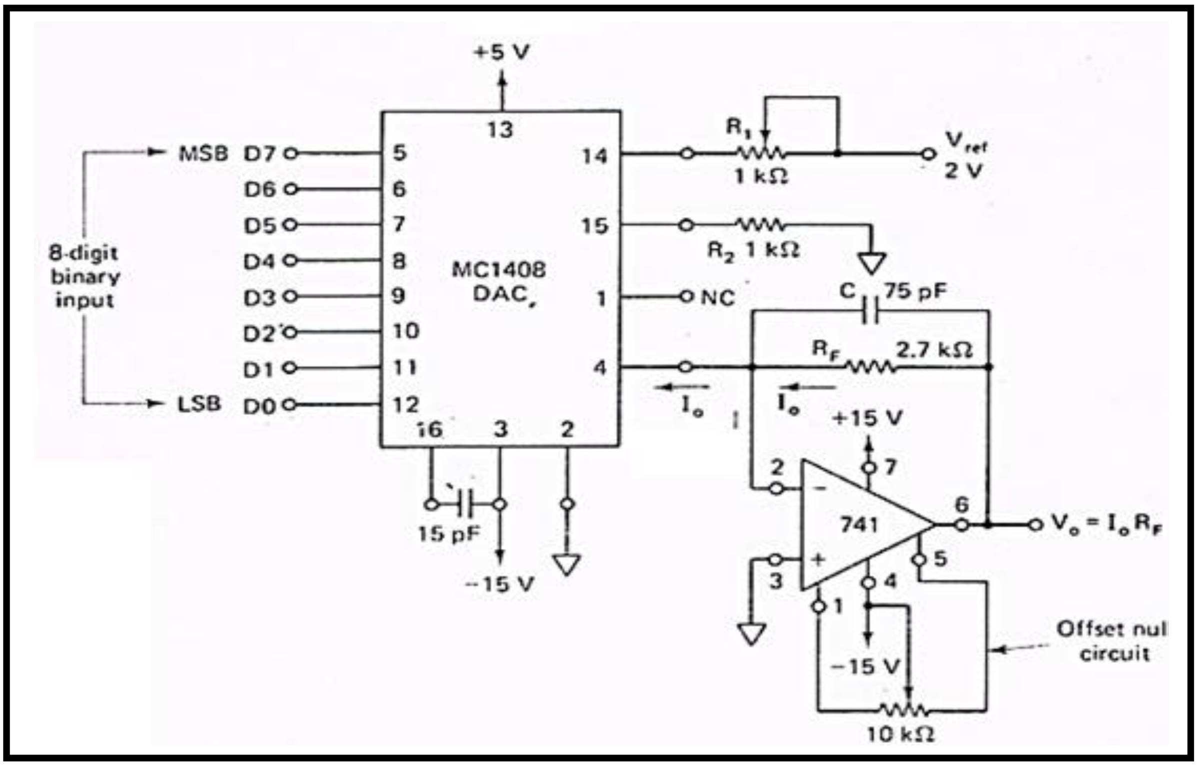
4. Note output for different combinations of inputs.

5. Off-set null the Op-Amp before use.

6. In unipolar mode, the output voltage of Op-Amp is

$$V_o = I_o R_F$$

$$\boldsymbol{I_o = \frac{V_{ref}}{R_{14}}\left[\frac{D_7}{2} + \frac{D_6}{4} + \frac{D_5}{8} + \frac{D_4}{16} + \frac{D_3}{32} + \frac{D_2}{64} + \frac{D_1}{128} + \frac{D_o}{256}\right]}$$

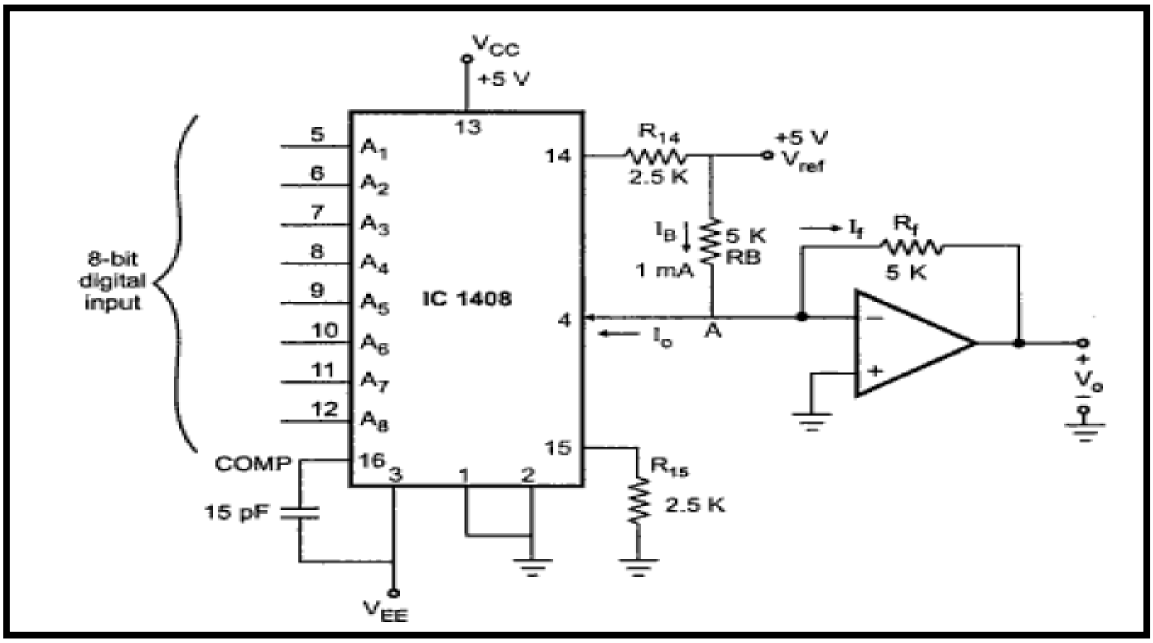


Unipolar Mode

7. For bipolar mode connect circuit as shown in figure. Take $R_B = 2R_{14}$, and $R_{14} = R_{15}$.
8. Adjust reference current and apply different input combinations, note the corresponding outputs. For bipolar mode output voltage is given by

$$V_0 = \frac{V_{ref}}{R_{14}} R_F \left[\frac{D_7}{2} + \frac{D_6}{4} + \frac{D_5}{8} + \frac{D_4}{16} + \frac{D_3}{32} + \frac{D_2}{64} + \frac{D_1}{128} + \frac{D_0}{256}\right] - \frac{V_{ref}}{R_B} \times R_F$$

Bipolar Mode



Observation:

Unipolar Mode:

DAC Inputs								Analog Output			
								I_{out}	V_{OO}	V_{OE}	Error

Bipolar Mode:

DAC Inputs								Analog Output			
								I_{out}	V_{OO}	V_{OE}	Error

Result:

Experiment 26

Study of 8085 Microprocessor Kit

Aim: To study the 8085 micro-processor kit.

Apparatus: 8085 IC, micro-processor kit, power supply.

Theory: Intel 8085 micro-processor is an 8-bit microprocessor. It is a 40 pin IC package, fabricated on a single LSI chip. It uses a single 5V power supply. Its clock pulse is about 3 MHz, it consists of three main sections:

1. **ALU (Arithmetic and Logical Unit):** The ALU performs arithmetic and logical operation, addition, subtraction, logical AND, OR, EX-OR, complement, increment, decrement, shift clear.

2. **Timing and Control Unit**: It generates timing and control signals, which are necessary for the execution of the instructions.

3. **Registers:** These are used for temporary storage of data and instructions. INTEL 8085 has following registers:
    a. One 8-bit accumulator and six 8-bit registers (B, C, D, E, H, L)
    b. One 16-bit stack pointer (SP) and one 16-bit program counter (PC)
    c. Instruction registers, Status register, Temporary register
    d. PC & SP contains the address of next instruction and stack top respectively
    e. IR holds the instruction until it is decoded

Bits of Flag Register:

a. Carry (CS)
b. Zero (Z)
c. Sign (S)
d. Parity (P)
e. Auxiliary carry (AC)

PSW: This 8-bit program word (status word) includes status flags and three undefined bits.

Data & Address Bus: Data bus is 8-bit wide and 8-bits of data can be transmitted parallel. It has a 16-bit wide address bus.

Pin Configuration: A8 – A15 (Outputs): These are address bus and are used for the most significant bits of the memory address.

AD0 – AD7 (Input / Output): These are multiplexed address-data bus. These are used for the least significant 8-bits of the memory address during first clock cycle and for data transfer during second and third clock cycle.

ALE (Address Latch Enable): It goes high during the 1st clock cycle of the machine. It enables the lower 8-bit of address to be latched in external memory.

IO/M: It is status signal, when IO go high, the address in the bus is for I/O device, otherwise it is for memory.

S0, S1: These are the status signal to distinguish various types of operation.

RD (Output): To control read operation.

WR (Output): To control write operation.

HOLD (Input): To indicate that another device is requesting.

HLDA (Input): It is the acknowledgement signal used to indicate HOLD request that has been received.

INTR (Input): When this goes high, micro-processor suspends its normal sequence of operations.

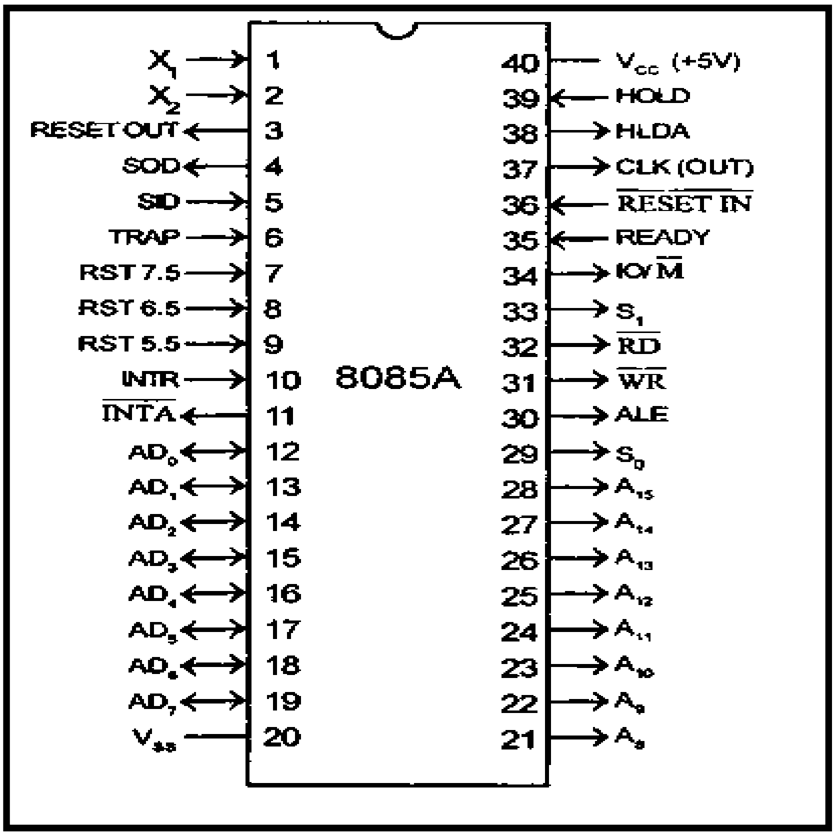
INTA (Output): It is interrupt acknowledgement signal sent by micro-processor after INTR is received.

RST 5.5, 6.5, 7.5 and TRAP (Input): These are various interrupt signals, with TRAP having highest priority

RESET IN (Input) & RESET OUT (Output): Resets PC to zero & CPU is reset.

X1, X2 (Input): This circuitry is required to produce a suitable clock for the µP.

CLK (Output): Clock output for users. Its frequency is same at which µP operates.

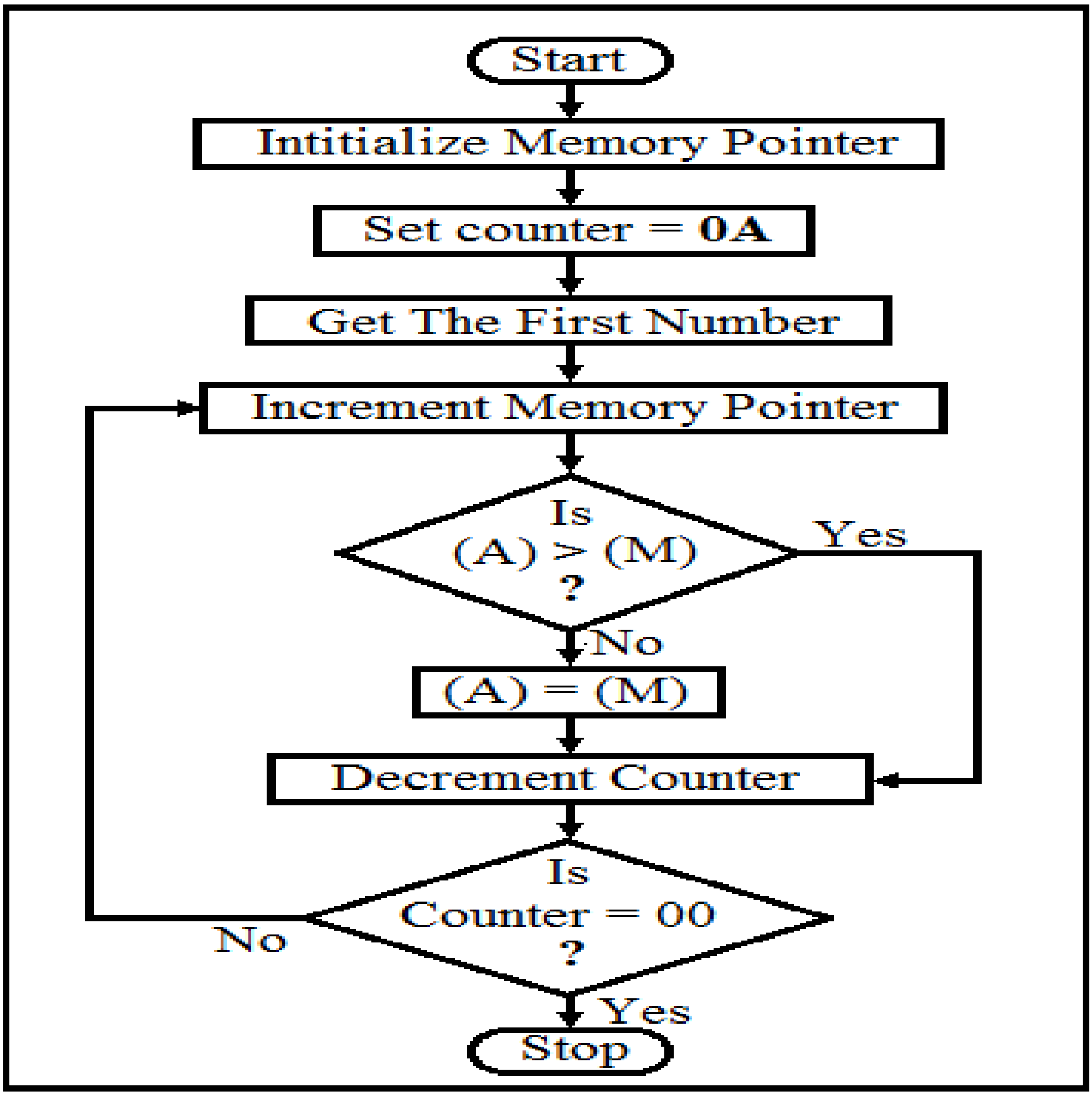


S1	S0	Operation
0	0	Halt
0	1	Write
1	0	Read
1	1	Fetch

SID (Input) & SOD (Output): Used for data line for serial input & serial output
Vcc: +5V supply & **GND:** Ground reference

<u>Program 1</u>

Ten data bytes are stored in memory locations starting from D000H. Write an ALP to find the maximum in the block of data.



Label	Mnemonic	Comments
	LXI H, D000	; initialize memory pointer
	MVI C, 0A	; set counter to 0AH
	MOV A, M	; get the first number
●	INX H	; increment memory pointer
	CMP M	; if (A)>(M), go to next number
	JNC ●●	
	MOV A, M	; store greater number
●●	DCR C	; decrement counter
	JNZ ●	; if not zero, repeat
	STA D100	; store result in (A), in memory location D100
	RST 1	; end execution

Memory	D000	D001	D002	D003	D004	D005	D006	D007	D008	D009
Data										

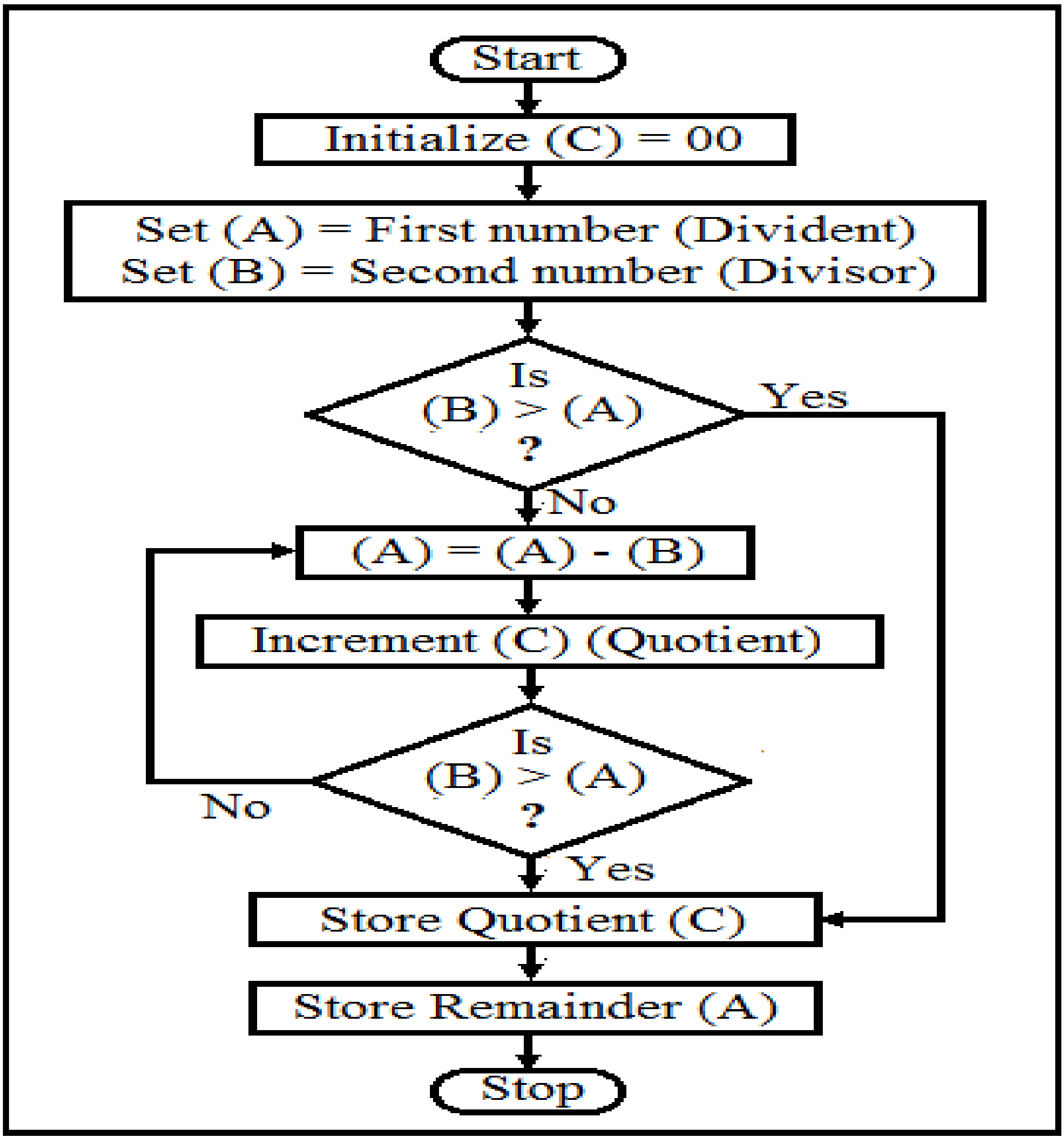
Result:

The greatest number from the block of data stored in the memory location D000 H is, (___) 16 and is stored in memory location D100 H.

*****Note: For lowest number replace JNC by JC**

Program 2

Two data bytes are stored in memory locations C050 H and C051 H. Write an ALP to divide the first number by the second.



Label	Mnemonic	Comments
	LXI H, C050	; initialize memory pointer
	MVI C, 00	; make (C) = 00, for storing quotient
	MOV A, M	; get the first number (Dividend) in (A)
	INX H	; increment memory pointer
	MOV B, M	; get the second number (Divisor) in (B)
	CMP B	; compare (B) with (A)
	JC ●	; if (A) < (B), jump
●●	SUB B	;(A) = (A) – (B)
	INR C	; increment (C)
	CMP B	; compare (B) with (A)
	JNC ●●	; if (A) > (B), repeat
●	INX H	; increment memory pointer
	MOV M, C	; store quotient (C) in C052 H
	INX H	; increment memory pointer
	MOV M, A	; store remainder (A), in C053 H
	RST 1	; end execution

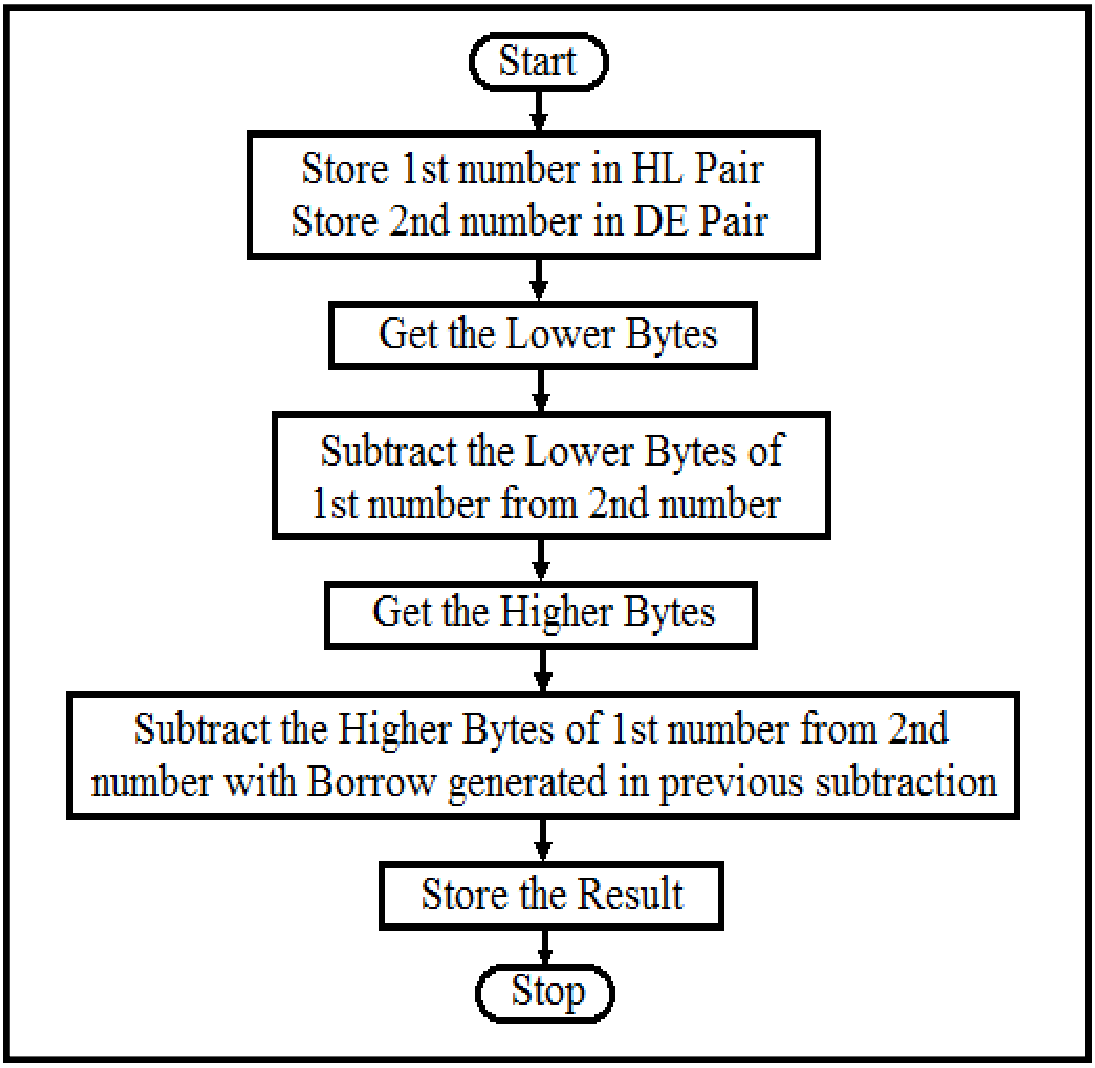
Observation:

Obs. No.	Dividend (C050)	Divisor (C051)	Quotient (C052)	Remainder (C053)
1.				
2.				

Note: For dividing 2nd number by the 1st number, store 1st number (divisor) in register 'B', and 2nd number (dividend) in register 'A' i.e. accumulator.

Program 3

Two 16-bit hexadecimal numbers are stored in memory location starting from D110H. Write an ALP to subtract 1st number from the 2nd number.



Label	Mnemonic	Comments
	LHLD D110	; store 1st number in HL pair
	XCNG	; exchange content of HL and DE pair
	LHLD D112	; store 2nd number in HL pair
	XCNG	; exchange content of HL and DE pair
	MOV A, E	; get lower byte of 2nd number
	SUB L	; (A) = (A) – (L), subtraction of lower bytes
	MOV L, A	; store result in register L
	MOV A, D	; get higher byte of 2nd number
	SBB H	; subtract higher bytes with borrow
	MOV H, A	; store result in register H
	SHLD D114	; store data in HL pair at D114 H
	RST 1	; end execution

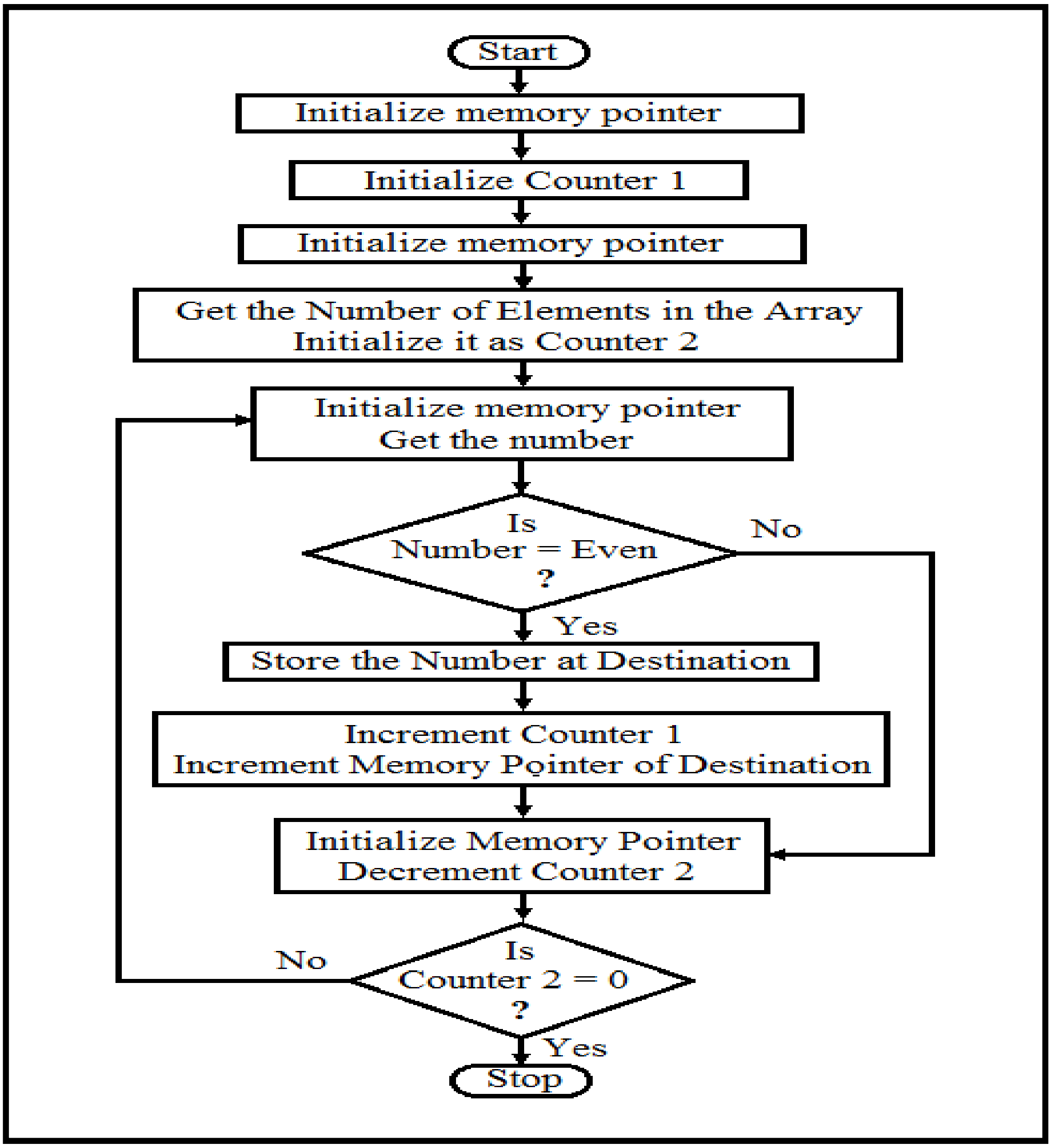
Observation:

No.	1st Number		2nd Number		Result	
	D111	D110	D113	D112	D115	D114
1.						
2.						
3.						

Note: To subtract 2nd number from the 1st number, store the 1st number in DE Pair, and the 2nd number in HL Pair.

Program 4

To sort, store and count total number of even numbers in an array starting from memory location C121 H and the length of the array is stored in C120 H.



Label	Mnemonic	Comments
	MVI C, 00	; counter 1 for counting even numbers
	LXI D, C151	; initialize destination memory pointer
	LXI H, C120	; initialize memory pointer
	MOV B, M	; counter 2, for number of elements
●	INX H	; increment memory pointer
	MOV A, M	; get the number
	RAR	; check if it is even
	JC ●●	; if odd, go for next number
	INR C	; increment counter 1
	MOV A, M	; get the even number
	STAX D	; store it in destination
	INX D	; increment destination memory pointer
●●	DCR B	; decrement counter 2
	JNZ ●	; if counter 2 ≠ 0
	MOV A, C	; copy content in (C) into (A)
	STA C150	; store the number in (A) in C150 H
	RST 1	; end execution

Note:

I. **ODD Numbers:** To sort and count odd numbers from an array, just replace the word 'even' by 'odd' and 'odd' by 'even'. And replace the instruction 'JC●●' by 'JNC ●●'

II. **POSITIVE Numbers:** To sort and count positive numbers from an array, just replace the word 'even' by 'positive' and 'odd' by 'negative'. And replace the instruction 'RAR' by 'RAL'

III. **NEGATIVE Numbers:** To sort and count negative numbers from an array, just replace the word 'even' by 'negative' and 'odd' by 'positive'. And replace the instruction 'RAR' by 'RAL' and the instruction 'JC●●' by 'JNC ●●'

Data:

Memory	C120	C121	C122	C123	C124	C125	C126	C127	C128	……
Data										

Observation:

Address	Even	Odd	Positive	Negative
C150				
C151				
C152				
C153				
C154				
C155				

Experiment 27

Waveform Generation: µP 8085 & PPI 8255

Aim: Interfacing of 8085 & 8255 to generate various (square, triangular, ramp, etc.) waveform using the concept of delays.

Apparatus: 8085 kit, power supply, DAC, dual supply, CRO, etc.

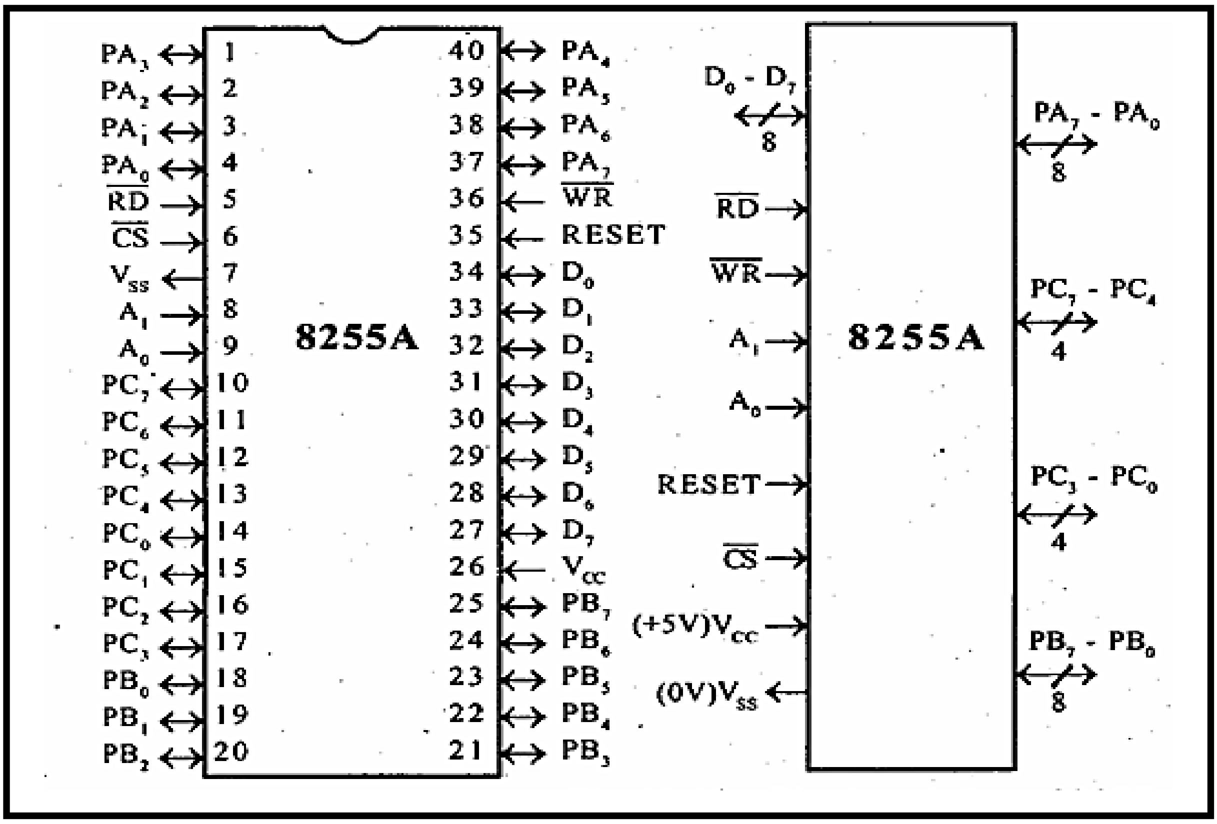
Theory: There are many situations in which it is desirable to generate a time, for example to generate periodic waveform. The execution time required by each instruction is the number of T-states in its instruction cycle. Each T-state is equal to one time period of the 8085-system clock. For example, if on 8085 µP has a clock frequency of 2MHz, then each T-state equals 0.5 µs. Assuming this clock frequency the instruction MVI A, XX H, will consume 7T- states and would be executed in;
Clock frequency of the system = f = 2×10^6 Hz
Clock period = T = $^1/_f = 0.5 \times 10^{-6}$ s/T-state
Time required to execute MVI A, XX H = 7 T-state = 3.5 µs. The delay can be further enhanced by nesting loops within other loops. The total delay will be product of the individual delay for each loop. If longer loops are required, register pairs may be used as counters for looping.

Peripheral Interfacing: Peripheral interfacing is considered to be a main part of µP, as it is the only way to interact with the external world. The main IC's which are to be interfaced with 8085 are

a. 8255 PPI
b. 8259 PPC
c. 8251 USTART
d. 8279 Key-board Display Controller
e. 8253 Timer/Counter
f. ADC & DAC interfacing

INTEL 8255: The INTEL 8255 is a device used for parallel data transfer between processor and slow peripheral devices like ADC, DAC, keyboard, 7-segment display, LCD, etc. It has 40 pins and uses a single +5V supply.

It has 3 ports: PA, PB, PC. PORT A can be programmed to work in any of the 3 operating modes; MODE 0, MODE 1, MODE 2 as input or output port. PORT B can be programmed to work either in MODE 0 or MODE 1 as input or output port. PORT C has different assignments depending on the mode of PORT A and PORT B. If PORT A and PORT B are programmed in MODE 0, then PORT C can perform any one of the following functions:



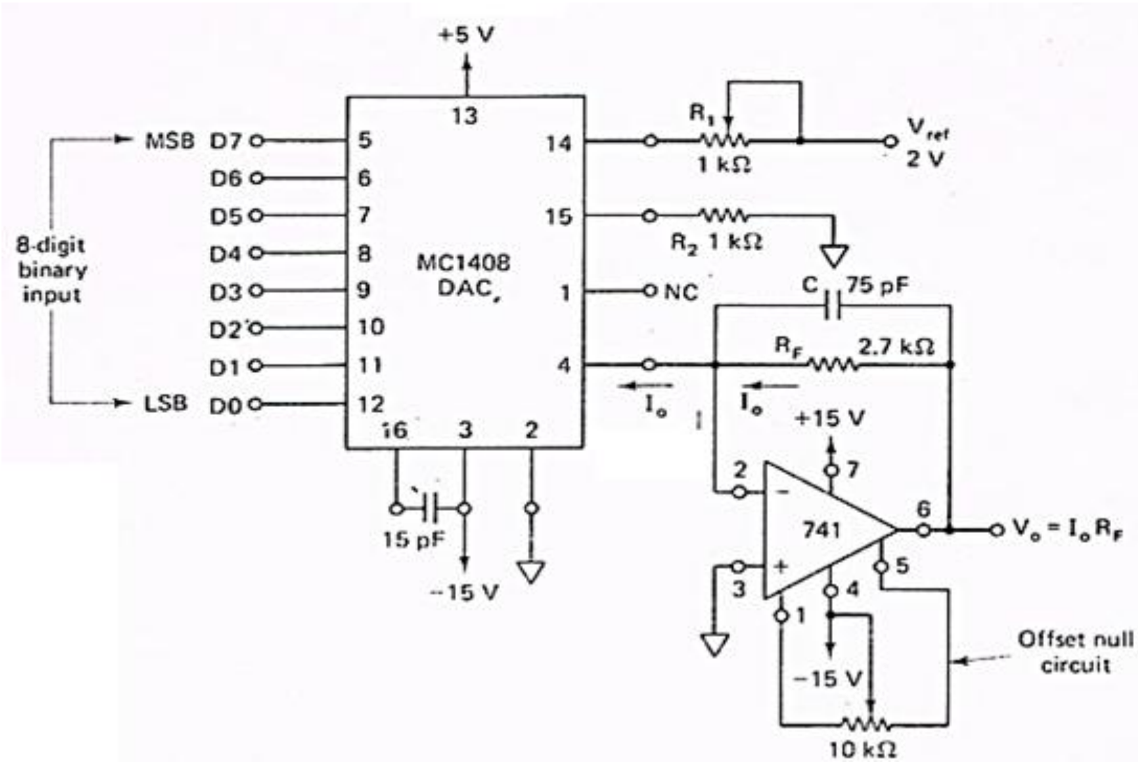
a. As 8-bit parallel port in MODE 0 for input or output.
b. As two 4-bit parallel ports in MODE 0 for input or output.
c. The individual pins of PC can be reset or set in BSR mode.
d. If PORT A is programmed in MODE 1 or MODE 2, and PORT B is programmed in MODE 1, then some of the pins of PORT C are used for hand-shake signals and the remaining pins can be used as input or output lines or individually set or reset for control application.

$\overline{\text{RD}}$ (READ): This control signal enables the read operation. When the signal is LOW the µP reads data from a selected I/O Port of the 8255A.

$\overline{\text{WR}}$ (WRITE): This control signal enables the write operation. When this signal goes LOW, the µP writes data from a selected I/O Port or the control register.

RESET: This is an active HIGH signal. It clears the control register and set all Ports in the input MODE.

$\overline{CS}$, A_1: These are device select signals.
The digital signals coming from µP through 8255, has to be converted into analog signal to see on a CRO. The conversion is done by a DAC Circuit.



$$I_O = \frac{V_{ref}}{R_1}\left(\frac{D_7}{2} + \frac{D_6}{4} + \frac{D_5}{8} + \frac{D_4}{16} + \frac{D_3}{32} + \frac{D_2}{64} + \frac{D_1}{128} + \frac{D_0}{256}\right)$$

Program 1: ALP to Generate Square Wave

Label	Mnemonic	Comments
	MVI A,80	; move control word (80)H into (A)
	OUT 13	; send C.W. to control register
●	MVI A, 00	; negative cycle of square wave
	OUT 10	; send (00)H into PORT A
	MVI B, FF	; counter for delay
●●	DCR B	;(B) = (B) – (01)H
	JNZ ●●	; delay program
	MVI A, FF	; negative cycle of square wave
	OUT 10	; send (FF)H into PORT A
	MVI B, FF	; counter for delay
Θ	DCR B	;(B) = (B) – (01)H
	JNZ Θ	; delay program
	JMP ●	; continue positive and negative cycles

Program 2: ALP to Generate Up-Ramp

Label	Mnemonic	Comments
	MVI A,80	; move control word (80)H into (A)
	OUT 13	; send C.W. to control register
●	MVI A, 00	; Up going cycle of ramp wave
	OUT 10	; send (00)H into PORT A
ϴ	INR A	;(A) = (A) + (01)H
	OUT 10	; send content in (A) to PORT A
	CPI FF	; compare content in (A) with (FF)H
	JNZ ϴ	; delay program
	JMP ●	; continue positive and negative cycles

Program 3: ALP to Generate Down-Ramp

Label	Mnemonic	Comments
	MVI A,80	; move control word (80)H into (A)
	OUT 13	; send C.W. to control register
●	MVI A, FF	; Down going cycle of ramp wave
	OUT 10	; send (00)H into PORT A
ϴ	DCR A	; (A) = (A) - (01)H
	OUT 10	; send content in (A) to PORT A
	CPI 00	; compare content in (A) with (00)H
	JNZ ϴ	; delay program
	JMP ●	; continue positive and negative cycles

Program 4: ALP to Generate Triangular Wave

Label	Mnemonic	Comments
	MVI A,80	; move control word (80)H into (A)
	OUT 13	; send C.W. to control register
●	MVI A, 00	; Up going cycle of triangular wave
	OUT 10	; send (00)H into PORT A
●●	INR A	;(A) = (A) + (01)H
	OUT 10	; send content in (A) to PORT A
	CPI FF	; compare content in (A) with (FF)H
	JNZ ●●	; jump if not zero
ϴ	DCR A	;(A) = (A) - (01)H, down going cycle
	OUT 10	; send content in (A) to PORT A
	CPI 00	; compare content in (A) with (00)H
	JNZ ϴ	; jump if not zero
	JNZ ●	; continue triangular wave function

Program 5: ALP to Generate Trapezoidal Wave

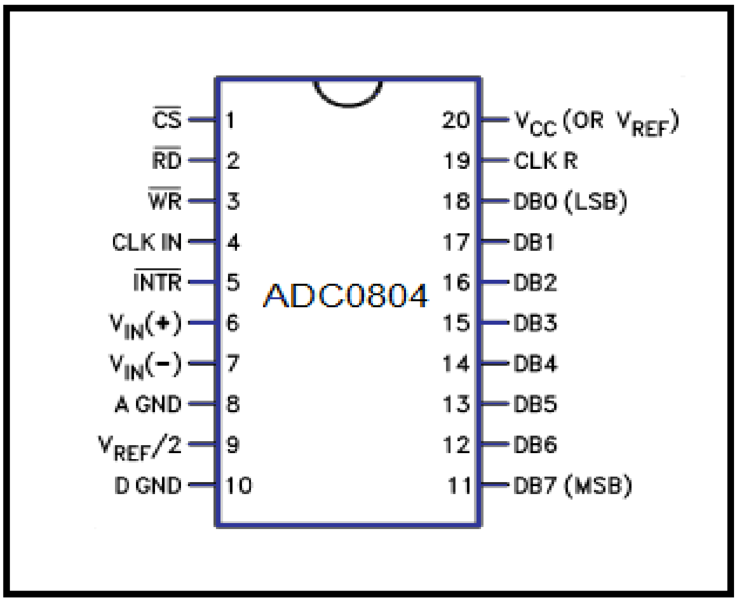
Label	Mnemonic	Comments
	MVI A, 80	; move control word (80)H into (A)
	OUT 13	; send C.W. to control register
●	MVI A, 00	; lower cycle of square wave
	OUT 10	; send (00)H into PORT A
	MVI B, FF	; counter for delay
●●	DCR B	;(B) = (B) – (01)H
	JNZ ●●	; delay program
ϴϴ	INR A	; (A) = (A) + (01)H, up going cycle of ramp
	OUT 10	; send content in (A) to PORT A
	CPI FF	; compare content in (A) with (FF)H
	JNZ ϴϴ	; jump if not zero
	MVI B, FF	; counter for delay, upper cycle of square wave
ϴ	DCR B	; (B) = (B) –(01)H
	JNZ ϴ	; delay program
▲	DCR A	; (A) = (A) – (01)H, down going cycle of ramp
	OUT 10	; send content in (A) to PORT A
	CPI 00	; compare content in (A) with (00)H
	JNZ ▲	; jump if not zero
	JNZ ●	; continue trapezoidal wave function

Experiment 28

Understanding 8-Bit ADC

Features of ADC 0804:

a. Easy to interface with all µP & µC/works standalone as well.
b. Single channel 8-bit ADC module.
c. On chip clock available.
d. Digital output varies from 0 to 255; step size is 19.53 mV.
e. For every 19.53 mV of analog value there will be rise of one bit on digital side.
f. Available in 20-pin PDIP, SOIC package.

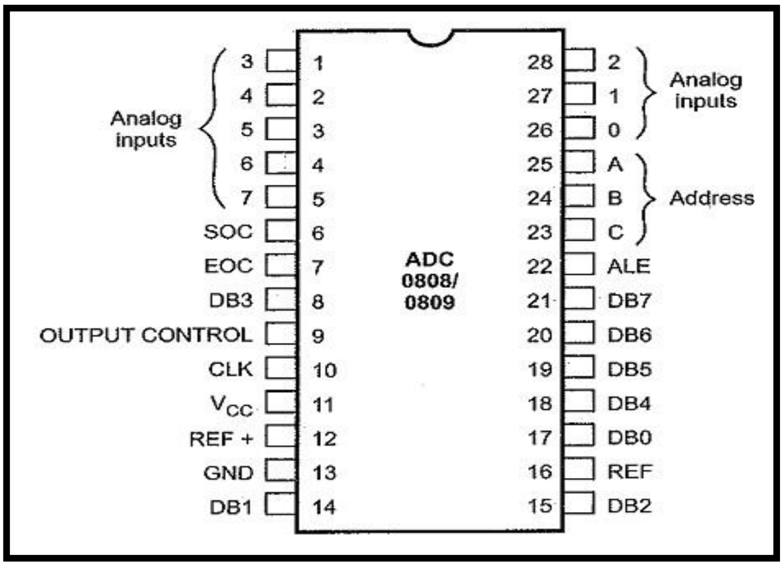


Where to use an ADC 0804: A compact ADC module with a resolution of 8-bit. The ADC 0804 is a commonly used ADC module, for projects were an external ADC is required. It is a 20-pin single channel 8-bit ADC module. Meaning, it can measure one ADC value from 0V to 5V and the precision is 19.53 mV (step size). That is for every increase of 19.53 mV on input side there will be an increase of 1-bit at the output side.

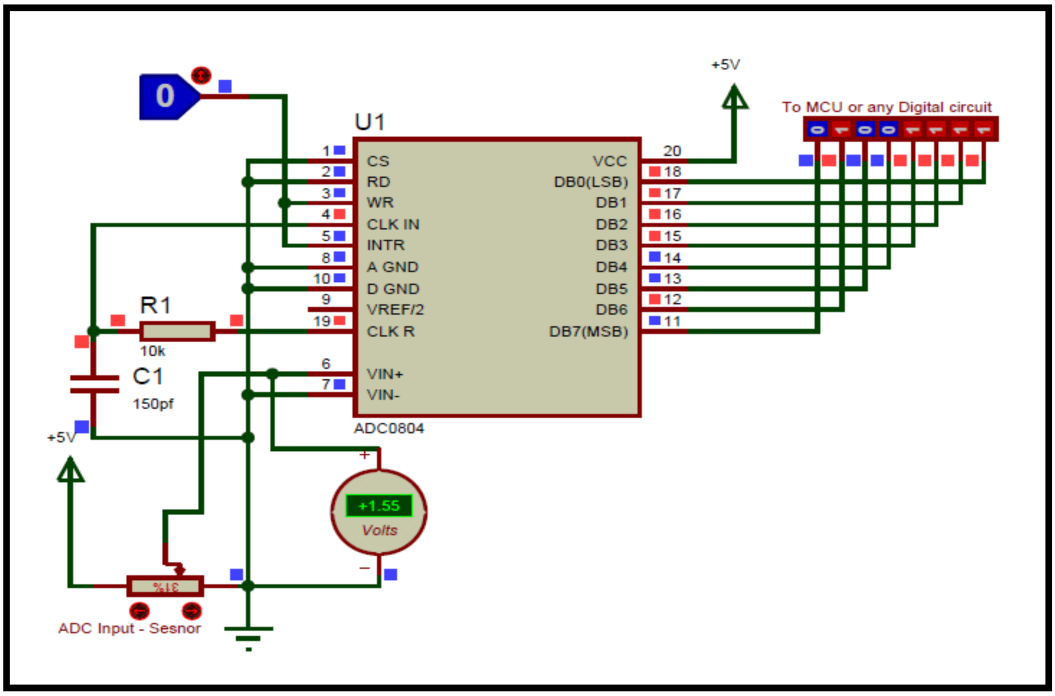
This IC is very Ideal to use with microprocessors like Raspberry Pi, Beagle bone etc. Every ADC module requires a clock to function; this IC comes with its own internal clock.

How to use ADC 0804: Since the IC comes with an internal clock, we do not need many components to make it work. However, to make the internal clock to work we have to use a RC circuit. The IC should be powered by +5V & both the ground pins should be tied to circuit ground. To design the RC circuit simply use a resistor of value 10k and capacitor of 100pf and connect them to CLK R and CLK IN pins as shown in the circuit below. The chip selects (CS) and Read/OE (R) pin should also be grounded. The $V_{ref}/2$ pin is left free because by default without any connection it will work for maximum input of +5V and set itself to 2.5 V.

The digital output will be obtained at the pins DB0 to DB7 and the analog voltage should be connected to V_{in} (+) pin as shown in the circuit. Also note that another end of the voltage source (sensor/module) should also be grounded to the circuit for the ADC conversion to work. For the ADC conversion to start, we have made the Write / SOC (WR) pin to go high momentary this can be done connecting the pin to I/O of MPU & toggling it high before every ADC read.



If we need to convert more analog voltages to digital, switch over to 8-channel ADC. The channel selection is done using CBA pins and the role of SOC, EOC & OE remains same as in the single Channel ADC.



In the above circuit a potentiometer is used to feed in a variable voltage of 0V to 5V to the Vin pin and the present voltage is read using a voltmeter. As you can see in the image the voltage value is 1.55V and the resulting binary value is 01001111. Let us see how this binary value can be converted to analog value, since we will need it while programming/designing. Binary Value = 01001111, Converting to
Decimal= (0x128) + (1x64) +(0x32) +(0x16) +(1x8) +(1x4) +(1x2) +(1x1) = 79
Analog Voltage = Decimal Value x Step Size = 79 x 19.53 mV= 1.54V
The obtained value is 1.54V and the measured voltage is 1.55V which are very much close. So, this is how you use an ADC0804 IC.

Applications:

Operates with any 8-Bit Processors or as a Stand-Alone Device.
Widely used with Raspberry Pi, Beagle Bone & other MPU.
Interface to Temp Sensors, Voltage Sources & Transducers.

Experiment 29

Understanding LCR Meter

An LCR meter is a type of electronic test equipment used to measure the inductance (L), capacitance (C) & resistance (R) of an electronic component. In the simpler versions of this instrument the impedance is measured internally and converted to display for the corresponding capacitance or inductance value. Readings should be reasonably accurate if the capacitor or inductor device under test does not have a significant resistive component of impedance. More advanced designs measure true inductance or capacitance, as well as the equivalent series resistance of capacitors and the Q factor of inductive components. The meter measures the voltage across and the current through the Device Under Test (DUT).

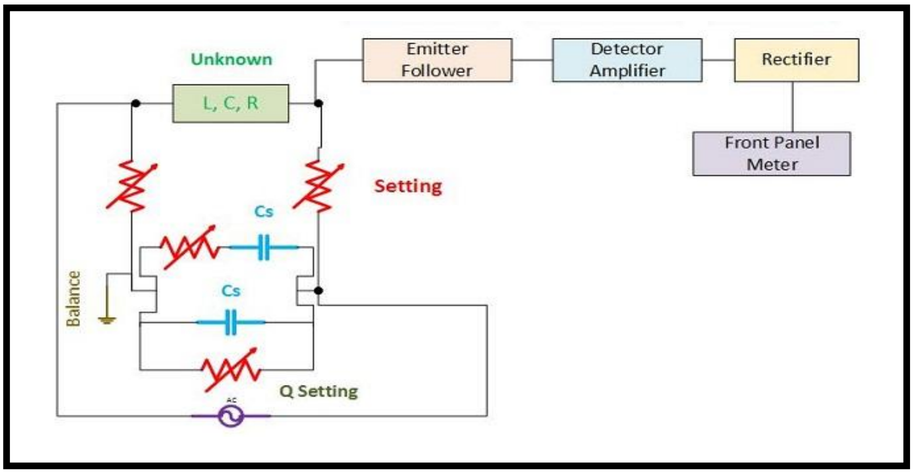
Hand held LCR meters typically have selectable test frequencies of 100 Hz, 120 Hz, 1 kHz, 10 kHz, and 100 kHz for top end meters. The display resolution and measurement range capability will typically change with the applied test frequency since the circuitry is more sensitive or less for a given component (i.e., an inductor or capacitor) as the test frequency changes.

Bench top LCR meters sometimes have selectable test frequencies of more than 100 kHz. They often include options to superimpose a DC voltage or current on the AC measuring signal. Lower end meters might offer the possibility to externally supply these DC voltages or currents while higher end devices can supply them internally. In addition, bench top meters typically allow the usage of special fixtures (ie, Kelvin wiring, that is to say, 4-wire connections) to measure SMD components, air-core coils or transformers.

LCR meter is just a multimeter, this is because it can measure resistance, inductance and capacitance as per the requirement. Thus, it is termed as LCR meter.

L; inductance, C; capacitance and R; resistance. The significant circuit of LCR meter is the Wheatstone bridge and RC ratio arm circuits. The component whose value is to be measured is connected in one of the arms of the bridge. There are different provisions for the different type of measurements. For example, if the value of resistance is to be measured, then Wheatstone bridge comes into picture while the value of inductance and capacitance can be measured by comparing it with standard capacitor present in RC ratio arm circuit.

The below block diagram clearly defines the connection diagram of the LCR meter. The measurement of DC quantities will be done by exciting the bridge with DC voltage. On the contrary, the AC measurements require excitation of the Wheatstone bridge with AC signal. For providing AC excitation, the oscillator is used in the circuit. It generates the frequency of 1 kHz.



Working of LCR Meter:

The bridge is adjusted in null position in order to balance it completely. Besides, the sensitivity of the meter should also be adjusted along with balancing of the bridge. The output from the bridge is fed to emitter follower circuit. The output from emitter follower circuit is given as an input to detector amplifier.

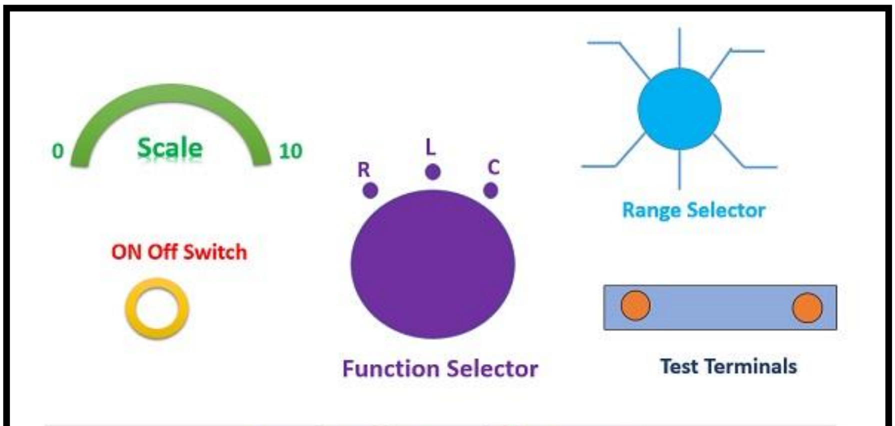
The significance of detector amplifier can be understood by the fact that if the measuring signal is low in magnitude, it will not be able to move the indicator of PMMC meter. Thus, in order to achieve the sustainable indication, we need to have a high magnitude measuring signal.

But it is often observed that while dealing with the measurement process, the magnitude of the measuring signal falls down due to attenuation factor. The problem to this solution is to utilize an amplifier.

The rectifier is used in the circuit to convert the AC signal into DC signal. When the bridge is provided with AC excitation then at the output end of the bridge the AC signal need to convert into DC signal.

Front Panel of LCR Meter:

The component which is to be measured is placed across the test terminals of LCR meter, after which according to the type of component the measurement is performed.



Controls on face panel of LCR meter

To understand the procedure of measurement by LCR meter, the functional controls on front panel needs to be understood. Let's have a look at the controlling terminals of the front panel of LCR meter.

a. **ON/OFF Switch:** The ON/OFF switch can be used to turn on or off LCR meter. When the switch is positioned to ON state, the main supply is connected with LCR meter. After this, it is crucial to leave the meter for 15 minutes so that it can warm up. The indicator on the front panel will start glowing to indicate that the LCR meter is ON.

b. **Test Terminals:** The two points on the front panel are test terminals. The component which is to be measured is connected to this test terminals.

c. **Function Selector:** The function selector is used for setting the meter in the mode in order to measure the particular type of the component. If resistance is to be measured, then the function selector is to be set at R mode, if inductance is to be measured it is to be adjusted to L mode and similarly in case of capacitance it is to be adjusted at C mode.

d. **Range Selector**: The range selector provides an extent of measuring range so that component of high magnitude or low magnitude values can be measured easily. The range selector should be adjusted properly in order to have correct measurement. For example; if a resistor of 10 MΩ is under measurement and the range selector is in the range of ohms, then it will not show reliable and accurate results. The range of instrument can be increased by using multipliers in the circuit. The multipliers should consist of higher precision resistors made up of the metal film. In addition to this, it should possess high-temperature stability.

e. **<u>Scale</u>:** The scale calibrated on the LCR meter will show the final values of the measurement. The indicator will move across the calibrated scale to show the measured value.

<u>Use of Meter:</u>

When we are measuring the unknown value component, select the range of the LCR meter at the highest value. This is because we do not know the range of the component. After this, achieve the null deflection in the bridge by adjusting the range, loss factor and sensitivity.

<u>Measurement of Capacitance of a Capacitor:</u>

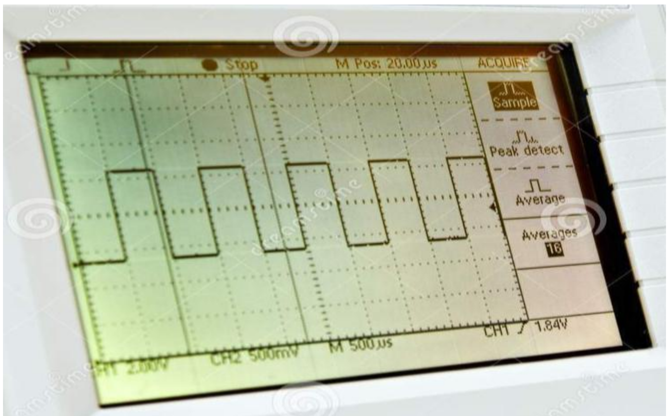
1. Select parameter L/C.
2. Select the appropriate test frequency and equivalent circuit.
3. Insert the DUT into the test component jig.
4. The display will show the capacitance of the DUT.
5. If EQV CKT LED is flashing press EQV CKT key.
6. If FREQ LED flashing press FRQ key.
7. If the unit (range) indication LED is flashing then it indicates that the measurement cannot measure the component value to the basic accuracy.
8. Electrolytic capacitors can be measured by applying 2V internal DC bias voltage or 50V external DC bias voltage.

<u>Measurement of Inductance of an Inductor:</u>

1. Select parameter L/C.
2. Select the appropriate test frequency and equivalent circuit.
3. Insert the DUT into the test component jig.
4. The display will show the inductance of the DUT.
5. If EQV CKT LED is flashing press EQV CKT key.
6. If FREQ LED flashing press FRQ key.
7. If the unit (range) indication LED is flashing then it indicates that the measurement cannot measure the component value to the basic accuracy.

Experiment 30

Understanding DSO



The basic concept behind digital oscilloscopes is the conversion of the incoming analog signal into a digital format where it can be processed using digital signal processing techniques. When the signal enters the scope, it is first pre-conditioned by some analog circuits to ensure that the optimum signal is presented to the next stage. This next stage involves the acquisition of the digital samples, to achieve this, an ADC is employed.

Oscilloscopes are used to observe the change of an electrical signal over time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such properties as amplitude, frequency, rise time, time interval, distortion etc. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales, built into the screen of the instrument.

The oscilloscope can be adjusted so that repetitive signals can be observed as a continuous shape on the screen. A storage oscilloscope allows single events to be captured by the instrument and displayed for a relatively long time, allowing observation of events too fast to be directly perceptible.

Oscilloscopes are used in the science, medicine, engineering, automotive and the telecommunications industry. General-purpose oscilloscopes are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram.

Early oscilloscopes used cathode ray tubes (CRTs) as their display element (hence they were commonly referred to as CROs) and linear amplifiers for signal processing. Storage oscilloscope uses special storage CRTs to maintain a steady display of a single signal. CROs were later largely superseded by digital storage oscilloscopes (DSOs) with thin panel displays, fast ADCs and digital signal processors. DSOs without integrated displays are available at lower cost and used as general-purpose digital computer to process and display waveforms.

Oscilloscope Specifications

a. **Bandwidth:** Oscilloscopes are most commonly used to measure waveforms which have a defined frequency. No scope is perfect, though they all have limits as to how fast they can see a signal change. The bandwidth of a scope specifies the range of frequencies it can reliably measure.

b. **Digital /Analog:** Oscilloscope can either be analog or digital. Analog scopes use an electron beam to directly map the input voltage to a display. Digital scopes incorporate microcontrollers, which sample the input signal with an ADC and map that reading to the display. Generally, analog scopes are older, have a lower bandwidth, and less features, but they may have a faster response.

c. **Number of Channels**: Many scopes can read more than one signal at a time, displaying them all on the screen simultaneously. Each signal read by a scope is fed into a separate channel. Two to four channel scopes are very common.

d. **Sampling Rate:** This characteristic is unique to digital scopes; it defines how many times per second a signal is read. For scopes that have more than one channel, this value may decrease if multiple channels are in use.

e. **Rise Time:** The specified rise time of a scope defines the fastest rising pulse it can measure. The rise time of a scope is very closely related to the bandwidth. It can be calculated as Rise Time = 0.35 / Bandwidth.

f. **Maximum Input Voltage:** Every piece of electronics has its limits when it comes to high voltage. Scopes should all be rated with a maximum input voltage; the scope will be damaged.

g. **Resolution:** The resolution of a scope represents how precisely it can measure the input voltage. This value can change as the vertical scale is adjusted.

h. **Vertical Sensitivity:** This value represents the minimum and maximum values of your vertical, voltage scale. This value is listed in volts per div.

i. **Time Base:** Time base usually indicates the range of sensitivities on the horizontal, time axis. This value is listed in seconds per div.

j. **Input Impedance:** When signal frequencies get very high, even a small impedance (resistance, capacitance, or inductance) added to a circuit can affect the signal. Every oscilloscope will add a certain impedance to a circuit it's reading, called the input impedance. Input impedances are generally represented as a large resistive impedance (>1 MΩ) in parallel (||) with small capacitance (in the pF range). The impact of input impedance is more apparent when measuring very high frequency signals and the probe you may use some compensatory effect.

k. **What Can Scopes Measure:** In addition to those fundamental features, many scopes have measurement tools, which help to quickly quantify frequency, amplitude and other waveform characteristics. In general, a scope can measure both time-based and voltage-based characteristics.

Timing Characteristics:

a. **Frequency & Period:** Frequency is defined as the number of times per second a waveform repeat. And the period is the reciprocal of that (number of seconds each repeating waveform takes). The maximum frequency a scope can measure varies, but it's often in the MHz range.

b. **Duty Cycle:** The percentage of a period that a wave is either positive or negative (there are both positive and negative duty cycles). The duty cycle is a ratio that tells you how long a signal is "on" versus how long it's "off" each period.

c. **Rise & Fall Time:** Signals can't instantaneously go from 0V to 5V, they have to smoothly rise. The duration of a wave going from a low point to a high point is called the rise time and fall time measures the opposite. These characteristics are important when considering how fast a circuit can respond to signals.

Voltage Characteristics:

a. **Amplitude:** Amplitude is a measure of the magnitude of a signal. There are a variety of amplitude measurements including peak-to-peak amplitude, which measures the absolute difference between a high and low voltage point of a signal. Peak amplitude, on the other hand, only measures how high or low a signal is past 0V.

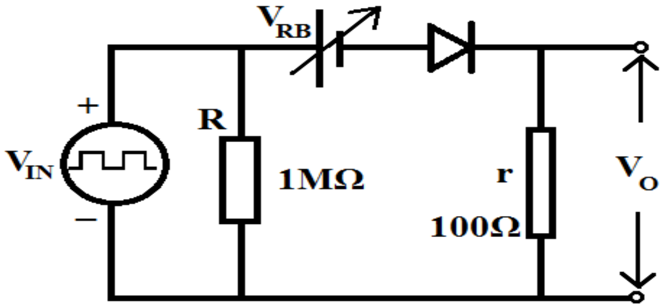
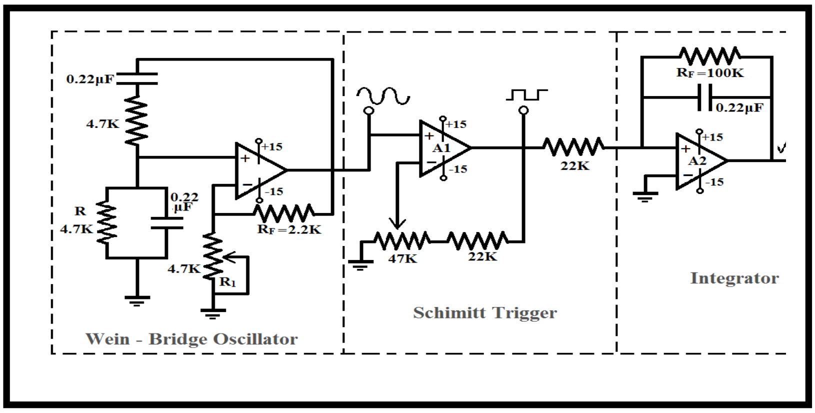
b. **Maximum & Minimum Voltages:** The scope can tell you exactly how high and low the voltage of your signal gets.

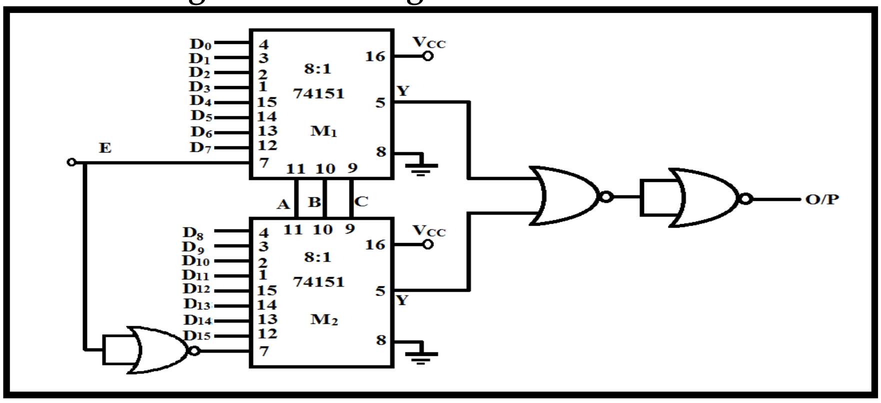
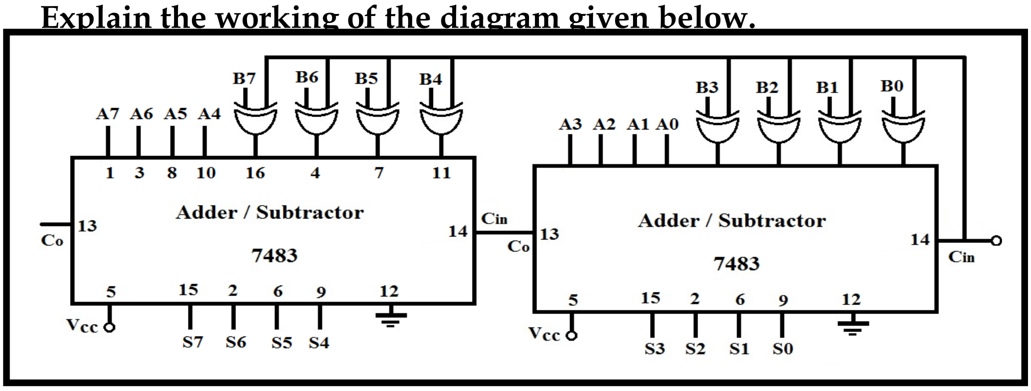
c. **Average Voltages:** Oscilloscopes can calculate the average or mean of your signal, and it can also tell you the average of your signal's minimum and maximum voltage.

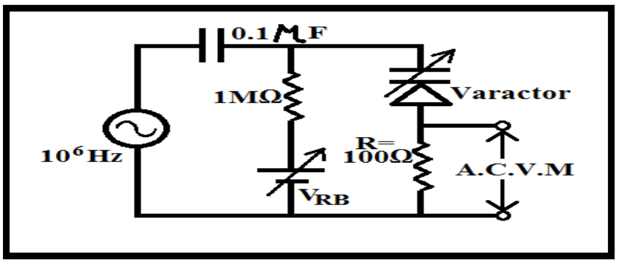
Experiment 31

Questionnaire

	Experiment
A	**Basics**
	1. Specific charge of an electron? **2. Is the measurement of 3.45 mm possible using Vernier calliper? Why?** **3. No zero error in case of spectrometer & travelling microscope. Why?** **4. If $Y_a = 10^{11}$ & $Y_b = 10^{12}$, which is more elastic material "a" or "b"?** **5. Why sound waves can't be polarized?** **6. Velocity of sound does not vary with pressure of the medium? Why?** **7. Sound propagation is an adiabatic or an isothermal process?** **8. What is human visible range in terms of wavelength?** **9. What are the criteria for diffraction of light?** **10. Distinguish between interference & diffraction.** **11. Distinguish: Waves in phase & out of phase.** **12. Define refractive index of a medium and TIR.** **13. How many Flip-Flops are to be cascaded to count up to 256?** **14. Explain UP/DOWN pre-settable counter.** **15. $(10001100111100000 1000)_2 = (X)_{16} = (Y)_8$; Find X and Y?** **16. What is the actual value (place value of 1 at) MSB in each case below?** **a. $(1111)_2$ b. $(1111)_8$ c. $(1111)_{10}$ d. $(1111)_{16}$** **17. Name any three passive & three active elements.** **18. Five important Characteristics of Op-Amp & their significance.** **19. Differentiate: Resistance, Reactance & Impedance?** **20. Basic principle behind the working of filters?** **21. Distinguish LCR series & LCR parallel circuits? What are tuning circuits?** **22. Explain loading problem & impedance match with a suitable example?** **23. Compare a C.C.S & a C.V.S? Compare a Voltmeter & an Ammeter?** **24. What is colour code of 0.22Ω, 2.2Ω, 22Ω, 100Ω, 22KΩ, 220 MΩ.**
B	**Michelson Interferometer**
	1. What is LC of the MI in your Lab? Use of compensating plate? **2. Interference by division of amplitude & division of wave front?** **3. Define coherent sources? Define constructive & destructive interference.** **4. Mention any four applications of MI?**
C	**h/e: Vacuum Photocell**
	1. Explain photoelectric effect? **2. Discuss the frequency, wavelength & intensity dependence of PEE.** **3. Explain work function, threshold frequency and stopping potential?** **4. Explain each term in the expression: $h\upsilon = \phi + K.E._{max} = \phi + {}^{1}/_{2}\, mv_{max}^2$**
D	**Measurement of Wavelength using Laser**
	1. Full form of LASER? Distinguish spontaneous & stimulated emission? **2. Explain the difference between excited state & metastable state.** **3. Define active medium and population inversion?**

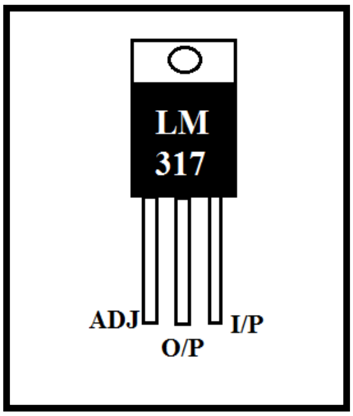
E	**Voltage Regulators**
	1. Differentiate: Rectification, Filtration & Regulation? 2. Differentiate load regulation & line regulation? 3. Refer datasheet and Compare LM 317 and LM 337.
F	**Constant Current Supply: IC 741 & LM317 (CCS)**
	1. Define CCS and how you can find its internal resistance? 2. Why internal resistance of CCS is usually high?
G	**Active Filters (2nd Order)**
	1. Distinguish Passive & Active filters? Distinguish I & II order filters 2. Define cut-off frequency? Why it is called half power point also? 3. Explain 20dB, 40dB & 60dB; roll on & roll off.
H	**Carrier Lifetime: Pulse Reverse Method**
	 1. Explain the role of each component in the diagram above? 2. Explain: Minority carrier diffusion length & Reverse saturation current?
I	**DC Hall Effect**
	1. Define DC Hall Effect? 2. Explain the role of $\vec{F} = e(\vec{v} \times \vec{B})$ in the phenomena of Hall Effect. 3. Distinguish isotropic and homogenous medium?
J	**Temperature Dependence: Breakdown Diodes**
	1. What is difference between Zener diode & Avalanche diode? 2. Mention any four applications of breakdown diodes? 3. Compare: Zener diode & Avalanche diode with reference to temperature?
K	**Waveform Generation**
	1. Explain the role of each block in the circuit diagram given below. 

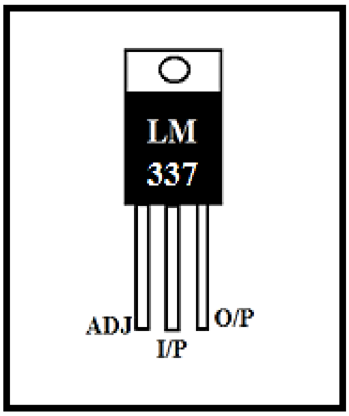
L	**Instrumentation Amplifier**
	1. Explain the role of each Op-Amp in an instrumentation amplifier? 2. Important characteristics of an instrumentation amplifier & their use. 3. Explain CMMR and its significance? 4. Why is the offset null necessary in case of instrumentation amplifier?
M	**16 Channel Digital Multiplexer**
	1. Explain the role of each pin in the IC 74151. 2. Explain the working of the circuit given below. 
N	**Geiger Muller Counter & Dead Time**
	1. Applications of G.M. tube? 2. Explain the construction & working of a G.M. Tube? 3. Starting Voltage, Plateau, Plateau Threshold Voltage, Plateau Length? 4. Explain: Recommended Supply Voltage and Dead Time?
O	**Ultrasonic Interferometer**
	1. Define ultrasonic, infrasonic & supersonic? 2. Precautions in using ultrasonic interferometer? 3. Explain the role of different parts of the Ultrasonic Interferometer?
P	**Refractive Index of Liquids using Laser**
	1. What is the principle behind the experiment? 2. Explain critical angle? Explain TIR? Relate critical angle & R.I?
Q	**Adder – Subtractor Circuits**
	Explain the working of the diagram given below. 
R	**Pre-Settable Counters: 74190 / 74193**
	1. Explain 4-bit synchronous binary up-down counter?

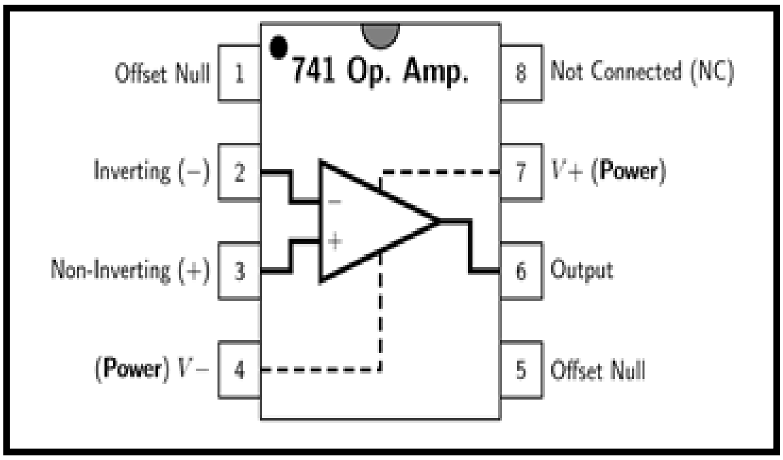
	2. What is the significance of the pin (CO)? 3. Advantages of de-bouncing circuit?
S	TTL Characteristics
	1. Disadvantages of TTL gates and of open collector outputs? 2. Explain the meaning of tristate device? 3. Explain noise immunity & noise margin? Explain loading problem?
T	Barrier capacitance of a PN junction diode
	1. Explain the role of each component in the diagram below. 
U	LVDT
	1. Explain the construction and working of LVDT? 2. Mention few applications of LVDT? 3. What are the disadvantages of LVDT?
V	Resistivity & Energy Band Gap: Four Probe Method
	1. Define band-gap in a semiconductor? How it varies with temperature? 2. Define resistivity of a material? How it varies with temperature? 3. Distinguish: Conductors, Semiconductors & Insulators @ band gap.
W	Shift Registers
	With reference to Shift register explain: Parallel in Parallel out, Serial in Parallel out and Parallel in Serial out.
X	Study of 8-bit DAC
	1. Distinguish unipolar and bi-polar mode of D/A converter. 2. Explain reference current in a DAC & its binary weight-age. 3. O/P of DAC is always one LSB lesser even for all I / P? Why? 4. Explain resolution & accuracy of a DAC.
Y	Waveform Generation using 8085 & 8255
	1. What do you mean by T-states? Their role in determining delay? 2. Explain how registers of 8085 can be used for small, big & bigger delays. 3. Explain BSR mode and I/O mode of 8255?

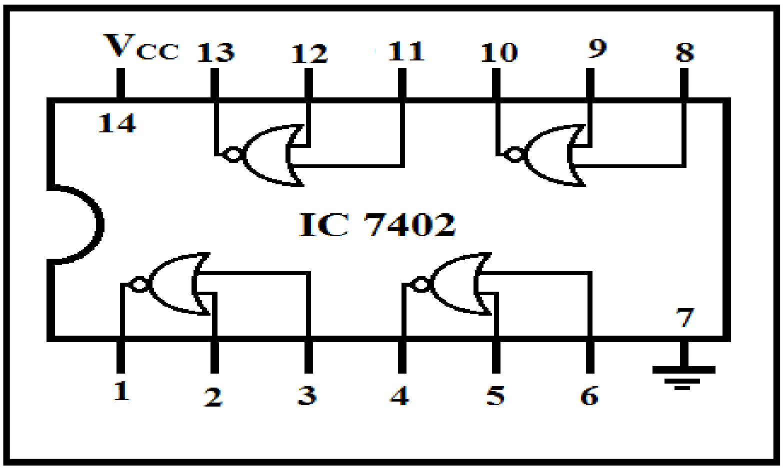
Experiment 32

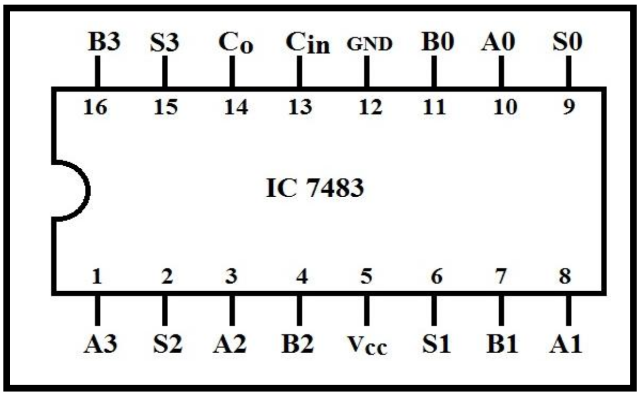
Pin Diagrams of Important ICs

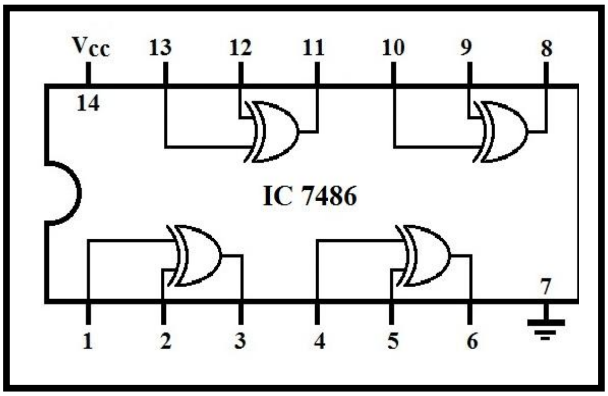


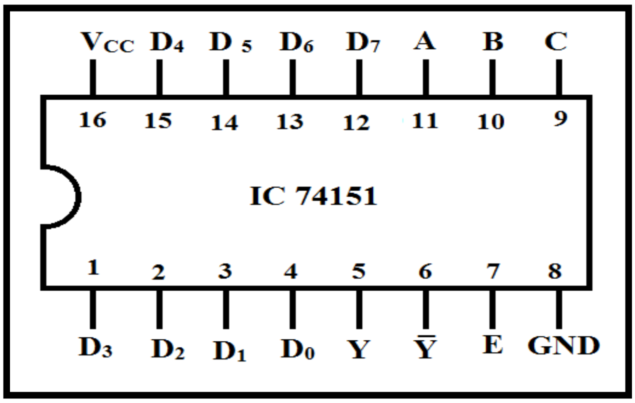


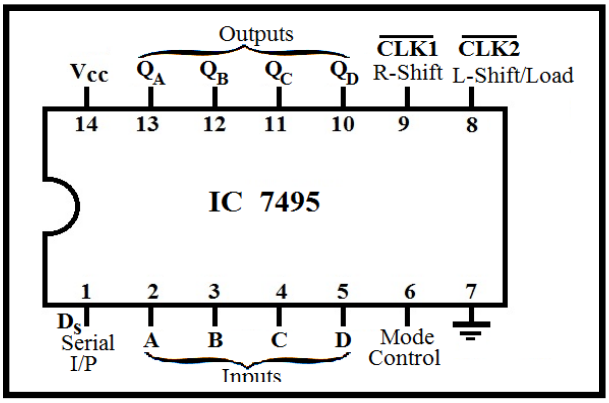


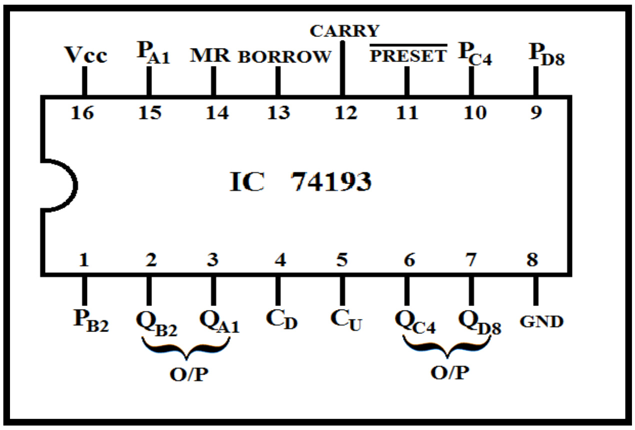


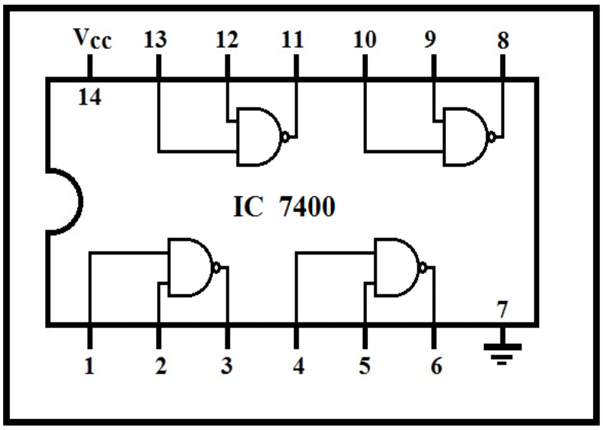

B3 S3 Co Cin GND B0 A0 S0
16 15 14 13 12 11 10 9
IC 7483
1 2 3 4 5 6 7 8
A3 S2 A2 B2 Vcc S1 B1 A1

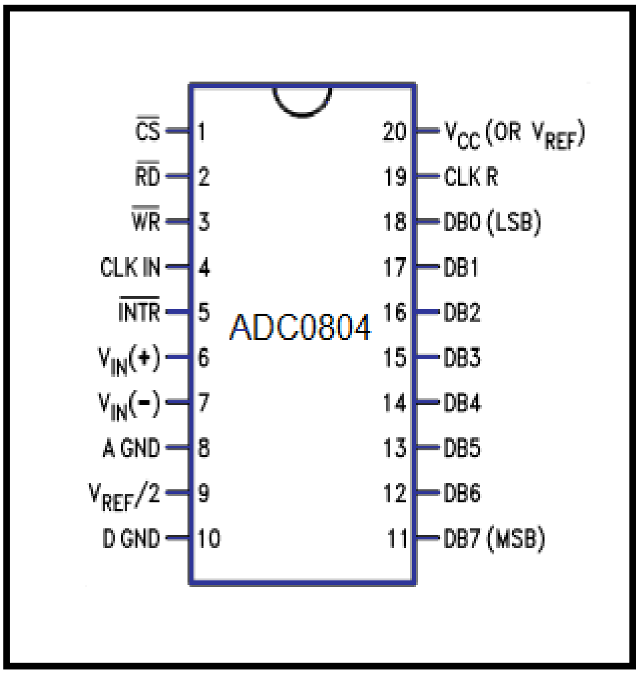

Vcc 13 12 11 10 9 8
14
IC 7486
7
1 2 3 4 5 6

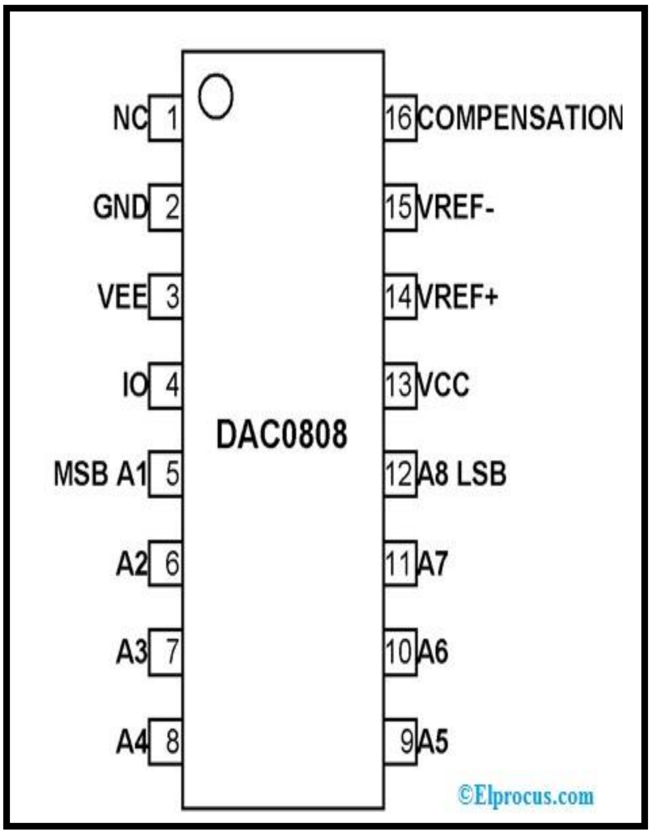

VCC D4 D5 D6 D7 A B C
16 15 14 13 12 11 10 9
IC 74151
1 2 3 4 5 6 7 8
D3 D2 D1 D0 Y Ȳ E GND


Outputs
Vcc QA QB QC QD
CLK1 R-Shift
CLK2 L-Shift/Load
14 13 12 11 10 9 8
IC 7495
1 2 3 4 5 6 7
DS Serial I/P
A B C D
Mode Control
Inputs


Vcc PA1 MR BORROW CARRY PRESET PC4 PD8
16 15 14 13 12 11 10 9
IC 74193
1 2 3 4 5 6 7 8
PB2 QB2 QA1 CD CU QC4 QD8 GND
O/P
O/P


Vcc 13 12 11 10 9 8
14
IC 7400
7
1 2 3 4 5 6


ADC0804
CS
RD
WR
CLK IN
INTR
VIN(+)
VIN(-)
A GND
VREF/2
D GND
VCC (OR VREF)
CLK R
DB0 (LSB)
DB1
DB2
DB3
DB4
DB5
DB6
DB7 (MSB)


DAC0808
NC
GND
VEE
IO
MSB A1
A2
A3
A4
COMPENSATION
VREF-
VREF+
VCC
A8 LSB
A7
A6
A5
©Elprocus.com

ABOUT THE AUTHOR

Dr. Dinesh V Kala, at present, is heading the Department of Physics, at Guru Nanak Khalsa College Autonomous, Matunga, Mumbai, Maharashtra, India.

Having 33 years of teaching experience in various branches of Physics and Electronics at UG and PG.

His field of research, Earthquakes Sensors and Renewable Energy. Under UGC funding, a Unique and Innovative, Green Lab is set up at the department of Physics. He has conducted various Short-Term courses under different central government's funding schemes, like, FIST, STAR, CPE, RUSA etc.

Currently, he is guiding students on Renewable Energy for their Research Program. He has been Invited for various Guest Lectures including the Lectures at Physics Refresher Courses.

Shouldered various important Academic & Administrative responsibilities at College, at Mumbai University, at SNDT University and HSNC University as well.

He has published various Research Papers at National and International Level.

He has authored various books, Precursors to Predictions of Earthquakes and Alarming Systems, Microprocessor 8085: Practical Manual and Solar Based Green Energy Solutions.

InSc Publication House (IPH)

Selfypage Developer's Pvt Ltd.

ISBN 978-81-948317-6-1

9 788194 831761

₹ 350/-