Bangladesh Army University of Engineering & Technology (BAUET)

Qadirabad, Natore 6431, Bangladesh

Department of Information and Communication Engineering (ICE)

Analog Electronics Lab Manual

Course Code	ICE-1221
Course Title	Analog Electronics Sessional
Credit Hours	1.5

Prepared by	Verified By
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Table of Content

ANNEXURE

Verification of the I/O Characteristics of High Pass and Low Pass R-C Filter

General Guideline and Safety Instructions

1. Strictly follow the written and verbal instructions given by the teacher /Lab Instructor. If you do not understand the instructions, the handouts and the procedures, ask the instructor or teacher.
2. Students are required to attend all labs with official dress code and wearing ID card.
3. Mobile phones should be switched off in the lab. Keep bags in the bag shelf.
4. Keep the labs clean at all times, no food and drinks allowed inside the lab.
5. Students should work individually/team in the hardware and software task.
6. Students have to bring the lab manual cum lab report file along with them whenever they come for lab work.
7. Should take only the lab manual, calculator (if needed) and a pen or pencil to the work area.
8. Should utilize 3 hour‟s time properly to perform the experiment and to record the readings. Do the calculations, draw the graphs and take signature from the instructor.
9. If the experiment is not completed in the stipulated time, the pending work has to be carried out in the leisure hours or extended hours.
10. Intentional misconduct will lead to expulsion from the lab.
11. Do not handle any equipment without reading the safety instructions. Read the handout and procedures in the Lab Manual before starting the experiments.
12. Do your wiring, setup, and a careful circuit checkout before applying power. Do not make circuit changes or perform any wiring when power is on.
13. Avoid contact with energized electrical circuits.
14. Do not insert connectors forcefully into the sockets.
15. **NEVER** try to experiment with the power from the wall plug.
16. Immediately report dangerous or exceptional conditions to the Lab instructor / teacher: Equipment that is not working as expected, wires or connectors are broken, the equipment that smells or "smokes". If you are not sure what the problem is or what's going on, switch off the Emergency shutdown.
17. Never use damaged instruments, wires or connectors. Hand over these parts to the Lab instructor/Teacher.
18. After completion of Experiment, return the bread board, trainer kits, wires, oscilloscope probes and other components to lab staff. Do not take any item from the lab without permission.
19. Handling of Semiconductor Components: Sensitive electronic circuits and electronic components have to be handled with great care. The inappropriate handling of electronic component can damage or destroy the devices. The devices can be destroyed by driving to high currents through the device, by overheating the device, by mixing up the polarity, or by electrostatic discharge (ESD). Therefore, always handle the electronic devices as indicated by the handout, the specifications in the data sheet or other documentation.
20. Special Precautions during soldering practice

a. Hold the soldering iron away from your body. Don't point the iron towards you.
b. Don't use a spread solder on the board as it may cause short circuit.
c. Do not overheat the components as excess heat may damage the components/board.
d. In case of burn or injury seek first aid available in the lab or at the college dispensary.

Course Description

Analog Electronics is the base of Electronics & Communication stream. Thus this course develops a basic understanding of the fundamentals and principles of analog circuits and electronic devices. This understanding is a critical step towards being able to design new electronic circuits or use them appropriately as part of a larger engineering system. Hence the course seeks to develop foundational concepts on design hardware implementation and software simulation of various types of amplifiers, filter circuits, feedback and oscillation circuits.

Course Objective:

1. To gather hands-on experience about various analog electronics circuits.
2. To develop technical hands on how to design, implement and test various types of electronics circuits.
3. To mature the skill of using various modern tools such as oscilloscope, function generator, digital multimeter, power supply, simulation software etc.
4. To translate the theoretical knowledge of analog electronics circuit in practical environment.

Statement of Course Outcomes (CO):

Upon completion of all sessional, the students will be able to:

1. Apply information and knowledge of analog electronics device to demonstrate and analyze the characteristics of circuit.
2. Design and develop solution for different components of complex engineering problem related to analog electronics circuit.
3. Analysis and Interpretation of collected data to provide valid conclusion acknowledging the limitations.
4. Function as effective team leader/member in multi-disciplinary problems.
5. Select and apply appropriate techniques and modern engineering tools to develop a systematic approach to analyze fundamentals of analog signals, analog devices and amplifiers with an understanding of the associated limitations.

Assessment of Course Outcomes (CO):

CO	PO	Bloom's Taxonomy Level	KP	CP	CA	Delivery methods and activities	Assessment Tools
CO1	PO1	C2, C3, C4	KP1			Lecture, Lab Manual, and Demonstration	Lab Quiz, Lab Viva
CO2	PO3	C3		CP1 CP3 CP7		Lab Manual, Demonstration	Lab Performance/Lab Test
CO3	PO4	C4				Lab Manual, Demonstration	Lab Report, Lab Test
CO4	PO9	A2				Consultation with course teachers	Project Performance, Presentation
CO5	PO5	C3		CP1 CP2 CP6		Lecture, Laboratory experiment and Data Collection & Calculations	Designing, Simulation, and Hardware Implementation

Assessment Criteria and Marks Distribution

Si. No.	Particulars	Marks
1	Lab Performance	10
2	Lab Reports	20
3	Lab Test	20
4	Quiz Test	20
5	Mini Lab Project	20
6	Lab Viva	10
Total		100

Format of Lab Report

All lab reports should have to follow the common format as below

- Experiment No
- Experiment Title
- Objectives
- Theory Overview (with formula/equations and/or figure if required)
- Circuit diagram (with adequate labeling and figure caption)
- Results

- Discussion
- Conclusion

Instruction for Lab Report Writing

- Lab report must be hand written without copying from other works.
- Writing should be neat and clean with proper caption and labeling in figure and table.
- The title page of report should contain all the basic information such as experiment no & title, course code & title, student's information, teacher's information, experiment date, submission date.
- Result should include calculated and/or simulated and/or measured data with proper unit.
- Table and/or graph of result should be neat and clear with axis label and units where applicable.
- The discussion should present your findings from the experiment. Evaluate the outcome objectively, taking a candid and unbiased point of view. Suppose that the outcome is not close to what you expected. Even then, after checking your results, give reasons why you believe that outcome is not consistent with the expected.
- In discussion, state the discrepancies between the experimental results and the model (theory), and discuss the sources of the differences in terms of the errors by offering logical inferences and suggest improvements.
- Conclusion should present, a brief summary of what was done, how it was done, show the results and conclusions of the experiment.
- Report should be submitted timely, late submission will cause reduction of marking.
- All lab reports have to be maintained in a single file which has to bring in every laboratory class.

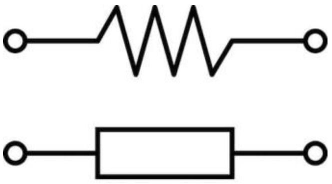
Mini Lab Project

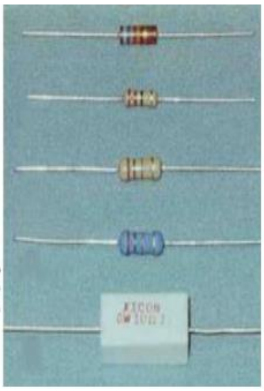
All students have to do a mini lab project under this sessional course. The project will be in different group with the number of group members assigned by course teacher. The project will be accessed by course teacher in three criteria: 1) project show, 2) project presentation, and 3) project report.

1. Resistor

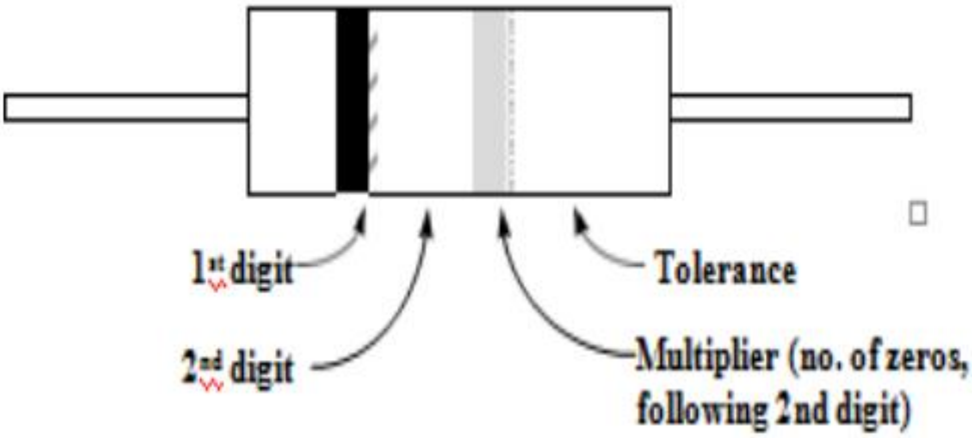
Resistor (R) is an electronic component whose function is to limit the flow of current in an electric circuit. It is measured in units called ohms. The symbol for ohm is Ω(omega). They are available in different values, shapes and sizes. Every material has some resistance. Some materials such as Rubber, Glass and air have very high opposition to current to flow .These materials are called insulators. Other materials such as Copper, Silver and Aluminum etc, has very low resistance, they are called Conductors.

Symbol:





Resistor Colour Codes



Colour-code bands on a resistor

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

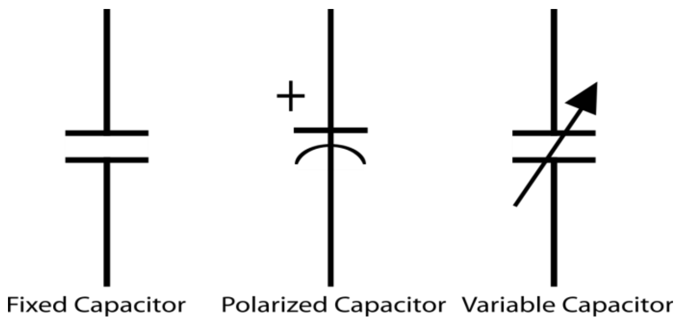
Applications:

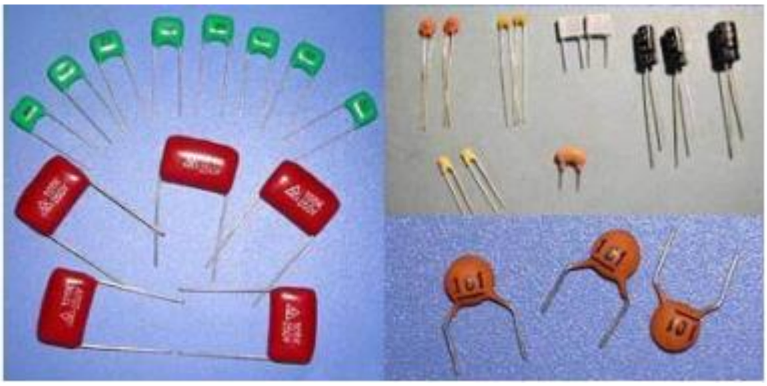
It is widely used in electronic circuits to limit the current

2. Capacitor

A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store energy electrostatically in an electric field. By contrast, batteries store energy via chemical reactions. The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric (insulator); for example, one common construction consists of metal foils separated by a thin layer of insulating film. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Capacitors are also very commonly used. A lot have their values printed on them, some are marked with 3-digit codes, and a few are color coded. The same resources listed above for resistors can also help you identify capacitor values. They are typically marked with an “C” on a circuit board.

Symbol:



Applications:

1. In tuned circuits.
2. As bypass capacitors to by pass ac through it.
3. Blocking capacitor to block dc components.

3. <u>Potentiometers</u>

The variable resistors are usually called Rheostats and the smaller variable resistors commonly used in electronic circuits are called potentiometers called pot.

Symbol:

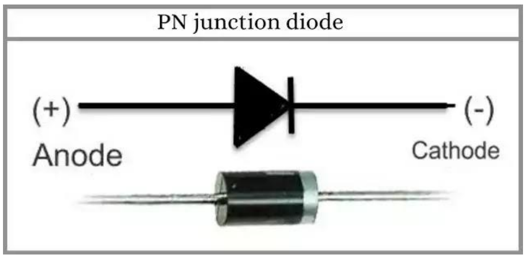
The arrow indicates a movable contact on a continuous resistance element. A potentiometer can be either linear or non-linear.

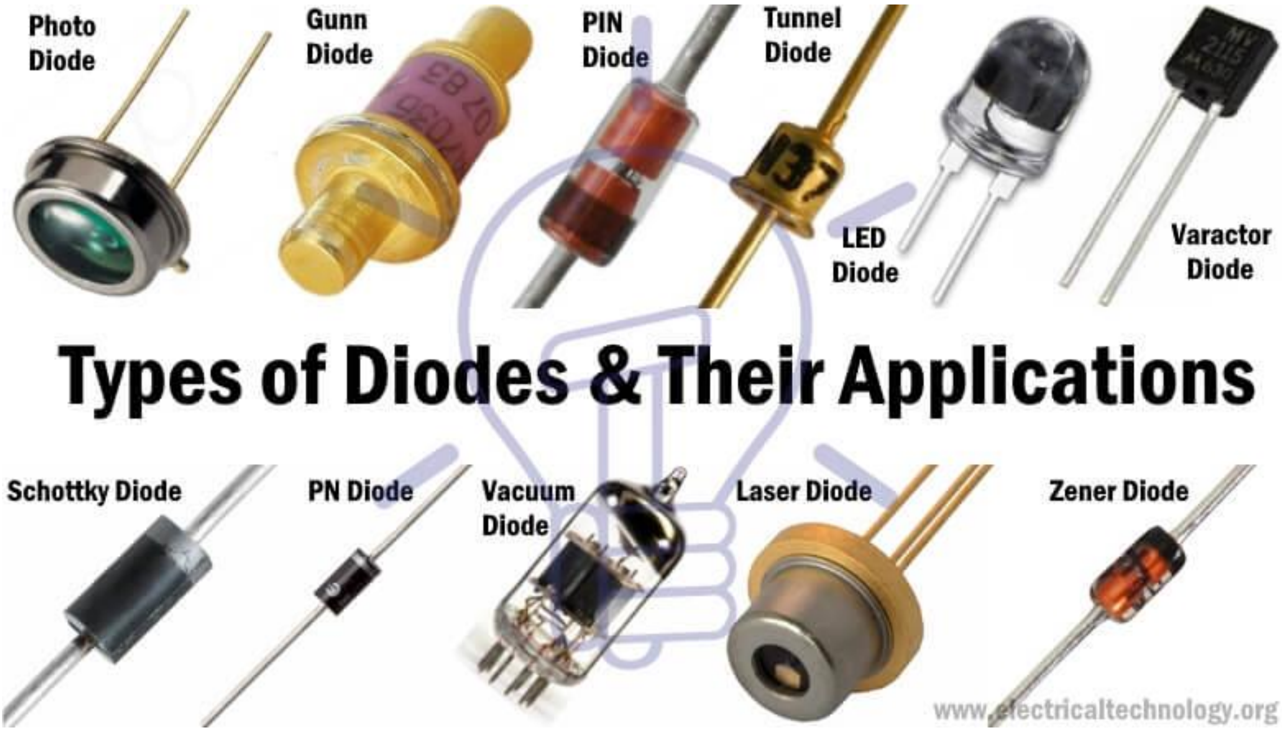
Applications:

Pots are used to change the volume of sound and brightness of picture.

4. <u>Diode</u>

A popular semiconductor device called a diode is made by combining P & N type semiconductor materials. The doped regions meet to form a P-N junction. Diodes are unidirectional devices that allow current to flow through them in one direction only. The schematic symbol for a semiconductor diode is shown in fig-1. The P-side of the diode is called the anode (A), while the N-side of the diode is called the cathode (K).





Diode specifications:

Breakdown voltage rating VBR

The Breakdown voltage rating VBR is the voltage at which avalanche occurs. This rating can be designed by any of the following: Peak Inverse Voltage (PIV); Peak Reverse Voltage (PRV); Break down voltage rating VBR

Average forward – current rating, IF

This important rating indicates the maximum allowable average current that the diode can handle safely, the average forward current rating is usually designated as IF Maximum reverse current, IR1N4007 silicon diode specifies a typical IR of 0.05 A for a diode junction.

Temperature TJ of 250C and a reverse voltage VR of 100 V.

The maximum rating of a diode should never be exceeded.

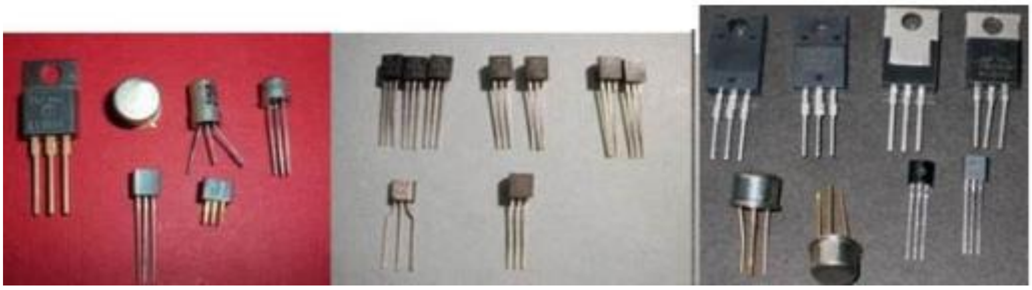
Testing of diode:

Using an ohmmeter to check a diode: when using an ohm meter, check the resistance of the diode in one direction, then reverse the meter leads and measure the resistance of the diode in the other direction. If the diode is good it should measure a very high resistance in one direction, and a low resistance in the other direction. For a silicon diode the ratio of reverse resistance RR , to forward resistance RF should be very large, such as 1000:1 or more. Note: If the diode is shorted it will measure a low resistance in both the directions. If the diode is open, it will measure a high resistance in both the directions. Using a DMM to check a diode: Most digital multimeters provide a special range for testing the diodes. This range is called the diode range. This is the only range setting on the DMM that can provide the proper amount of forward bias for the diode being tested. It is important to note that when the digital multimeter forward biases the diode being tested, the digital display will indicate the forward voltage dropped across the diode rather that the forward resistance, RF.

APPLICATIONS:

- Rectifiers, Clippers and Clampers.
- Signal detector.
- Digital logic gates.

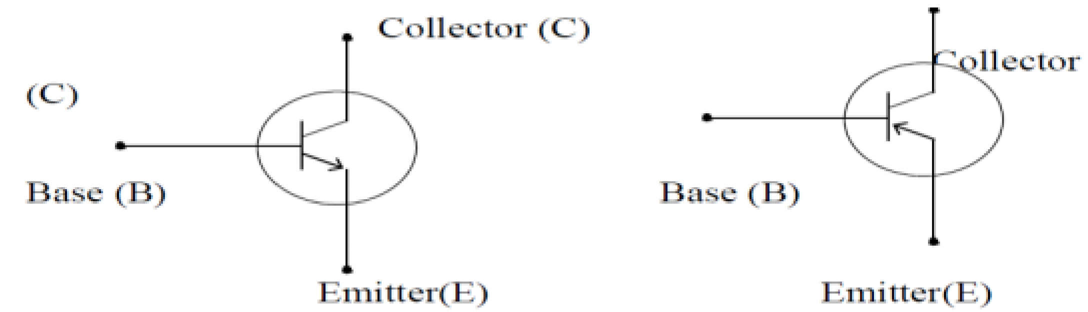
5. <u>Bipolar Junction Transistor (BJT):</u>



A transistor has three doped regions there are two types of transistors one is npn and other is pnp. Notice that for both types, the base is narrow region sandwiched between the larger collector and moderate emitter regions.

In npn transistors, the majority current carriers are free electrons in the emitter and collector, while the majority current carriers are holes in the base. The opposite is true in the pnp transistor where the majority current carriers are holes in the emitter and collector, and the majority current carriers are free electrons in the base.

1. Emitter 2. Base 3. Collector



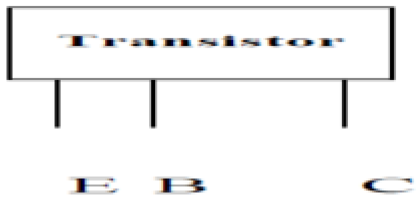
Schematic symbols for transistors (a) npn transistor (b) pnp transistor.

In order for a transistor to function properly as an amplifier, the emitter-base junction must be forward biased and the collector base junctions must be reverse biased.

Transistor lead Identification:

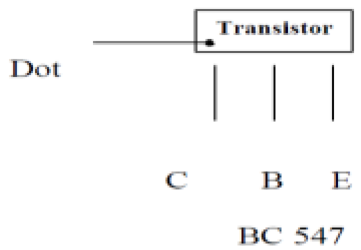
There are three leads in a Transistor called collector, emitter and base. When a transistor is to be connected in a circuit it is necessary to identify the leads of transistor before connecting in a circuit. The identification of the leads of transistor varies with manufacturer.

There are three systems in general.

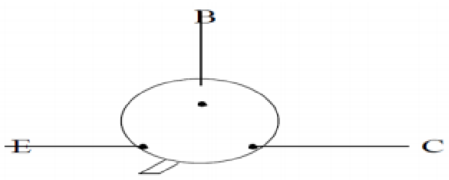


When the lead of a transistor is in the same plane and unevenly as in above fig., they are identified by the position and spacing of leads. The central lead is the base lead. The collector lead is identified by the large spacing existing between it and the base lead. The remaining is the emitter.

When the leads of a transistor are in the same plane but evenly spaced, the central lead is the base, the lead identified by dot is the collector and the remaining lead is the emitter.



When the leads of a transistor are spaced around the circumference of a circle, the three leads are generally in E-B-C order clockwise from a notch.



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SPECIFICATIONS:

In all cases, the maximum ratings are given for collector-base voltage, collector emitter voltage, emitter base voltage, collector current and power dissipation.

Power dissipation rating Pd (Max):

The product of V_{CE} and I_C gives the power dissipation, Pd of the transistor. The product of V_{CE} x I_C must not exceed the maximum power dissipation rating, Pd (Max) of the transistor is nearly 1Watt.

Derating factor:

Manufacturers usually supply derating factors for determining the power dissipation rating at any temperature above 25^0C. The derating factor is specified in Watt/^{0}C. For example if a transistor has a derating factor of 2 mW/^{0}C, then for each 10^oC rise in junction temperature the power rating of the transistor is reduced by 2 mW.

Breakdown voltage ratings;

A data sheet lists the breakdown voltage ratings for the emitter- base, collector-base, and collector-emitter junctions. Exceeding these voltage ratings can destroy the transistor.

BVCBO is 60V, BVCEO is 40V and BVEBO is 6V.

Testing of BJTs:

Checking a transistor with an ohmmeter:

To check the base-emitter junction of an npn transistor, first connect the ohmmeter and then reverse the ohmmeter leads. The resistance indicated by the ohmmeter should be low since the base emitter junction is forward biased. The resistance indicated by the ohmmeter should read high because the base emitter junction is reverse biased. For a good pn junction made of silicon the ration RR/RF should be equal to or greater than 1000:1. To check the collector-base junction, repeat the process described for the base-emitter junction.

Shorted and open junctions:

A low resistance across the junction in both directions implies that the emitter-base or collector-base junctions are shorted. If the ohmmeter indicates a high resistance in both directions, then the junctions are open. In both cases the transistor is defective and must be replace.

Checking a transistor with a Digital Multimeter (DMM):

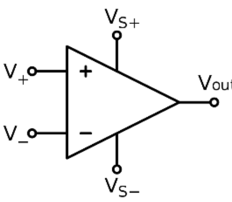
Insert the transistor in the provided slots, position the knob of DMM in hFE mode and check the hFE value.

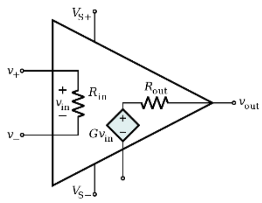
Applications:

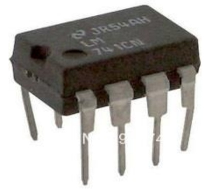
- Amplifiers.
- Oscillators.
- Switches.

6. <u>Operational Amplifier</u>

An operational amplifier (often op amp or opamp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op amp produces an output potential (relative to circuit ground) that is typically 100,000 times larger than the potential difference between its input terminals. Operational amplifiers had their origins in analog computers, where they were used to perform mathematical operations in linear, non-linear, and frequency-dependent circuits.

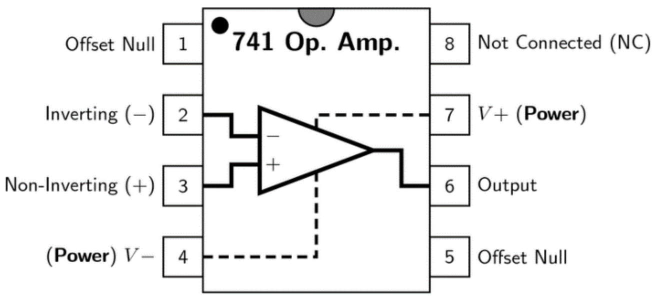


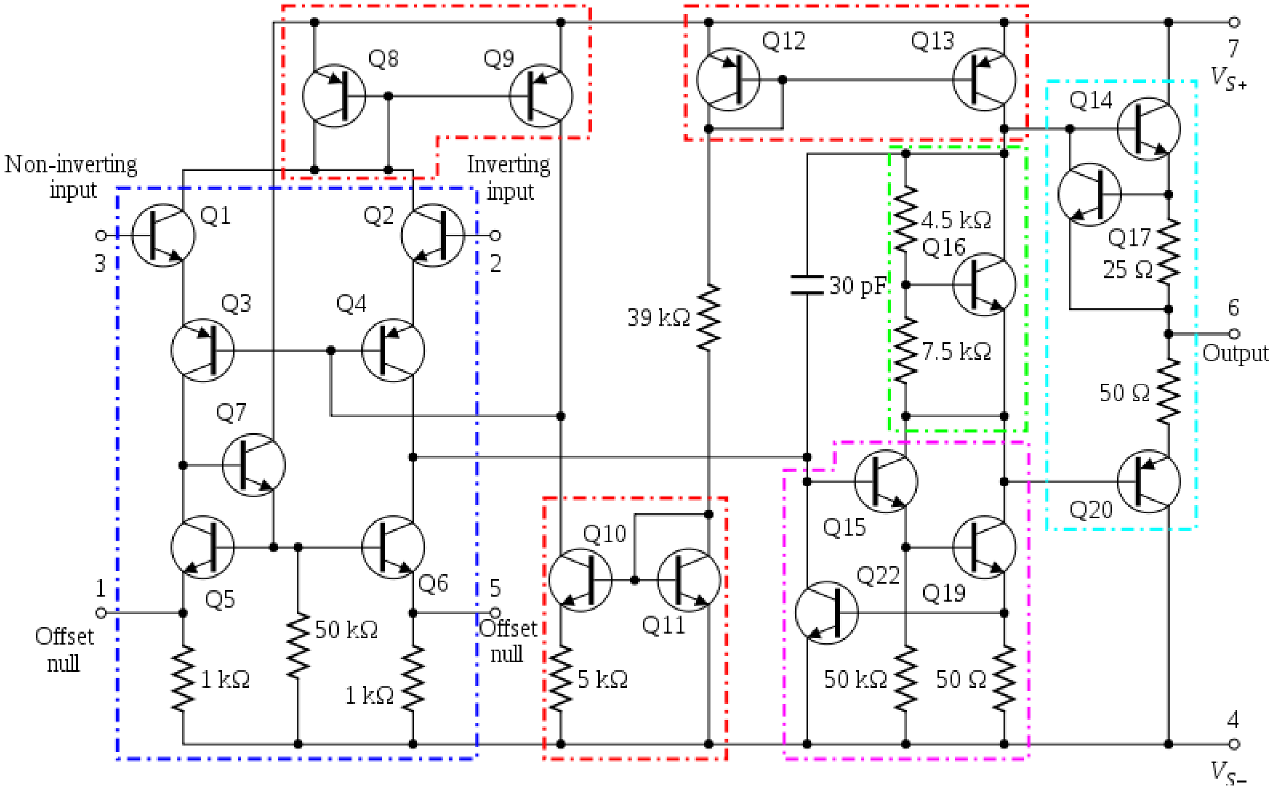




Symbol Equivalent circuit IC

Pin Configuration of Op Amp IC 741





A component-level diagram of the common 741 op amp

7. <u>Digital Multimeter (DMM)</u>

A Multimeter is an electronic device that is used to make various electrical measurements, such as AC and DC voltage, AC and DC current, and resistance. It is called a Multimeter because it combines the functions of a voltmeter, ammeter, and ohmmeter. Multimeter may also have other functions, such as diode test, continuity test, transistor test, TTL logic test and frequency test.

Parts of Multimeter

A Multimeter has three parts:

- Display
- Selection Knob
- Ports

The display usually has four digits and the ability to display a negative sign. A few multimeters have illuminated displays for better viewing in low light situations.

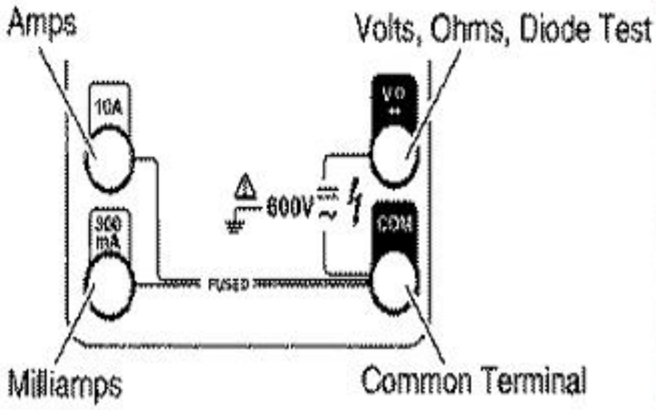
The selection knob allows the user to set the multimeter to read different things such as milliamps (mA) of current, voltage (V) and resistance (Ω). Two probes are plugged into two of the ports on the front of the unit. COM stands for common and is almost always connected to Ground or „-‟ of a circuit. The COM probe is conventionally black but there is no difference between the red probe and black probe other than color. 10A is the special port used when measuring large currents (greater than 200mA). mAVΩ is the port that the red probe is conventionally plugged in to. This port allows the measurement of current (up to 200mA), voltage (V), and resistance (Ω). The probes have a banana type connector on the end that plugs into the multimeter. Any probe with a banana plug will work with this meter.

Safety Measures

- Be sure the test leads and rotary switch are in the correct position for the desired measurement.
- Never use the meter if the meter or the test leads look damaged.
- Never measure resistance in a circuit when power is applied.
- Never touch the probes to a voltage source when a test lead is plugged into the 10 A or 300 mA input jack.
- To avoid damage or injury, never use the meter on circuits that exceed 4800 watts.
- Never apply more than the rated voltage between any input jack and earth ground.
- Be careful when working with voltages above 60 V DC or 30 V AC rms. Such voltages pose a shock hazard.
- Keep your fingers behind the finger guards on the test probes when making measurements.
- To avoid false readings, which could lead to possible electric shock or personal injury, replace the battery as soon as the battery indicator appears.

Input Jacks

The black lead is always plugged into the common terminal. The red lead is plugged into the 10 A jack when measuring currents greater than 300 mA, the 300 mA jack when measuring currents less than 300 mA, and the remaining jack (V-ohms-diode) for all other measurements.



Range Fixing

The meter defaults to auto range when first turned on. You can choose a manual range in V AC, V DC, A AC, and A DC by pressing the button in the middle of the rotary dial. To return to autorange, press the button for one second.

Procedure For Measurement Voltage Measurement

A.C. Voltage Measurment

1. Connect the positive(red) test lead to the „V/mA‟ jack socket and the negative(black) lead to the „COM‟ jack socket.

2. Set the selector switch to the desired mV D.C./D.C.V/A.C.V range.

3. Connect the test leads to the circuit to be measured.

4. Turn on the power to the circuit to be measured, the voltage value should appear on the digital display along with the voltage polarity(if reversed only).

Current Measurement

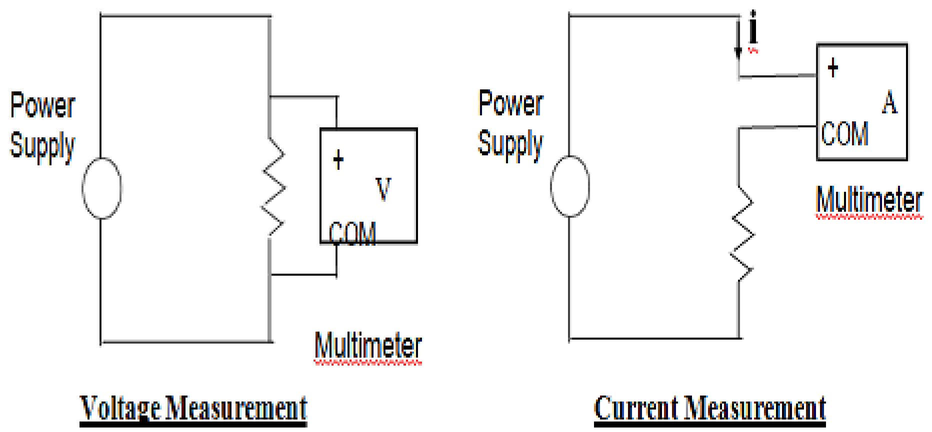
1. Connect the positive(red) test lead to the „V/mA‟ jack socket and the negative(black) lead to the „COM‟ jack socket(for measurements up to 200mA). For measurements between 200mA and 10A connect the red test lead to the „10mA‟ socket.

2. Set the selector switch to the desired uA/mA/A range.

3. Open the circuit to be measured and connect the test leads in SERIES with the load in which current is to be measured.

4. To avoid blowing an input fuse, use the 10A jack until you are sure that the current is less than 300 mA. Turn off power to the circuit. Break the circuit. (For circuits of more than 10 amps, use a current clamp.) Put the meter in series with the circuit and turn power on.

Connection Methods to Measure Voltage and Current



Resistance Measurement

1. Connect the positive (red) test lead to the "V/mA" jack socket and the negative(black) lead to the "COM" jack socket.

2. Set the selector switch to the desired "OHM Ω".

3. If the resistance to be measured ia part of a circuit, turn off the power and discharge all capacitors before measurement.

4. Connect the test leads to the circuit to be measured.

5. The resistance value should now appear on the digital display.

6. If the resistance to be measured is part of a circuit, turn off the power and discharge all capacitors before measurement.

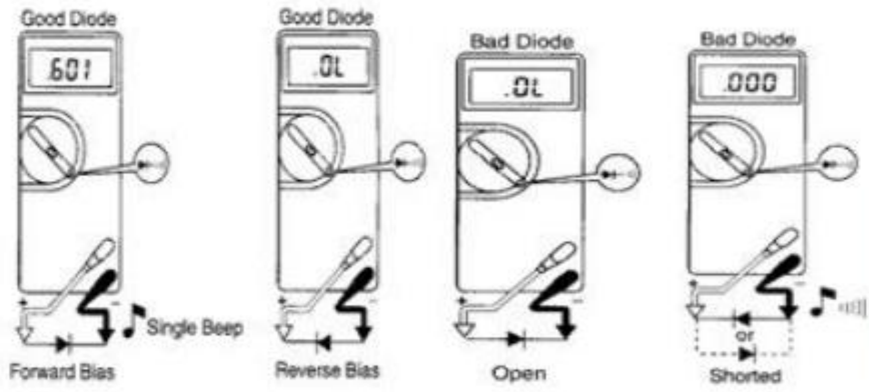
Diode Test

1. Connect the positive (red) test lead to the „V/mA" jack socket and the negative (black) lead to the "COM" jack socket.

2. Set the selector switch to the "diode" position

3. Connect the test leads to be measured.

4. Turn on the power to the circuit to be measured and the voltage value should appear on the digital display.

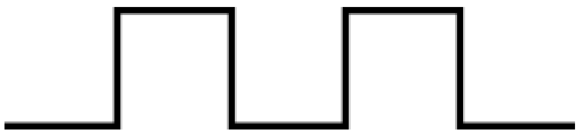


8. <u>Function Generator</u>

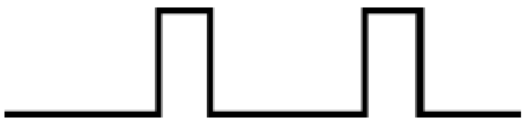
A function generator is electronic test equipment used to generate different types of waveforms over a wide range of frequencies. Function generators are capable of producing a variety of repetitive waveforms, generally from the list below

- ***Sine wave:*** A function generator will normally have the capability to produce a standard sine wave output. This is the standard waveform that oscillates between two levels with a standard sinusoidal shape.

- ***Square wave:*** A square wave is normally relatively easy for a function generator to produce. It consists of a signal moving directly between high and low levels.



- ***Pulse:*** A pulse waveform is another type that can be produced by a function generator. It is effectively the same as a square wave, but with the mark space ratio very different to 1:1.



- ***Triangular wave:*** This form of signal produced by the function generator linearly moves between a high and low point.

- ***Saw tooth wave:*** Again, this is a triangular waveform, but with the rise edge of the waveform faster or slower than the fall, making a form of shape similar to a saw tooth.

These waveforms can be either repetitive or single-shot Function generators are used in the development, test and repair of electronic equipment.

9. <u>Variable Power Supply</u>

A power supply is a device that supplies electric power to an electrical load. The term is most commonly applied to electric power converters that convert one form of electrical energy to another, though it may also refer to devices that convert another form of energy (mechanical, chemical, solar) to electrical energy. A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source.

A power supply may be implemented as a discrete, stand-alone device or as an integral device that is hardwired to its load. Examples of the latter case include the low voltage DC power supplies that are part of desktop computers and consumer electronics devices.

Commonly specified power supply attributes include:

- The amount of voltage and current it can supply to its load.
- How stable its output voltage or current is under varying line and load conditions.

Power Supplies Types

1. Battery
2. DC power supply
3. AC power supply
4. Linear regulated power supply
5. Switched mode power supply
6. Programmable power supply
7. Uninterruptible power supply
8. High voltage power supply
9. Voltage multipliers

Dc Power Supply Specification

a. Adjustable 0~30V/0~2A
b. The design is limit the voltage overload
c. The power supply input 220V, 230V, 240V AC
d. Output voltage: 0-30V DC
e. Work temperature: -10oC-40oC

Main Function

1. Output constant current adjustable.
2. Output constant voltage adjustable.
3. LCD voltage and current display.
4. Constant voltage and current operation in individual.
5. Over current protection.

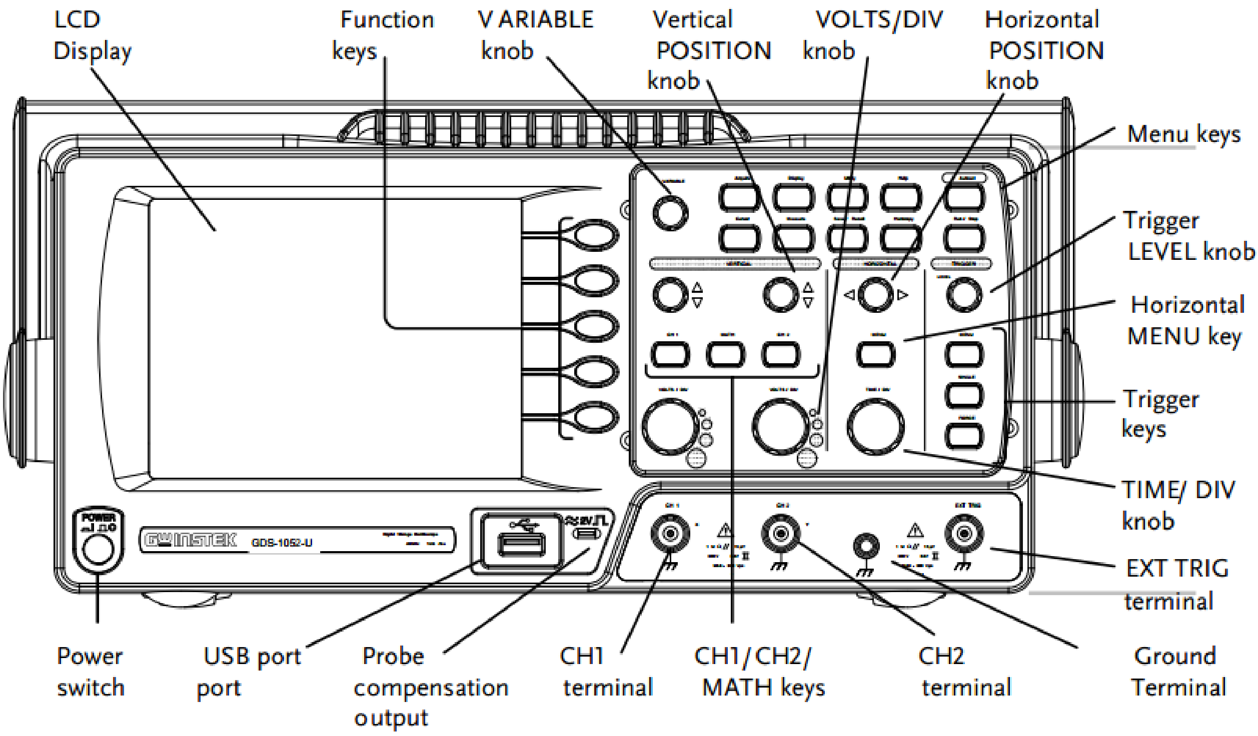
Adjustable power supply

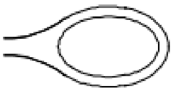
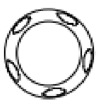
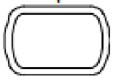
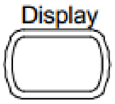
10.<u>Oscilloscope</u>

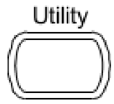
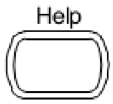
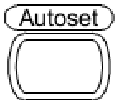
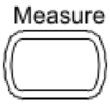
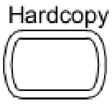
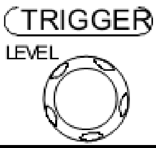
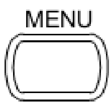
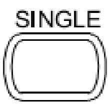
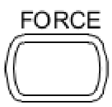
An oscilloscope, previously called an oscillograph, and informally known as a scope or o-scope, CRO (for cathode-ray oscilloscope), or DSO (for the more modern digital storage oscilloscope), is a type of electronic test instrument that graphically displays varying signal voltages, usually as a calibrated two-dimensional plot of one or more signals as a function of time. The displayed waveform can then be analyzed for properties such as amplitude, frequency, rise time, time interval, distortion, and others. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument. Modern digital instruments may calculate and display these properties directly.

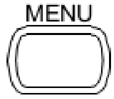
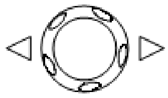
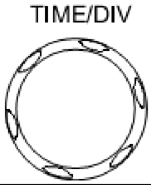
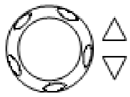
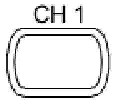
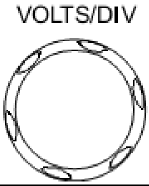
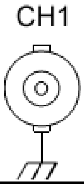
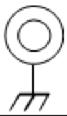
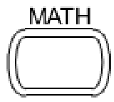
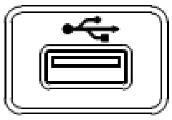
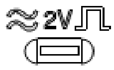
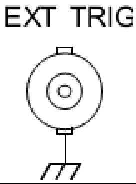
Panel Overview

Front Panel

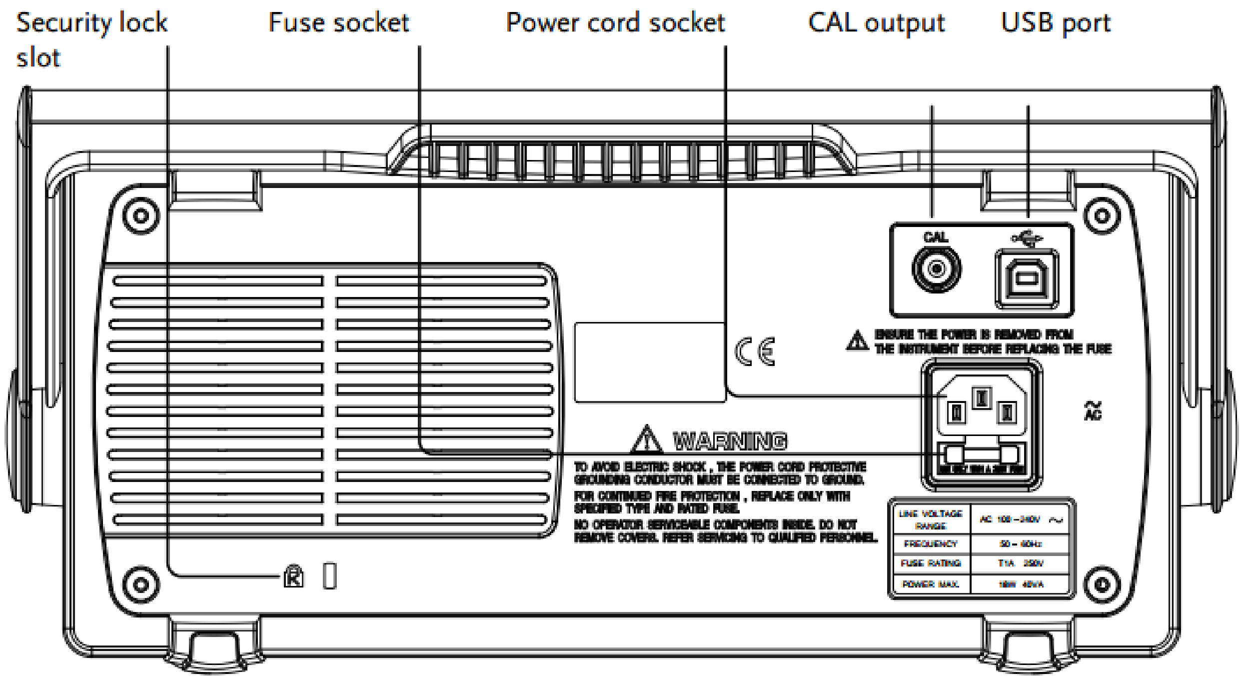


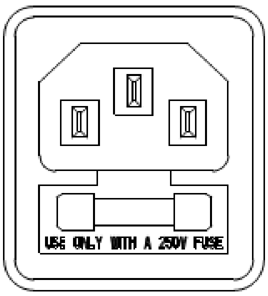
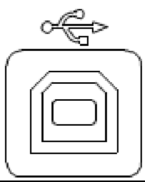
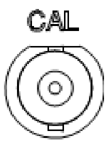
LCD display	TFT color, 320 x 234 resolution, wide angle view LCD display.	
Function keys: F1 (top) to F5 (bottom)		Activates the functions which appear in the left side of the LCD display.
Variable knob	VARIABLE 	Increases or decreases values and moves to the next or previous parameter.
Acquire key	Acquire 	Configures the acquisition mode (page 71).
Display key	Display 	Configures the display settings (page 75).
Cursor key	Cursor 	Runs cursor measurements (page 54).

Utility key		Configures the Hardcopy function (page 100), shows the system status (page 93), selects the menu language (page 93), runs the self calibration (page 115), configures the probe compensation signal (page 116), and selects the USB host type (page 92).
Help key		Shows the Help contents on the display (page 43).
Autoset key		Automatically configures the horizontal, vertical, and trigger settings according to the input signal (page 45).
Measure key		Configures and runs automatic measurements (page 51).
Save/Recall key		Saves and recalls images, waveforms, or panel settings (page 95).
Hardcopy key		Stores images, waveforms, or panel settings to USB (page 100).
Run/Stop key		Runs or stops triggering (page 46).
Trigger level knob		Sets the trigger level (page 84).
Trigger menu key		Configures the trigger settings (page 84).
Single trigger key		Selects the single triggering mode (page 90).
Trigger force key		Acquires the input signal once regardless of the trigger condition at the time (page 90).

Horizontal menu key		Configures the horizontal view (page 77).
Horizontal position knob		Moves the waveform horizontally (page 77).
TIME/DIV knob		Selects the horizontal scale (page 77).
Vertical position knob		Moves the waveform vertically (page 81).
CH1/CH2 key		Configures the vertical scale and coupling mode for each channel (page 81).
VOLTS/DIV knob		Selects the vertical scale (page 81).
Input terminal		Accepts input signals: 1MΩ±2% input impedance, BNC terminal.
Ground terminal		Accepts the DUT ground lead to achieve a common ground.
MATH key		Performs math operations (page 57).
USB port		Facilitates transferring waveform data, display images, and panel settings (page 98).
Probe compensation output		Outputs a 2Vp-p, square signal for compensating the probe (page 116) or demonstration.
External trigger input		Accepts an external trigger signal (page 84).

Rear Panel



Power cord socket Fuse socket		Power cord socket accepts the AC mains, 100 ~ 240V, 50/60Hz. The fuse socket holds the AC main fuse, T1A/250V. For the fuse replacement procedure, see page 121.
USB slave port		Accepts a type B (slave) male USB connector for remote control of the oscilloscope (page 92).
Calibration output		Outputs the calibration signal used in vertical scale accuracy calibration (page 115).
Security lock slot		Standard laptop security lock slot for ensuring the security of the GDS-1000-U.

Safety Guidelines

General Guideline ⚠ CAUTION	• Make sure the BNC input voltage does not exceed 300V peak. • Never connect a hazardous live voltage to the ground side of the BNC connectors. It might lead to fire and electric shock.
Operation Environment	• Location: Indoor, no direct sunlight, dust free, almost non-conductive pollution (Note below) • Relative Humidity: ≤ 80%, 40°C or below ≤ 45%, 41°C~50°C • Altitude: < 2000m • Temperature: 0°C to 50°C

Experiment No. 2: Implementation and investigation on Op Amp Comparator

Objective

In this experiment, the performance of a typical op amp will be examined in the open-loop mode. This circuit is often referred to as a comparator. The investigation will include the effect of both DC and AC input signals.

Theory Overview

The open-loop voltage gain of the typical op amp is very high, approaching 100,000 at low frequencies. With such a high gain, even minute differences between the inverting and non-inverting input signals will be magnified to the point of causing saturation. Thus, if the non-inverting input signal exceeds the inverting input signal, the output will be at positive saturation. If the signals are reversed, then negative saturation results. If both inputs are identical, then the output will go to either positive or negative saturation, depending on the internal offsets of the op amp.

Equipment

(1) Oscilloscope model:_________________ srn:___________________

(1) Function generator model:_________________ srn:___________________

(1) Dual DC power supply model:_________________ srn:___________________

(1) DMM model:_________________ srn:___________________

Components

(1) General purpose op amp (741, 351, 411, etc.)

(2) 1µ F actual:___________________

(1) 2k2 Ω actual:___________________

(1) 4k7 Ω actual:___________________

(2) 10k Ω actual:___________________

(1) 15k Ω actual:___________________

(1) 22k Ω actual:___________________

Circuit Diagram

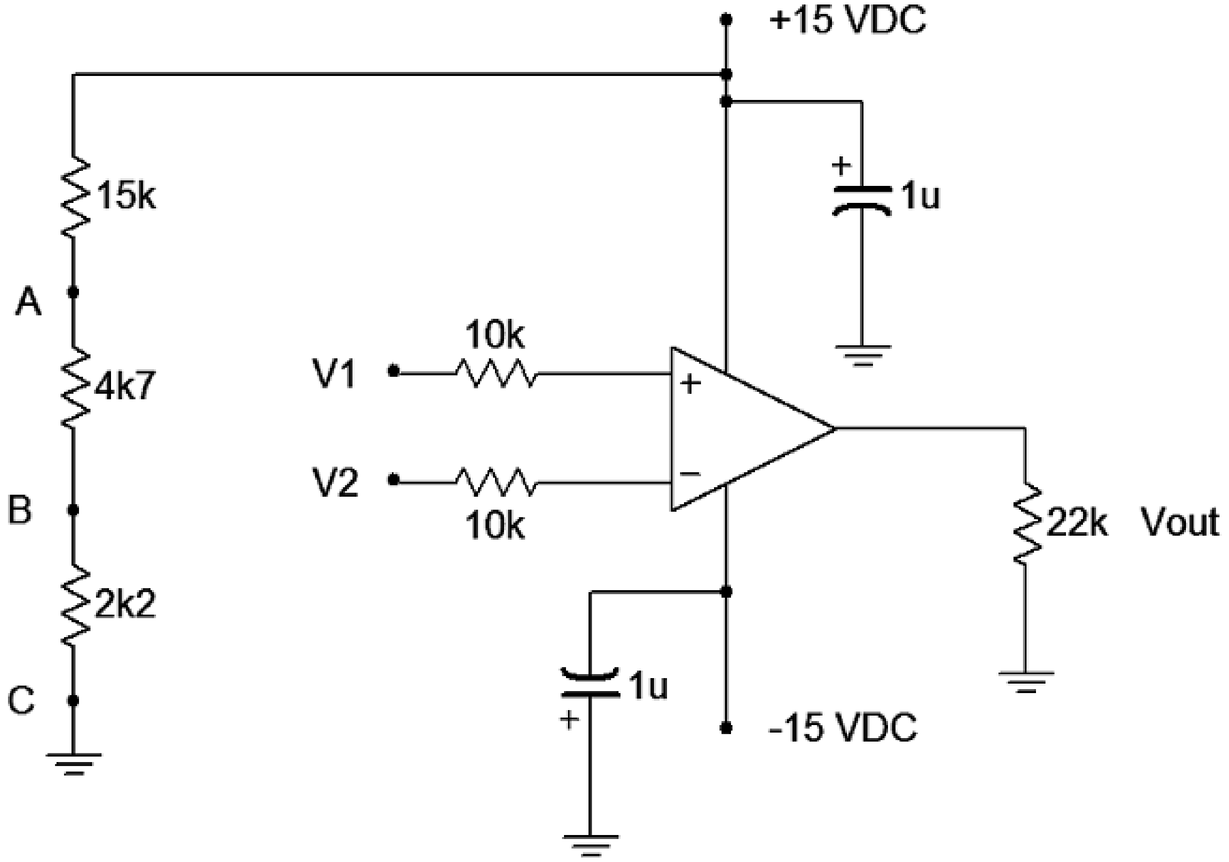


Figure 1.1: Circuit diagram of Op-Amp Comparator

Procedure

1. Calculate the voltages V_A, V_B and V_C at points A, B, and C using the following equation and record them in Table 6.1.

$$V_A = IR = \frac{15V}{(15+4.7+2.2)K\Omega} * (4.7+2.2)K\Omega$$

$$V_B = IR = \frac{15V}{(15+4.7+2.2)K\Omega} * 2.2K\Omega$$

$$V_A = IR = \frac{15V}{(15+4.7+2.2)K\Omega} * 0K\Omega$$

2. Assemble the circuit of Figure 1.1.
3. Using the input combinations listed in Table 1.2, apply the appropriate signals to V1 and V2. Measure the output signal using the oscilloscope, and record the values in Table 1.2.

4. Connect V1 to a 10 volt peak-to-peak 1 kHz sine wave. Make sure the oscilloscope inputs are set to DC Coupling, and then connect probe 1 to V1, probe 2 to V2 and probe 3 to V_{out}.
5. Connect V2 to point A. Measure the output voltage and save a copy of the oscilloscope display as Graph 1.
6. Connect V2 to point B. Measure the output voltage and save a copy of the oscilloscope display as Graph 2.
7. Connect V2 to point C. Measure the output voltage and save a copy of the oscilloscope display as Graph 3.

Computer Simulation

8. Build the circuit of Figure 1 in a simulator and run the simulation in transient analysis repeating steps 4 through 7. Compare the results to the waveforms generated experimentally.

Data Table 1.1

Connection Node	Voltage
A	
B	
C	

Data Table 1.2

V_1 (+)	V_2 (-)	V_{out}
A	A	
A	B	
A	C	
B	A	

B	B	
B	C	
C	A	
C	B	
C	C	

Questions

1. What happens when V1> V2? Why?

2. What happens when V1< V2? Why?

3. What happens when V1= V2? Why?

4. Explain the differences in the waveforms recorded in Graphs 1 through 3.

5. How would the waveform displays be altered if the oscilloscope inputs were set to AC Coupling instead of DC Coupling in step 4?

6. How would the results of this exercise change if the op amp had a very low gain, say only 1 or 2?

Experiment No. 3: Implementation and investigation on Opamp Inverting Voltage Amplifier

Objective

In this exercise, the performance of the inverting voltage amplifier will be examined. The investigation will include the effect of feedback resistors on setting voltage gain, stability of gain with differing op amps, and the concept of virtual ground.

Theory Overview

The inverting voltage amplifier is based on parallel-parallel negative feedback. This amplifier exhibits modest input impedance, low output impedance, and stable inverting voltage gain. The voltage gain is set by the two feedback resistors, Ri and Rf.

Equipment

(1) Oscilloscope model:_________________ srn:___________________

(1) Function generator model:_________________ srn:___________________

(1) Dual DC power supply model:_________________ srn:___________________

(1) DMM model:_________________ srn:___________________

Components

(3) General purpose op amps (1 each of 741, 351, 318, 411, etc.)

(2) 1μ F actual:___________________

(1) 1k Ω actual:___________________

(1) 4k7 Ω actual:___________________

(1) 10k Ω actual:___________________

(1) 22k Ω actual:___________________

(1) 33k Ω actual:___________________

(1) 47k Ω actual:___________________

Circuit Diagram

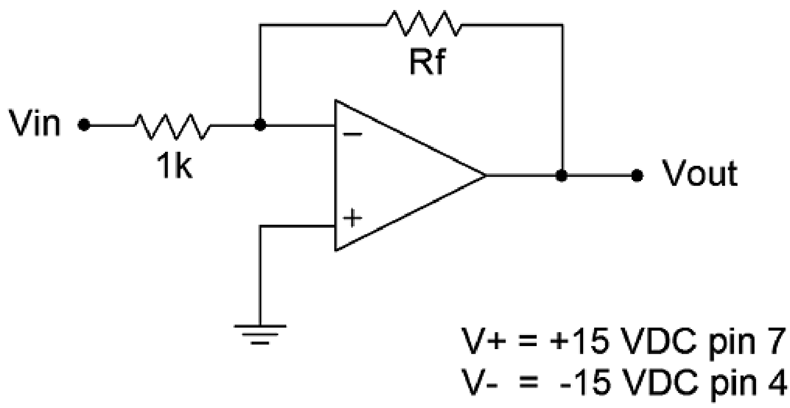


Figure 3.1: Circuit diagram of Opamp inverting voltage amplifier.

Procedure

1. The voltage gain of the inverting amplifier can be determined accurately from the feedback resistors R_{in} and R_f. Calculate the voltage gains for the amplifier of Figure 3.1 for the R_f values specified, and record them in Table 3.1.

   $$\text{Theoritical gain } A_{VT} = -\frac{R_f}{R_{in}}$$

2. Assemble the circuit of Figure 1 using the 4k7 resistor.
3. Set the generator to a 1 kHz sine wave, 100 millivolts peak.
4. Apply the generator to the amplifier. Measure and record the output voltage in Table 3.1, noting its phase relative to the input. Also, compute the resulting experimental voltage gain and gain deviation using the formula given below:

   $$\text{Experimental gain } A_{VE} = \frac{V_{out}}{V_{in}} \quad \text{and} \quad \%\text{ Deviation} = \frac{|A_{VT} - A_{VE}|}{A_{VT}} * 100\%$$

5. Repeat step 4 for the remaining R_f values in Table 3.1.
6. For any given R_{in}, R_f combination, the voltage gain should be stable regardless of the precise op amp used, even if it is of an entirely different model. To verify this, first set R_f to 22kΩ.
7. Set the generator to a 1 kHz sine wave, 100 millivolts peak.
8. Apply the generator to the amplifier. Measure and record the output voltage in Table 3.2. Also, compute the resulting experimental voltage gain and gain deviation.
9. Repeat step 8 for two other op amps.
10. The concept of virtual ground is very important. A virtual ground exists at the inverting input of the op amp in this circuit. Ideally, the voltage at this point should be very close to 0. Through voltage divider effect, this implies that all of the input

signal must be dropping across R_{in}, and thus R_{in} must establish the input impedance of the amplifier.

11. Set Rf to 4k7.
12. Set the generator to a 200 Hz sine wave, 1 volt peak.
13. Apply the generator to the amplifier. Use a DMM to measure and record the AC potential at the inverting terminal of the op amp. Record the value in Table 3.3.

Computer Simulation

14. Build the circuit in a simulator and run a Transient Analysis repeating steps 2 through 5. Compare the results to the waveforms generated experimentally.

15. Repeat step 14 but this time use the Distortion Analyzer instrument to compare voltage gain to THD.

Data Table 3.1

R_f	A_v Theory	V_{out}	Phase	Experimental A_v	% Deviation
4k7 Ω					
10k Ω					
22k Ω					
33k Ω					
47k Ω					

Data Table 3.2

Op Amp	A_v Theory	V_{out}	Experimental A_v	% Deviation
1				
2				
3				

Data Table 3.3

$V_{inverting\text{-}input}$	

Questions

1. What is the effect as Rf is increased?

2. How does the voltage gain vary as the op amp is changed?

3. Does the inverting voltage amplifier exhibit a predictable and stable voltage gain?

4. What can be said about the input impedance of this type of amplifier?

5. Based on the simulation, what is the relationship between gain, feedback and distortion for this circuit?

Experiment No. 4: Implementation and investigation on Op-Amp non-inverting voltage Amplifier

Objective

In this exercise, the performance of the non-inverting voltage amplifier will be examined. The investigation will include the effect of feedback resistors on setting voltage gain, stability of gain with differing op amps, and input impedance.

Theory Overview

The non-inverting voltage amplifier is based on series-parallel negative feedback. As the ideal voltage-controlled voltage source, this amplifier exhibits high input impedance, low output impedance, and stable voltage gain. The voltage gain is set by the two feedback resistors, Ri and Rf.

Equipment

(1) Oscilloscope model:_________________ srn:___________________

(1) Function generator model:_________________ srn:___________________

(1) Dual DC power supply model:_________________ srn:___________________

(1) DMM model:_________________ srn:___________________

For Distortion Measurement Only

(1) Low Distortion Sine Source model:________________ srn:__________________

(1) Distortion Analyzer model:________________ srn:__________________

Components

(3) General purpose op amps (1 each of 741, 351, 318, 411, etc.)

(2) 1µ F actual:___________________ ___________________

(1) 1k Ω actual:___________________

(1) 4k7 Ω actual:___________________

(1) 10k Ω actual:___________________

(1) 22k Ω actual:___________________

(1) 33k Ω actual:___________________

(1) 47k Ω actual:__________________

(1) 100k Ω actual:__________________

Circuit Diagram

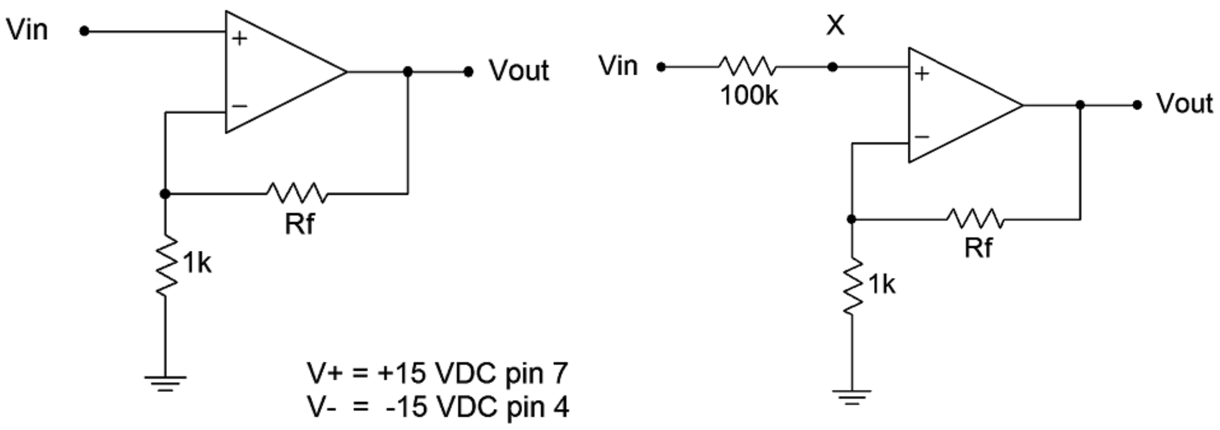


Figure 4.1: Circuit diagram of Opamp non-inverting voltage amplifier.

Procedure

1. The voltage gain of the non-inverting amplifier can be determined accurately from the feedback resistors Ri and Rf. Calculate the voltage gains for the amplifier of Figure 4.1 for the Rf values specified, and record them in Table 4.1.

2. Assemble the circuit of Figure 4.1 using the 4k7Ω resistor.

3. Set the generator to a 1 kHz sine wave, 100 millivolts peak.

4. Apply the generator to the amplifier. Measure and record the output voltage in Table 4.1. Also, compute the resulting experimental voltage gain and gain deviation.

5. Repeat step 4 for the remaining Rf values in Table 4.1.

6. For any given Ri, Rf combination, the voltage gain should be stable regardless of the precise op amp used, even if it is of an entirely different model. To verify this, first set Rf to 22k Ω.

7. Set the generator to a 1 kHz sine wave, 100 millivolts peak.

8. Apply the generator to the amplifier. Measure and record the output voltage in Table 4.2. Also, compute the resulting experimental voltage gain and gain deviation.

9. Repeat step 8 for two other op amps.

10. It is not practical to use an ohmmeter to determine the input impedance of an active circuit. Instead, input impedance can be found by utilizing the voltage divider effect. Modify the circuit by adding the extra input resistor as shown in Figure 4.1 (Right).

11. Set Rf to 4k7 Ω.

12. Set the generator to a 200 Hz sine wave, 1 volt peak.

13. Apply the generator to the amplifier. Use a DMM to measure and record the AC potential from Vin to point X (i.e., VA, the voltage across the 100k) in Table 4.3. Using KVL, determine the voltage from point X to ground (VB) and record in Table 4.3(don't forget to compensate for peak versus RMS readings). Finally, compute the resulting input impedance by using the voltage divider rule. Note: If the DMM is not sensitive enough and registers 0 volts for VA, it is safe to assume that Zin is considerably larger than the 100kΩ sensing resistor.

Distortion Measurement

14. Return to the amplifier of Figure 1 with Rfset to 10k. If available, the LF351 is a good choice for the op amp in this portion. Replace the general-purpose generator with the low distortion sine source set to 1 kHz. Adjust its output level so that the output of the op amp is approximately 0 dBV.

15. Apply the distortion analyzer to the output of the op amp, read the resulting THD percentage and record it in Table 4.

16. Repeat steps 14 and 15 using the remaining Rf values in Table 4.4.

Troubleshooting

17. Continuing with the amplifier of Figure 1, reset Rf to 4k7 Ω. Estimate and then measure the results for each individual error presented in Table 4.5.

Data Table 4.1

R_f	Theoretical A_v	V_{out}	Experimental A_v	% Deviation
4k7 Ω				
10k Ω				
22k Ω				
33k Ω				
47k Ω				

Data Table 4.2

Op Amp	Theoretical A_v	V_{out}	Experimental A_v	% Deviation
1				
2				
3				

Data Table 4.3

V_A	V_B	Z_{in}

Data Table 4.4

R_f	% THD
10k Ω	
22k Ω	
47k Ω	

Data Table 4.5

Error	Quantity	Estimate	Actual
R_i's third band is orange	V_{out}		
f_{in} is 100 Hz	V_{out}		
R_i is swapped with R_f	V_{out}		
+ and – signal input pins swapped	V_{out}		

Questions

1. What is the effect as Rf is increased?

2. How does the voltage gain vary as the op amp is changed?

3. Does the non-inverting voltage amplifier exhibit a predictable and stable voltage gain?

4. What can be said about the input impedance of this type of amplifier?

5. What is the relationship between gain, feedback and distortion?

Experiment No. 5: Implementation and investigation on Op-Amp differential voltage Amplifier

Objective

In this exercise, the performance of an op amp based differential amplifier will be examined. The investigation will include the effects of differential gain and common-mode rejection ratio (CMRR).

Theory Overview

An op amp differential amplifier can be created by combining both a non-inverting voltage amplifier and an inverting voltage amplifier in a single stage. Proper gain matching between the two paths is essential to maximize the common-mode rejection ratio. Differential gain is equal to the gain of the inverting path.

Equipment

(1) Oscilloscope model:________________ srn:__________________

(1) Function generator model:________________ srn:__________________

(1) Dual DC power supply model:________________ srn:__________________

(1) DMM model:________________ srn:__________________

Components

(2) General purpose op amps (741, 351, etc.)

(2) 1 µF actual:__________________ __________________

(2) 10 kΩ actual:__________________ __________________

(1) 15 kΩ actual:__________________

(1) 22 kΩ actual:__________________

(2) 100 kΩ actual:__________________ __________________

(1) 10 kΩ potentiometer

Circuit Diagram

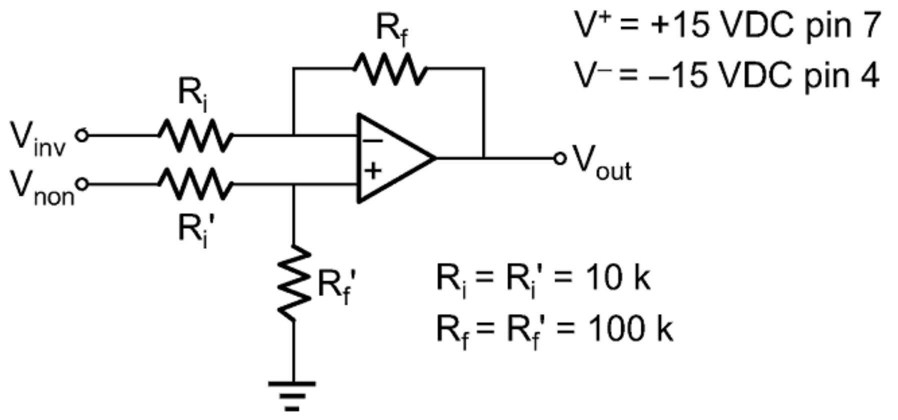


Figure 1

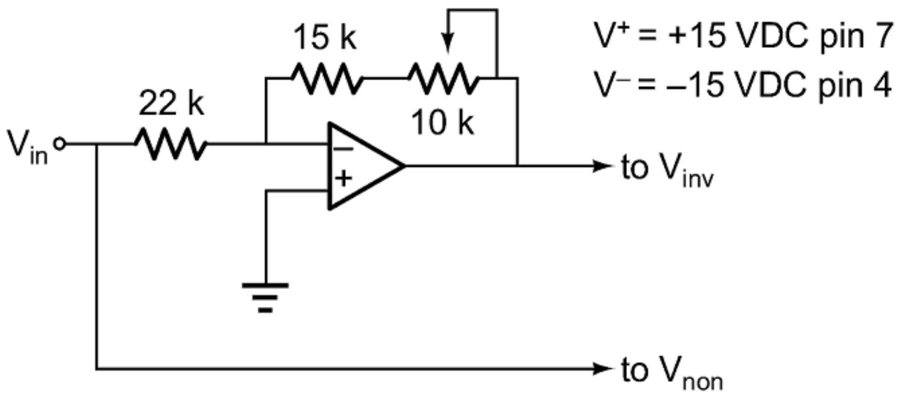


Figure 2

Procedure

1. This circuit can be examined through the use of the Superposition Theorem. The contribution of each input can be measured individually, combined, and then compared with common-mode and differential inputs.

2. Calculate the differential voltage gain for the amplifier and record it in Table 5.1

3. Assemble the circuit of Figure 5.1. Try to get the Ri/Rf ratio as close as possible to the Ri'/Rf' ratio, even if you have to mix and match several resistors.

4. Set the generator to a 1 kHz sine wave, 0.5 volts peak.

5. Apply the generator to the Vinv input, and ground the Vnon input.

6. Measure and record the output voltage in Table 5.2, noting the phase relative to the input. Also, compute the resulting voltage gain.

7. Swap the inputs by connecting the Vnon input to the generator, and grounding the Vinv input.

8. Measure and record the output voltage in Table 5.2, noting the phase relative to the input. Also, compute the resulting voltage gain.

9. Compare the results of step 6 to step 8. The gains should be identical except that one is inverting while the other is non-inverting. Calculate the results of adding the two output signals and place the values in Table 5.3.

10. To measure the common-mode gain, connect both inputs to the generator (removing the Vinv ground). Record the output voltage and resulting gain in Table 5.3.

11. Assemble the circuit of Figure 2. Adjust the potentiometer to set the voltage gain to precisely –1. This circuit is a simple phase-splitter and is used to generate a differential input signal.

12. Connect the circuit of Figure 2 to the original circuit as shown.

13. Measure and record the output voltage in Table 5.3.

14. Based on the results of Table 5.3, compute the experimental common-mode rejection ratio and place it in Table 5.4.

Data Table 5.1

Theoretical Differential Gain	

Data Table 5.2

Input	V_{out}	Phase	A_v
V_{inv}			
V_{non}			

Data Table 5.3

Circuit	V_{out}	A_v
Superposition		
Common-mode		
Differential		

Data Table 5.4

Experimental CMRR	

Questions

1. What controls the differential gain?

2. Why is it important to match the resistor ratios in step 3?

3. Why is it important to set the gain of the phase-splitter to precisely one in step 11?

4. What determines the theoretical maximum CMRR for the op amp differential amplifier?

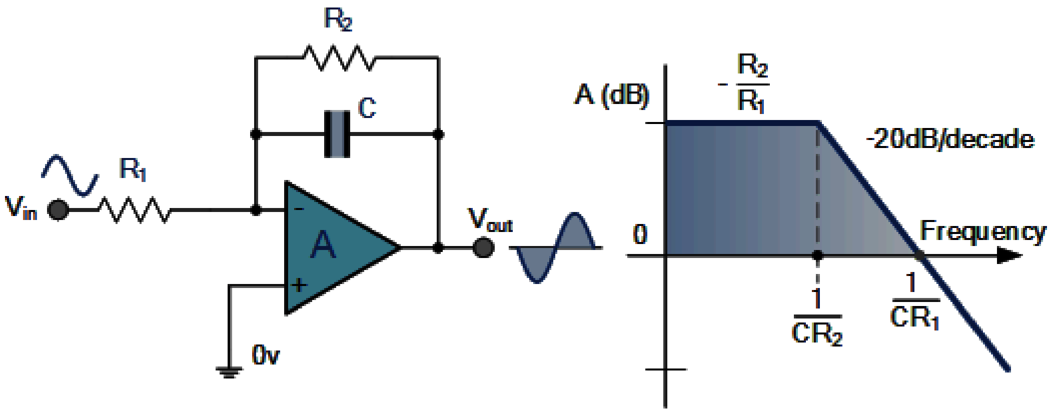
Experiment No: 6 Implementation and investigation on Op-Amp Integrator

Objective

In this exercise, the concept of waveform integration will be examined. The investigation will include the effect of frequency on accurate and useful integration. Several wave shapes will be utilized.

Theory Overview

The concept of integration is usually described as "finding the area under the curve". There are many uses for this function, including wave shaping and analog computing. An ordinary amplifier ideally changes only the amplitude of the input signal. An integrator can change the waveform of the input signal, for example, turning a square wave into a triangle wave. A practical integrator cannot be used at just any frequency. There exists a useful range of integration, outside of which the circuit does not produce the desired effect. The frequency response of op-amp integrator is shown below.



Where the output voltage and lowest frequency to perform integration can be calculated as below.

$$V_{out} = -\frac{1}{R_1 C}\int_0^t V_i dt \text{ and}$$

$$f_{low} = \frac{1}{2\pi C R_2}$$

Equipment

(1) Oscilloscope model:______________ srn:____________________

(1) Dual DC power supply model:______________ srn:____________________

(1) Function generator model:______________ srn:____________________

(1) DMM model:______________ srn:____________________

Components

(1) Medium speed FET-input op amp (351, 411, etc.)

(2) 1 µF actual:__________________ __________________

(1) .01 µF actual:__________________

(1) 910Ω actual:__________________

(1) 1 kΩ actual:__________________

(1) 10 kΩ actual:__________________

Circuit Diagram

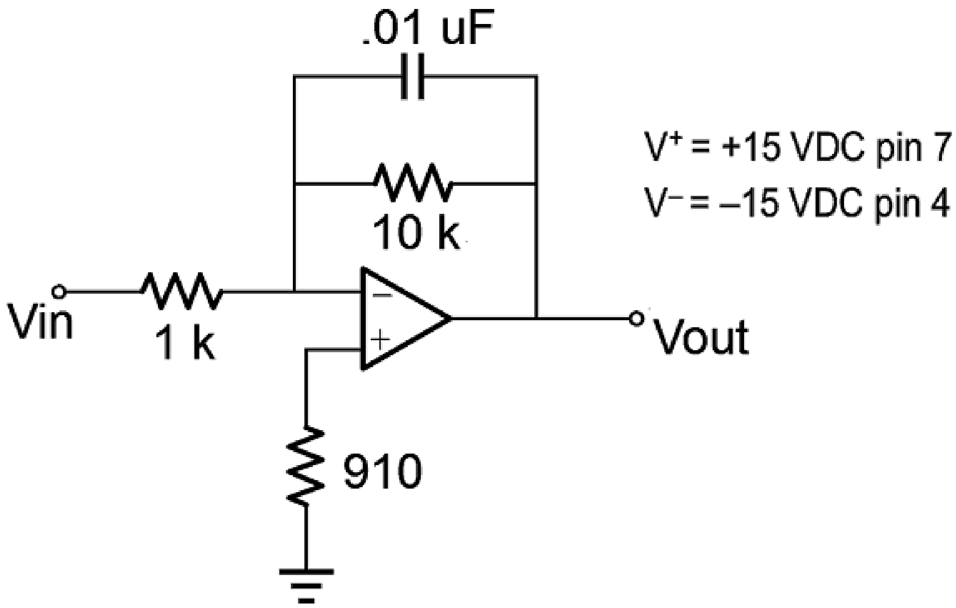


Figure 6.1: Circuit diagram of Op-Amp integrator.

Procedure

1. Derive the equation for V_{out} for the circuit of Figure 6.1. Calculate the lowest usable ("integratable") frequency, f_{low}. Record these items in Table 6.1.

2. Calculate the integrator's output voltage for the following inputs and record them in Table 6.2:

- 1 volt peak sine wave at 2 times f_{low}
- 1 volt peak sine wave at 10 times f_{low}
- 1 volt peak square wave at 2 times f_{low}
- 1 volt peak square wave at 10 times f_{low}

3. Assemble the integrator circuit.

4. Save the display of the output of the integrator for each of the inputs listed in step 2, above. Call these Graphs 1 through 4, respectively. It is very important to note the phase of the output waveform with respect to the input waveform.

5. Apply a 1 volt peak sine wave one decade below flow. Save the output signal as Graph 5. Does the circuit appear to be integrating?

6. Apply a 1 volt peak square wave one decade below flow. Save the output signal as Graph 6. Does the circuit appear to be integrating?

Data Table 6.1

Equation for V_{out}	
f_{low}	

Data Table 6.2

Input Signal	Output Signal
1 volt peak sine wave at 2 times f_{low}	
1 volt peak sine wave at 10 times f_{low}	
1 volt peak square wave at 2 times f_{low}	
1 volt peak square wave at 10 times f_{low}	

Questions

1. What happens to the accuracy of integration as the input frequency is increased?

2. At very low frequencies, does the integrator behave more like a true integrator, or like an amplifier?

3. What are the advantages of using a medium speed FET-input op amp such as a 351 over a slower bipolar device such as a 741?

4. What is the purpose of the 10 kΩ resistor?

5. What is the purpose of the 910Ω resistor?

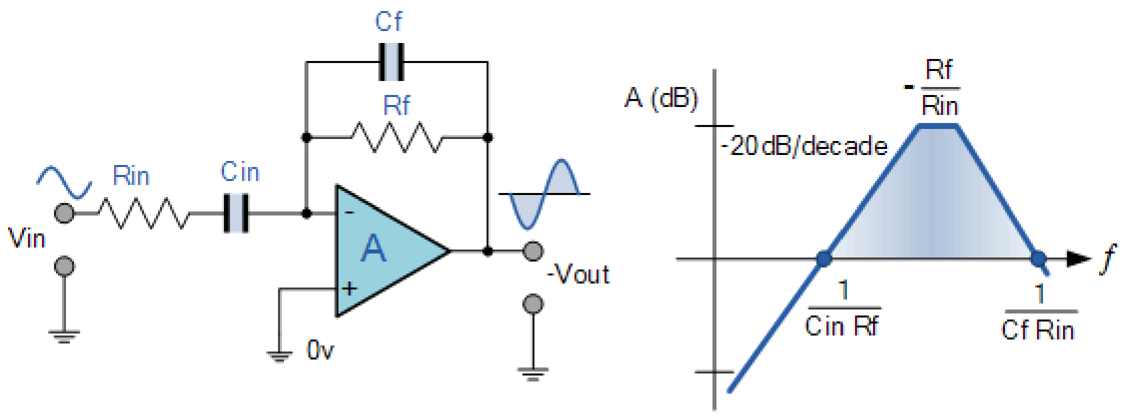
Experiment No: 7 Implementation and investigation on Op-Amp Differentiator.

Objective

In this exercise, the concept of waveform differentiation will be examined. The investigation will include the effect of frequency on accurate and useful differentiation. Several wave shapes will be utilized.

Theory Overview

The concept of differentiation is usually described as "finding the slope of the curve." There are many uses for this function, including wave shaping and analog computing. An ordinary amplifier ideally changes only the amplitude of the input signal. A differentiator can change the waveform of the input signal, for example, turning a triangle wave into a square wave. A practical differentiator cannot be used at just any frequency. There exists a useful range of differentiation, outside of which the circuit does not produce the desired effect. The frequency response of op-amp differentiator is shown below.



Where the output voltage and highest frequency to perform differentiation can be calculated as below.

$$V_{out} = -R_f C_{in} \frac{dV_{in}}{dt}, \text{ and}$$

$$f_{high} = \frac{1}{2\pi R_{in} C_f}$$

Equipment

(1) Oscilloscope model:_________________ srn:____________________

(1) Dual DC power supply model:_________________ srn:____________________

(1) Function generator model:_________________ srn:____________________

(1) DMM model:_________________ srn:____________________

Components

(1) Medium speed FET-input op amp (351, 411, etc.)

(2) 1 µF actual:__________________ __________________

(1) .01 µF actual:__________________

(1) .0015 µF actual:__________________

(1) 100 Ω actual:__________________

(1) 1 kΩ actual:__________________

Circuit Diagram

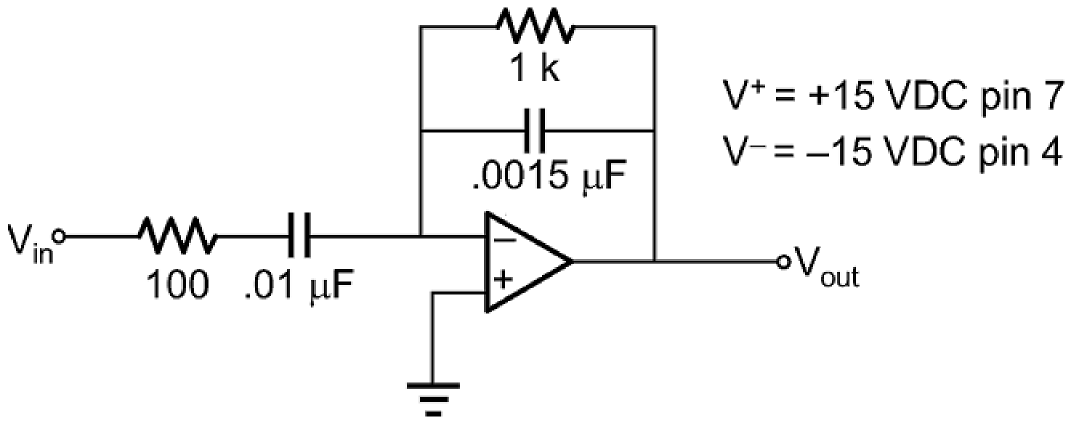


Figure 7.1: Circuit diagram of differentiator

Procedure

1. Derive the equation for V_{out} for the circuit of Figure 7.1. Calculate the highest usable (“differentiable”) frequency, f_{high}. Record these items in Table 7.1.

2. Calculate the differentiator’s output voltage for the following inputs and record them in Table 7.2:

- 1 volt peak sine wave at one-half f_{high}
- 1 volt peak sine wave at one-tenth f_{high}
- 1 volt peak triangle wave at one-half f_{high}
- 1 volt peak triangle wave at one-tenth f_{high}

3. Assemble the differentiator circuit.

4. Save the display of the output of the differentiator for each of the inputs listed in step 2. Call these Graphs 1 through 4, respectively. It is very important to note the phase of the output waveform with respect to the input waveform.

3. Apply a 1 volt peak sine wave one decade above f_{high}. Save the output signal as Graph 5. Does the circuit appear to be differentiating?

4. Apply a 1 volt peak triangle wave one decade above f_{high}. Save the output signal as Graph 6. Does the circuit appear to be differentiating?

Data Table 7.1

Equation for V_{out}	
f_{high}	

Data Table 7.2

Input Signal	Output Signal
1 volt peak sine wave at $^1/_2$ f_{high}	
1 volt peak sine wave at $^1/_{10}$ f_{high}	
1 volt peak triangle wave at $^1/_2$ f_{high}	
1 volt peak triangle wave at $^1/_{10}$ f_{high}	

Questions

1. What happens to the accuracy of differentiation as the input frequency is decreased?

2. At very high frequencies, does the differentiator behave more like a true differentiator, or like an amplifier?

3. What are the advantages of using a medium speed FET-input op amp such as a 351 over a slower bipolar device such as a 741?

4. What is the purpose of the 100Ω resistor?

5. What is the purpose of the 0.0015 µF capacitor?

Experiment No. 8: Implementation and investigation on Wien bridge oscillator using Op-Amp

Objective

In this exercise, a Wien bridge sine wave generator is examined. The investigation will include the effect of capacitance on output frequency and gain control of the op amp.

Theory Overview

The Wien bridge is a four-element resistor-capacitor network that can be thought of as a combination of lead and lag networks. As such, it attenuates very high and very low frequencies. At its critical frequency, where the magnitude of Xc equals R, the bridge voltage produces no phase shift and exhibits a modest signal loss of 1/3. An op amp with a voltage gain of 3 may be used to overcome this loss, and as long it produces no additional phase shift, the system can produce stable oscillation at the critical frequency. A non-inverting amplifier is ideally suited to this task. The gain needs to be slightly greater than 3 to begin oscillation and should fall back to 3 to maintain oscillation. The gain variation may be achieved through the use of limiting diodes in the negative feedback network.

Equipment

(1) Oscilloscope model:________________ srn:__________________

(1) Dual DC power supply model:________________ srn:__________________

(1) DMM model:________________ srn:__________________

Components

(1) Low speed op amp (741)

(1) Medium speed op amp (351, 411, 081, etc.)

(2) 1µ F actual:__________________ __________________

(2) 1n F actual:__________________ __________________

(2) 10n F actual:__________________ __________________

(2) 100n F actual:__________________ __________________

(1) 2k7 Ω actual:__________________

(1) 5k6 Ω actual:__________________

(3) 10kΩ actual:__________________ __________________ __________________

Circuit Diagram

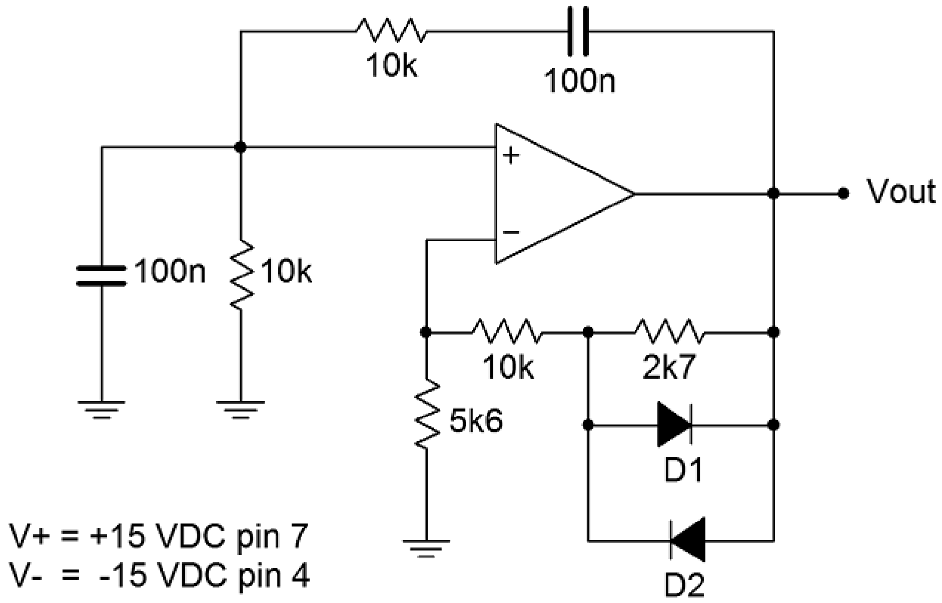


Figure 8.1: Circuit diagram of Wien bridge oscillator.

Procedure

1. Determine the theoretical output frequency for the circuit of Figure 8.1. Also, estimate the output amplitude. Record these in Table 8.1.

2. Construct the circuit of Figure 1 using the medium speed op amp.

3. Record the output frequency and amplitude of the sine wave in Table 8.1 and determine the deviation between the theoretical and experimental results.

4. Save a copy of the oscilloscope display of the output wave as Graph 1.

5. Replace the capacitors with the 10n F units. Determine the theoretical output frequency using this new value and record the result in Table 8.2.

6. Record the output frequency and amplitude of the wave in Table 8.2 and determine the deviation between the theoretical and experimental results.

7. Save a copy of the oscilloscope display of the output wave as Graph 2.

8. Replace the capacitors with the 1n F units. Determine the theoretical output frequency using this new value and record the result in Table 8.2.

9. Record the output frequency and amplitude of the wave in Table 8.2 and determine the deviation between the theoretical and experimental results.

10. Save a copy of the oscilloscope display of the output wave as Graph 3.

11. Replace the medium speed op amp with the low speed op amp and examine the output.

12. Save a copy of the oscilloscope display of the output wave as Graph 4. Swap out the capacitors with the 10n F and then the 100 nF units. Are the wave shapes identical to those created with the faster opamp?

13. In order for this circuit to oscillate, the forward gain of the op amp must compensate for the loss through the Wien bridge, in this case, a gain of 3 is required. To verify this, open the 5k6 resistor. This will drop the gain to about 1 and oscillation should cease.

Computer Simulation

14. One of the trickier parts of this oscillator is getting the op amp gain adjusted properly. If it is too high, the signal will be distorted. In this circuit, the initial gain is greater than 3 but as the signal grows, the two diodes turn on, partially shunting the 2k7 and reducing the effective value of R f, and hence, the voltage gain. To demonstrate this, build the circuit in the simulator with a 741 op amp and 10n F capacitors. First perform a Transient Analysis and inspect the output wave shape. Replace the 2k7 with larger values and note the effect on the wave shape. Finally, return the resistor to 2k7, delete the two diodes and observe the new wave shape.

Data Table 8.1

	Theoretical	Experimental	% Deviation
f_{out}			
V_{out}			

Data Table 8.2

	Theoretical	Experimental	% Deviation
f_{out}			
V_{out}			

Data Table 8.3

	Theoretical	Experimental	% Deviation
f_{out}			
V_{out}			

Questions

1. How does the oscillation frequency vary with capacitance?

2. By comparing Graphs 1, 2, and 3, what sorts of non-ideal behavior occur at higher output frequencies?

3. By comparing Graphs 3 and 4, what are the advantages of using a medium speed op amp such as a 351 over a slower device such as a 741?

4. In general, what do you think the output waveforms would look like if the medium speed op amp had been used with a 100p F capacitor?

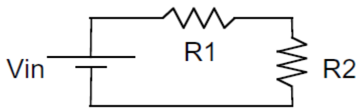
Experiment No. 9: Verification of the I/O Characteristics of High Pass and Low Pass R-C Filter

Objective

The purpose of this experiment is to use a capacitor and a resistor to build and study the properties of a high-pass filter which blocks low frequencies, and a low-pass filter which blocks high frequencies.

Theory

For a resistor with resistance *R* in an electrical circuit, the relationship between the applied voltage (*V*) and the current (*I*) passing through the resistor is given by Ohm's Law: $V=IR$. Similarly, for a capacitor with capacitance *C* the relationship is $V=IX_C$. Here X_C is called the capacitive reactance and whose magnitude is defined by $X_C=1/\omega_C$. ω_C is the angular frequency ($2\pi f$) of the applied voltage. This is the analog of Ohm's Law for capacitors, and the capacitive reactance is analogous to resistance. So, we can use Ohm's law in AC circuits involving capacitors. We notice that for a DC voltage ($\omega=0$) the capacitive reactance is infinite, so no current passes through the capacitor. At low frequencies the reactance is high and at high frequencies the reactance is low. So, we can think of a capacitor as a resistor with a resistance that depends upon the frequency of the applied voltage.



First consider the above circuit. Kirchhoff's voltage law says that $V_{in} = I\,(R_1+R_2)$. The voltage across R_2 is given by $V_2 = I\,R_2$ so $V_2 = V_{in}\,R_2/(R_1+R_2)$. Similarly, the voltage across V_1 is given by $V_1 = V_{in}\,R_1/(R_1+R_2)$. Hence the resistor with the larger resistance has a larger voltage across it.

This result will be used below in AC circuits with capacitors and resistors. Remember that the reactance *Xc* plays the role of resistance for a capacitor.

(Here we are only interested in the magnitude of the capacitive reactance,

$$Xc = 1/\omega C$$

For high pass filter, at low frequencies the capacitor acts like a high resistance, so most of the input voltage will be across it, so $V_{out,}$ which is measured across the resistor will be much smaller than V_{in}. At high frequencies the capacitor acts like a small resistance so most of the input voltage will appear across the resistor and V_{out} will be almost equal to $V_{in.}$

For low pass filter, at low frequencies the capacitor acts like a high resistance, so most of the input voltage will be dropped across it, so V_{out} will be almost equal to $V_{in.}$ At high frequencies the capacitor acts like a small resistance so most of the input voltage will appear across the resistor and V_{out} will be much smaller than $V_{in.}$ This circuit is called a low pass filter. It passes low frequency input signals but blocks high frequencies. This could be used to keep high frequencies out of a bass speaker.

Equipment

(1) Oscilloscope model:________________ srn:__________________

(1) Function generator model:________________ srn:__________________

(1) DMM model:________________ srn:__________________

List of Component

1. Resistors (1200Ω) actual:…………………….__________________
2. Capacitors (0.01μF) actual:…………………….__________________

Circuit Diagram

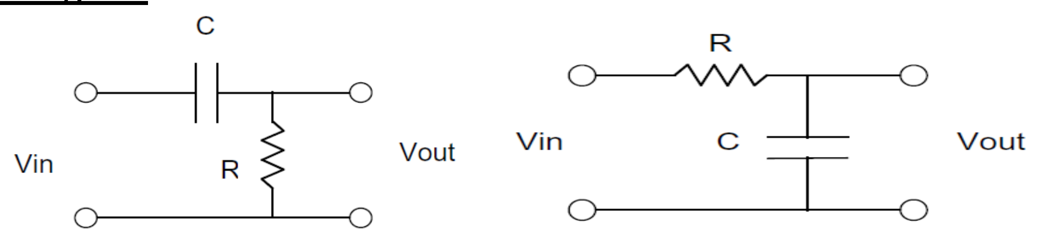


Figure 9.1: Circuit diagram of high pass (left one) and low pass filter (right one)

Procedure

1. Measure the values of the resistor and capacitor. Construct a circuit like Circuit 1 by connecting the capacitor and the resistor in series. Connect the oscilloscope and the voltmeter to measure the voltage across the resistor.
2. Calculate the cutoff frequency from $fc=1/2\pi RC$. This should be the frequency at which the output power is equal to one half of the input power, or, equivalently, the output voltage is equal to 0.707 of the input voltage. Record this number.
3. Set the input voltage, the voltage across the signal generator, to 2 volts peak to peak.

4. Measure the output voltage of the circuit over a frequency range of 1 kHz to 10 kHz in 1 kHz increments. You will need to adjust the input voltage back to 2 volts as you change the frequency. Plot gain (V_{out}/V_{in}) vs. frequency. Fill up table -1 and draw plot.
5. Print this plot.
6. Find the cutoff frequency from the plot by locating the frequency at which the gain is equal to 0.707.
7. Compare the calculated and measured cutoff frequency.
8. Repeat for Circuit 2 and fill up table-2 and draw the plot.

Data Table

Table: 9.1

No. of Obs.	Frequency of input voltage, F (KHz)	V_{in} (Volt)	V_{out} (Volt)	Gain= V_{out}/V_{in}
1	1			
2	2			
3	3			
4	4			
5	5			
6	6			
7	7			
8	8			
9	9			
10	10			

Table: 9.2

No. of Obs.	Frequency of input voltage, F (KHz)	Vin (Volt)	Vout (Volt)	Gain= V_{out}/Vin
1	1			
2	2			
3	3			
4	4			
5	5			
6	6			
7	7			
8	8			
9	9			
10	10			

Experiment No. 10: Verification of the I/O Characteristics of Band Pass R-C Filter

Objectives

1. To construct a Band Pass Filter by cascading a low pass filter and a high pass filter.
2. To obtain the frequency response of the filter and learn using the Bode Analyzer.

Theory

A Band Pass Filter allows a specific frequency range to pass, while blocking lower and higher frequencies. It allows frequencies between two cut-off frequencies while attenuating frequencies outside the cut-off frequencies.
A good application of a band pass filter is in Audio Signal Processing, where a specific range of frequencies of sound are required while eliminating the rest. Another application is in the selection of a specific signal from a range of signals in communication systems.
A band pass filter may be constructed by cascading a High Pass R_L filter with a roll-off frequency f_L and a Low Pass RC filter with a roll-off frequency f_H, such that

$$f_L < f_H$$

The Lower cut-off frequency is given as $f_L = \frac{1}{2\pi R_1 C_1}$ (1)

The higher cut-off frequency is given as : $f_H = \frac{1}{2\pi R_2 C_2}$ (2)

The Band Width of frequencies passed is given by: $BW = f_H - f_L$

Thus, all the frequencies below f_L and above f_H are attenuated and those in between are passed by the filter.

Frequency Response: It is a graph of magnitude of the output voltage of the filter as a function of the frequency. It is generally used to characterize the range of frequencies in which the filter is designed to operate within. Figure 3 shows a typical frequency response of a Band Pass filter.

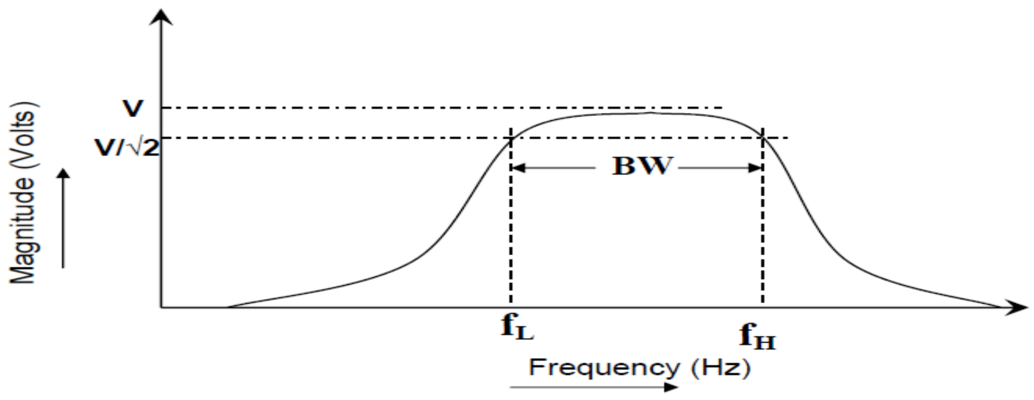


Figure 10.1: Frequency response of Band Pass filter.

Equipment

(1) Oscilloscope model:________________ srn:__________________

(1) Function generator model:________________ srn:__________________

(1) DMM model:________________ srn:__________________

List of Component

1. Resistors (1200Ω, 1K Ω) actual:………………………
2. Capacitors (1.00µF, 2.5 µF) actual:………………………

Circuit Diagram

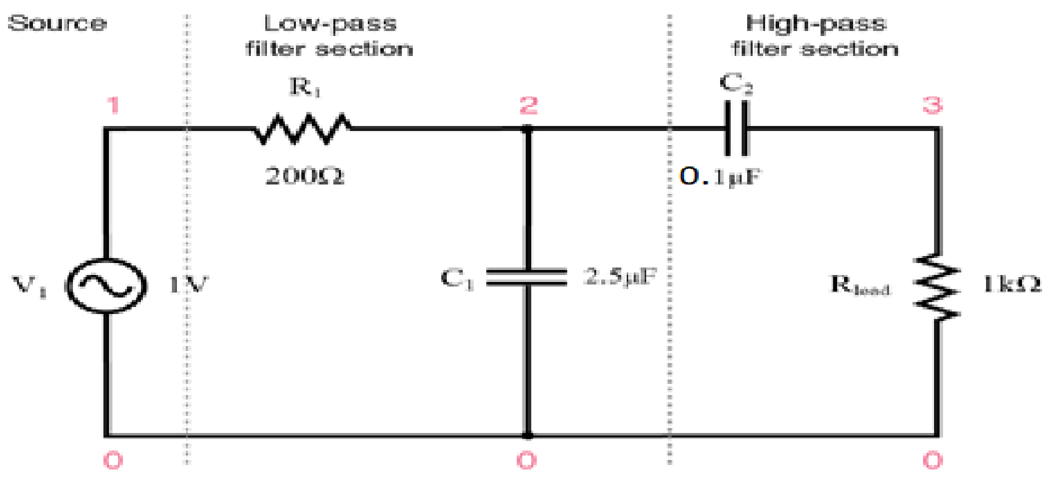


Figure 10.2: Circuit Diagram for a Band Pass Filter.

Procedure

1. Set up the circuit shown in the **Figure 10.2** with the component values $R_1 = 200\Omega$, $C_1 = 2.5\mu F$, $R_2 = R_{load} = 1K\Omega$, $C_2 = 0.1\mu F$. Switch on the Elvis Power Supply.
2. Select the Function Generator from the NI-ELVIS Menu and apply a 1 V peak-peak Sinusoidal wave as input voltage to the circuit.
3. Select the Oscilloscope from the NI-ELVIS Menu. Make sure the Source on Channel A, Source on Channel B, Trigger and Time base input boxes are properly set.
4. Fill up table-1.
5. Compute the 70 % of Vp-p and obtain the frequencies at which this occurs on the Oscilloscope. (Note that it occurs twice on the band pass filter, near Lower cutoff and near upper cutoff). This gives the cut-off (roll-off) frequencies for the constructed Band Pass filter.

Data Table

Table-2.1

No. of Obs.	Frequency of input voltage, F (KHz)	V_{in} (Volt)	V_{out} (Volt)	Gain= V_{out}/V_{in}
1	0.01			
2	0.1			
3	0.3			
4	0.6			
5	0.9			
6	1.2			
7	1.5			
8	1.8			
9	2.0			

Experiment No. 11: Observation of the Characteristics of Photo Diode

Objective

The objective of this exercise is to examine the operation of the photodiode in both the photovoltaic and photoconductive modes.

Theory Overview

The photodiode is, in essence, the reverse of the LED. In fact, depending on their design, LEDs can be used as a type of photodiode. Photodiodes are responsive to light in one of two ways. The first method is the photovoltaic mode. In this mode, a voltage appears across the PN junction that is proportional to the amount of light striking it. It can be thought of as a small voltage source or battery. The second mode is photoconductive. In this mode, the photodiode is reverse biased by an external DC supply. The amount of current flowing through the diode will be proportional to the amount of light striking the junction. Typically, this current will pass through a series resistor to create a voltage or it can be sent into a current amplifier circuit. A photo emitter/detector pair is a pairing of an LED and a photodiode that are designed to produce and detect the same wavelength of light. The wavelength of light may be outside the range of the human visible spectrum. Infrared (IR) is often used for consumer remote control devices. Emitter/detector pairs might use a phototransistor in place of a photodiode. The performance is similar except that photodiodes tend to have a quicker response while phototransistors tend to produce higher currents.

Equipment

(1) Adjustable DC power supply model:_________________ srn:_______________
(2) DMM model:_________________ srn:____________________
(3) Non-diffuse light source (pen light)

List of Component

1) Yellow LED
2) Blue LED
3) IR emitter/detector pair (Lite-On LTE-302 emitter, LTR-301 detector)
4) 470 Ω resistor ¼ watt actual: __________________________
5) 33 k Ω resistor ¼ watt actual: __________________________

IR Emitter Datasheet: http://optoelectronics.liteon.com/upload/download/DS-50-92-0009/E302.pdf

IR Detector Datasheet: http://optoelectronics.liteon.com/upload/download/DS-50-93-0013/LTR-301.pdf

Circuit Diagram

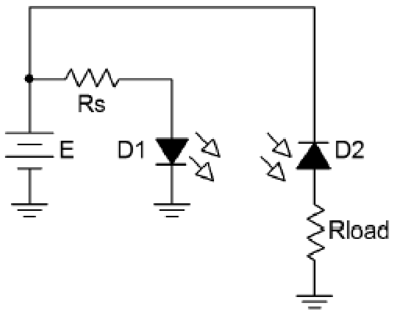


Figure 11.1: Measurement of the characteristics of photo diode

Procedure

LED as Detector

1.Most LEDs can be used as light detectors. In photovoltaic mode, the output potential is a function of the light level and the make-up of the device (i.e., typically its color). Insert a yellow LED into a proto board with nothing obstructing it. Place a DMM across it and measure the resulting DC voltage, recording it in Table 11.1 under "Normal".

2. Shade the LED so that minimal light strikes it and measure the resulting voltage. Record the value in Table 1 under "Dark".

3.Using the pen light, illuminate the LED from a distance of approximately 10 centimeters, measure and record the voltage in Table 1 under "Bright". Also, slowly vary the distance of the pen light from a few centimeters to 20 or so and note what happens to the voltage.

4.Replace the yellow LED with the blue LED and repeat steps 1 through 3. IR Emitter/Detector Pair

IR Emitter/Detector Pair

1. Figure 3.1 shows an emitter/detector pair. These devices will emit and detect light at the same wavelength and tend to not produce or detect light at other wavelengths. This aids in avoiding interference. The detector is configured in photoconductive

mode. Its current will increase with increasing light level. This current also flows through R_{load} meaning that V_{load} will be proportional to light level.

2. Build the circuit of Figure 1 using E = 7 volts, R_s = 470 Ω and R_{load} = 33 kΩ. The emitter diode is denoted with a yellow dot on its case while the detector diode shows a red dot. It is very important Laboratory Manual for Semiconductor Devices: Theory and Application **37** that the pair properly be aligned. The bubbles should face each other and cases should be at same height, effectively aiming one bubble at the other. Further, they should only be a few millimeters apart. Finally, the short leads indicate the cathodes.

3. Energize the circuit. Because this pair operates in the infrared, nothing will be apparent to the human eye. Verify that the emitter is operating by measuring the voltage across it. It should be in the vicinity of 1.1 volts.

4. Measure V_{load} and record the value in Table 11.2.

5. Slip an opaque card such as a thin piece of black plastic or cardboard between the emitter/detector pair. Measure and record V_{load} in Table 11.2.

Data Tables

Table 11.1

Variation	$V_{\text{LED-YELLOW}}$	$V_{\text{LED-BLUE}}$
Normal		
Dark		
Bright		

Table 11.2

Variation	V_{Load}
Open	
Blocked	

Experiment No. 12: Verification of the I/O Characteristics of Class A Power Amplifier

Objective

The objective of this exercise is to examine large signal class A operation. A voltage follower will be investigated by plotting the AC load line and determining output compliance, maximum load power, supplied DC power and efficiency. The effects of clipping will be noted.

Theory Overview

The maximum output signal, or compliance, of a class A amplifier is determined by its AC load line. The maximum peak level is determined by the smaller of V_{CEQ} and $I_{CQ} \cdot r_{Load}$. If either of these levels is hit, the output signal will begin to clip causing greatly increased distortion. Knowing this voltage and the load resistance, the maximum load power may be determined. Dividing this power by the total supplied DC power will yield the efficiency. The maximum theoretical efficiency of an RC coupled class A amplifier is 25% although real-world circuits may be far less. In fact, the power dissipation of the transistor itself (PDQ) may be greater than the maximum load power, clearly not a desirable condition. Note that the total supplied power is the product of the total supplied voltage and the average total current. In a class A amplifier that is not clipping, the average supplied current is equal to the quiescent DC current. In the case of a dual supply emitter biased circuit, this is simply the collector current and can be measured with a DC ammeter.

Equipment

1) Dual adjustable DC power supply Model:________________ srn:_____________
2) DMM Model:________________ srn:_____________
3) Dual Channel oscilloscope Model:________________ srn:_____________
4) Low distortion function generator Model:________________ srn:_____________
5) Distortion analyzer Model:________________ srn:_____________

List of Components

(1) Small signal transistors (2N3904)
(1) 100Ω resistor $^1/_4$ watt actual__________________________________
(1) 1kΩ resistor $^1/_4$ watt actual__________________________________
(1) 47kΩ resistor $^1/_4$ watt actual__________________________________

(1) 470 µF capacitor actual________________________________

Circuit Diagram

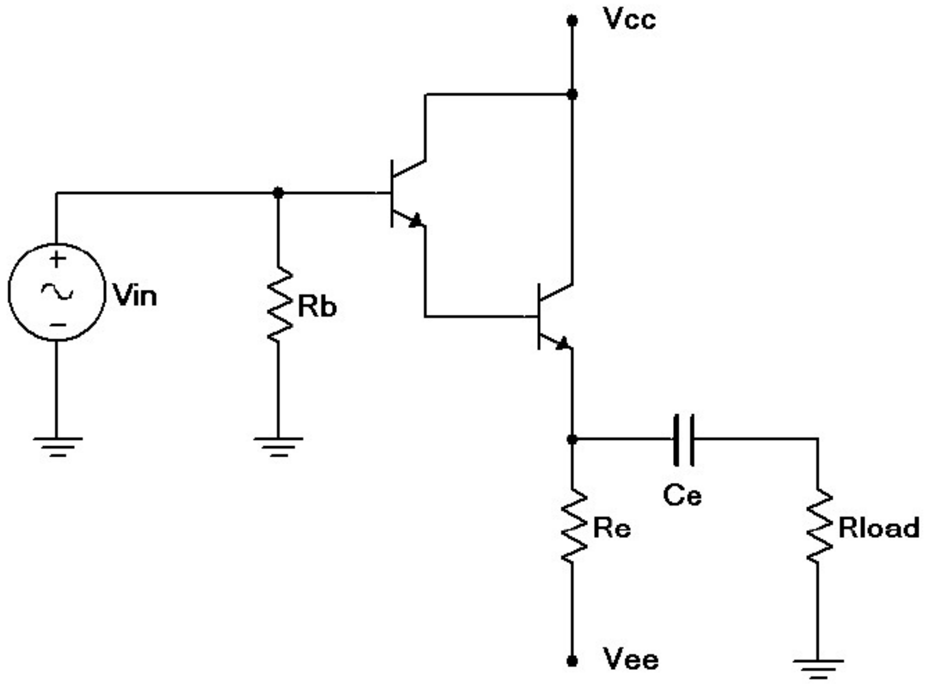


Figure 12.1: Circuit diagram of class A power amplifier

Procedure

AC Load Line and Power Analysis

1. Consider the circuit of Figure 1 using V_{cc} = 5 volts, V_{ee} = −12 volts, R_b = 47 kΩ, R_e = 1 kΩ, R_{load} = 100 Ω and C_e = 470 µF. Determine the theoretical I_{CQ}, $V_{CEQ,}$ V_{CE}*(cutoff)* and i_C*(sat)*, and record these in Table 1. It is helpful to plot the AC load line for step three. Note that the collector-emitter saturation voltage for a Darlington pair cannot be assumed to be 0 volts, and may be closer to one volt, thus reducing the expecting voltage swing toward the saturation point. It is also worth noting that this amplifier has a *direct coupled* input (i.e., no input capacitor is required due to the very small DC base voltage).

2. Build the circuit of Figure 1 using V_{cc} = 5 volts, V_{ee} = −12 volts, R_b = 47 kΩ, R_e = 1 kΩ, R_{load}=100 Ω and C_e = 470 µF. Disconnect the signal source and measure the DC transistor voltages to ensure the circuit is biased correctly. Record V_{CEQ} and I_{CQ} in Table 1 (Experimental).

3. Based on the data recorded in Table 1, determine the theoretical maximum unclipped load voltage (compliance) and record it in Table 12.2. Based on this, determine the maximum load power and record it Table 12.2 as well. Also determine and record the expected values for the quiescent power dissipation of the transistor (PDQ), the supplied DC current and power, and the resulting efficiency.

4. Using a 1 kHz sine wave setting, apply the signal source to the amplifier and adjust it to achieve a load voltage that just begins to clip. Reduce the amplitude *slightly* to produce a clean, unclipped wave. Record this level as the experimental compliance in Table 12.2. From this, determine and record the experimental maximum load power. Also, capture an image of the oscilloscope display.

5. Insert an ammeter in the collector and measure the resulting current with the signal still set for maximum unclipped output. Record this in Table 12.2 as $I_{supplied}$ (Experimental).

6. Using the data already recorded, determine and record the experimental PDQ, $P_{Supplied}$, and η. Finally, determine the deviations for Table 12.2.

Clipping and Distortion

7. Increase the signal until both peaks begin to clip. Record these clipping levels in Table 12.3. Make sure the oscilloscope is **DC coupled** for this measurement as any offset is important. Compare these peaks to those predicted by the AC load line. Also, capture an image of the oscilloscope display.

8. Decrease the signal level so that it is about 90% of the maximum unclipped level. Set the distortion analyzer to 1 kHz and % total harmonic distortion (% THD). Apply it across the load and record the resulting reading in Table 4 (Normal). Increase the signal by about 20% so that one of the peaks is obviously clipped and take a second distortion reading, recording it Table 12.4 (Clipped).

Computer Simulation

9. Build the circuit in a simulator and run a Transient Analysis. Use a 1 kHz 7 volt peak sine for the source. Inspect the voltage at the load. Record the peak clip points in Table 5. Reduce the input signal so that clipping disappears. If available, add the Distortion Analyzer instrument at the load and record the resulting value.

Data Tables

Tabel 12.1

	Theory	Experimental
I_{CQ}		
V_{CEQ}		
$I_{C\,(sat)}$		X
$V_{CE\,(cutoff)}$		X

Table 12.2

	Theory	Experimental	% Deviation
Compliance			
$P_{Load\,(max)}$			
$I_{Supplied}$			
P_{DQ}			
$P_{Supplied}$			
n			

Table 12.3

Positive Clip	
Negative Clip	

Table 12.4

% THD Normal	
% THD Normal	

Table 12.5

Positive Clip	Negative Clip	% Distortion

Experiment No. 13: Verification of the I/O Characteristics Class B Amplifier

Objective

The objective of this exercise is to examine large signal class B operation. A voltage follower will be investigated to determine output compliance, maximum load power, supplied DC power and efficiency. The effects of crossover distortion will be noted by comparing resistor and diode biasing schemes.

Theory Overview

The maximum output signal, or compliance, of a class B amplifier is determined by its AC load line. The peak to peak compliance is roughly equal to the total DC supply voltage(s). As two output devices are used, each conducting for half of the cycle, the quiescent current can remain low, unlike a class A amplifier. This results in vastly improved efficiency, theoretically up to 78.5%. The switchover from one transistor to the other is problematic and can result in crossover or notch distortion. To alleviate this, the transistors are given a small idle current so that each base-emitter junction is just about fully on. While resistors can be used to create this bias, trying to match the linear current-voltage characteristic of a resistor to the logarithmic characteristic of a PN junction is tricky. Consequently, another PN junction, namely a diode, is used instead. The diode will result in a more stable circuit which produces less notch distortion.

Equipment

(1) Dual adjustable DC power supply Model:__________ srn:____________
(1) DMM Model:__________ srn:____________
(1) Dual Channel oscilloscope Model:_________ _ srn:____________
(1) Low distortion function generator Model:__________ srn:____________
(1) Distortion analyzer Model:__________ srn:____________

List of Components

(1) Small signal NPN transistors (2N3904)
(1) Small signal PNP transistors (2N3906)
(2) Switching Diodes (1N914 or 1N4148)
(1) 100Ω resistor $^1/_4$ watt actual________________________________
(1) 220Ω resistor $^1/_4$ watt actual________________________________
(1) 1kΩ resistor $^1/_4$ watt actual________________________________
(1) 10µF capacitor actual________________________________
(1) 100µF capacitor actual________________________________

Circuit Diagram

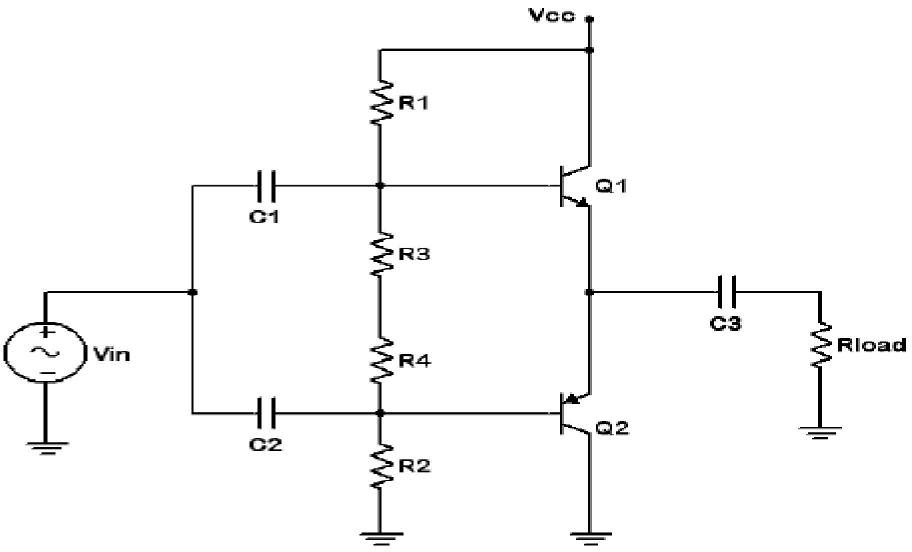


Figure 13.1

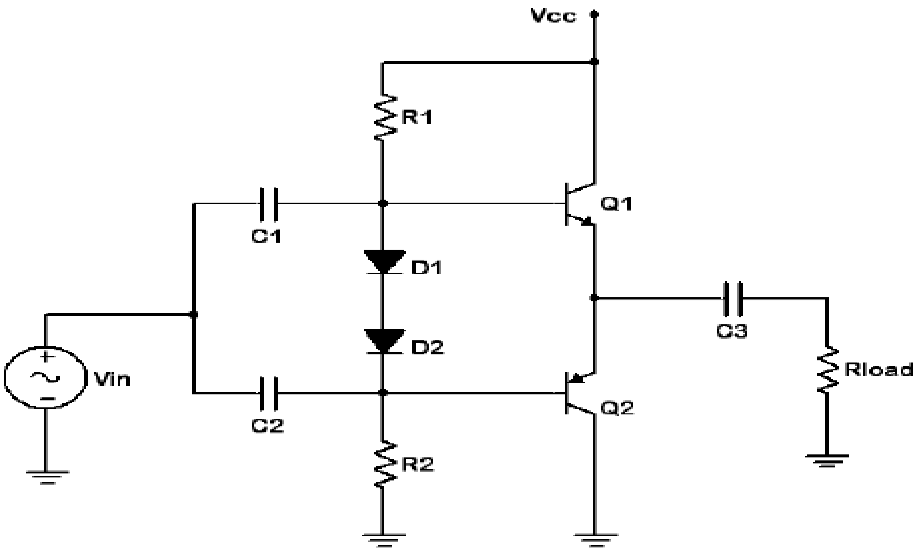


Figure 13.2

Procedure

Resistor versus Diode Bias and Crossover Distortion

1. Consider the circuit of Figure 13.1 using V_{cc} = 6 volts, $R_1 = R_2 = 2.2$ kΩ, $R_3 = R_4 = 220$ Ω, $R_{load} = 100$ Ω, $C_1 = C_2 = 10$ μF and $C_3 = 100$ μF. Ideally this circuit will produce a compliance of just under 6 volts peak-peak.

2. Build the circuit of Figure 1 using V_{cc} = 6 volts, $R_1 = R_2 = 2.2$ kΩ, $R_3 = R_4 = 220$ Ω, $R_{load} = 100$Ω, $C_1 = C_2 = 10$ μF and $C_3 = 100$ μF. Disconnect the signal source and insert an ammeter into the collector of Q_1. Record I_{CQ} in Table 13.1.

3. Connect the signal source and apply a 1 kHz sine at 2 volts peak. Look at the load voltage and capture the oscilloscope image. There should be considerable notch or crossover distortion.

4. Cycle through the remaining supply voltages in Table 13.1, repeating steps 2 and 3. Only images of the first and last trials need be captured. As the bias current increases, the notch distortion should decrease.

5. Replace R_3 and R_4 with switching diodes, as shown in Figure 13.2. Repeat steps 2 through 4 using this circuit and Table 13.2. Overall, the superior matching of the diodes to the transistors should result in decreased notch distortion.

Dual Supply and Power Analysis

6. Add the negative power supply so that the circuit now appears as Figure 13.3. Set the power supplies to +/−6 volts DC. This should produce similar bias and amplification results to the single 12 volt supply circuit of Figure 13.2. Although the output coupling capacitor is no longer needed (one advantage of the dual supply topology), leave it in for safety sake.

7. Based on the I_{CQ} recorded for the 12 volt supply in Table 13.2, determine the theoretical PDQ. Also determine the expected compliance, and efficiency. Record these values in the Theoretical column of Table 13.3. $P_{Load}(max)$, $I_{supplied}$, $P_{supplied}$

8. Apply the signal source to the amplifier and adjust it to achieve a load voltage that just begins to clip. Reduce the amplitude *slightly* to produce a clean, unclipped wave. Record this level as the experimental compliance in Table 13.3. From this, determine and record the experimental maximum load power. Also, capture an image of the oscilloscope display.

9. Insert an ammeter in the collector and measure the resulting current with the signal still set for maximum unclipped output. Record this in Table 13.3 as $I_{supplied}$ (Experimental). Remove the ammeter.

10. Using the data already recorded, determine and record the experimental PDQ, $P_{Supplied}$, and η. Finally, determine the deviations for Table 13.3.

Distortion

11. Unlike class A distortion which gets worse as the signal increases, notch distortion is relatively fixed. Therefore, it represents a smaller percentage of the overall output signal as the signal increases. To see this effect, adjust the signal level to achieve a load voltage of 8 volts peak-peak. There should be no clipping. Set the distortion

analyzer to 1 kHz and % total harmonic distortion (% THD). Apply it across the load and record the resulting reading in Table 13.4 (8 Vpp). Decrease the generator to achieve a load voltage of 1 volt peak-peak and record the resulting THD.

Computer Simulation

12. Build the circuit in a simulator and run a Transient Analysis. Use a 1 kHz 7 volt peak sine for the source. Inspect the voltage at the load. Record the peak clip points in Table 13.5. Reduce the input signal so that clipping disappears. Add the Distortion Analyzer instrument at the load and record the resulting value.

<u>Data Tables</u>

Table 13.1

Supply	I_{CQ}- Resistors
6 V	
8 V	
10 V	
12V	

Table 13.2

Supply	I_{CQ}- Diodes
6 V	
8 V	
10 V	
12V	

Table 15.3

	Theory	Experimental	% Deviation
Compliance			
$P_{Load\ (max)}$			
$I_{Supplied}$			
P_{DQ}			
$P_{Supplied}$			
η			

Table 15.4

% THD 8 Vpp	
% THD 1 Vpp	

Table 15.5

Positive Clip	Negative Clip	% Distortion

ANNEXURE-I

Assessment Rubric

1. Laboratory Report

Category	Outstanding (Up to 100%)	Accomplished (Up to 75%)	Developing (Up to 50%)	Beginner (Up to 25%)
Write up format	Aim, Apparatus, material requirement, theoretical basis, procedure of experiment, sketch of the experimental setup etc. is demarcated and presented in clearly labeled and neatly organized sections.	The write up follows the specified format but a couple of the specified parameters are missing.	The report follows the specified format but a few of the formats are missing and the experimental sketch is not included in the report	The write up does not follow the specified format and the presentation is shabby.
Observations and Calculations	The experimental observations and calculations are recorded in neatly prepared table with correct units and significant figures. One sample calculation is explained by substitution of values	The experimental observations and calculations are recorded in neatly prepared table with correct units and significant figures but sample calculation is not shown	The experimental observations and calculations are recorded neatly but correct units and significant figures are not used. Sample calculation is also not shown	The experimental observations and results are recorded carelessly. Correct units significant figures are not followed and sample calculations not shown
Results and Graphs	Results obtained are correct within reasonable limits. Graphs are drawn neatly with labeling of the axes. Relevant calculations are performed from the graphs. Equations are obtained by regression analysis or curve fitting if relevant	Results obtained are correct within reasonable limits. Graphs are drawn neatly with labeling of the axes. Relevant calculations from the graphs are incomplete and equations are not obtained by regression analysis or curve fitting	Results obtained are correct within reasonable limits. Graphs are not drawn neatly and or labeling is not proper. No calculations are done from the graphs and equations are not obtained by regression analysis or curve fitting	Results obtained are not correct within reasonable limits. Graphs are not drawn neatly and or labeling is not proper. No calculations are done from the graphs and equations are not obtained by regression
Discussion of results	All relevant points of the result are discussed and justified in light of theoretical expectations. Reasons for divergent results are identified and corrective measures discussed.	Results are discussed but no theoretical reference is mentioned. Divergent results are identified but no satisfactory reasoning is given for the same.	Discussion of results is incomplete and divergent results are not identified.	Neither relevant points of the results are discussed nor divergent results identified

2. Individual Presentation

Category	Outstanding (Up to 100%)	Accomplished (Up to 75%)	Developing (Up to 50%)	Beginner (Up to 25%)
Content	A concise summary of the topic; Convincing justification for choice of topic; Comprehensive and complete coverage of information	A good summary of the topic; Acceptable justification for choice of topic; Most important information covered; Little irrelevant information	Informative but much of the information irrelevant; Confused justification for choice of topic; Coverage of some of the major points	A brief look at the topic; Little justification for choice of topic; Majority of information irrelevant and significant points left out
Organization	Clear purpose and subject; Pertinent examples, facts, and/or statistics; Supports conclusions/ideas with evidence	Somewhat clear purpose and subject; Some examples, facts, and/or statistics that support the subject; Some data or evidence that supports conclusions	Attempts to define purpose and subject; Weak examples, facts, and/or statistics not adequately supporting the subject; Very thin data or evidence to support conclusion	Subject and purpose not clearly defined; Weak or no support of subject; Insufficient support for ideas or conclusions
Visual Aids	Information is clear and concise with proper key information in points or phrases; Visually appealing/ engaging	Too much information in complete sentences on slides along with proper key information in phrases; Significant visual appeal	Too much information in complete sentences on many slides; Some proper key information; Minimal effort made to make slides appealing	Too much information in complete sentences on slides; No or few proper key information; Repetition of the same information on multiple slides; No visual appeal
Delivery Style	Regular eye contact; Appropriate speaking volume & body language; Proper pace and diction; Fluent avoidance of repetitions, hesitations, gap fillers	Steady eye contact; Adequate volume and energy; Generally good pace and diction; Few or no distracting Gestures; Few repetitions, hesitations, gap fillers	More volume or energy needed at times; Pace too slow or fast; Some distracting gestures or posture; Some repetitions, hesitations, gap fillers	Low volume and energy; Pace too slow or fast; Poor diction; Lots of distracting gestures or posture; Frequent repetitions, hesitations, gap fillers
Question -answer Session	Demonstrates knowledge by answering all types of questions with explanations and elaboration in professional manner	Is at ease with expected answers to all questions without elaboration in somewhat professional manner	Is uncomfortable with information and can answer only rudimentary questions	Does not have grasp of information and cannot answer questions about subject

ANNEXURE-II

Program Outcomes

Program Outcomes (POs) represent the knowledge, skills and attitudes the students should have at the end of a four year engineering program. CSE program of BAUET has 12 Program Outcomes. They are briefly described in the following table.

Sl. No	PO	Category	Description
1	**PO 1**	**Engineering Knowledge**	Apply the **knowledge** of **mathematics**, **science**, **engineering fundamentals**, and an **engineering specialization** to the solution of complex engineering problems.
2	**PO 2**	**Problem Analysis**	**Identify**, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions **using first principles** of mathematics, natural sciences, and engineering sciences.
3	**PO 3**	**Design/Development of Solutions**	**Design solutions** for complex engineering problems and **design system** components or processes that meet the specified needs with appropriate consideration for public health and safety as well as cultural, social and environmental concerns.
4	**PO 4**	**Investigation**	**Conduct investigations** of complex problems, considering design of experiments, analysis and interpretation of data and synthesis of information to provide valid conclusions.
5	**PO 5**	**Modern Tool Usage**	**Create, select, and apply** appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6	**PO 6**	**The Engineer and Society**	**Apply reasoning** informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7	**PO 7**	**Environment and Sustainability**	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of need for sustainable development.
8	**PO 8**	**Ethics**	Apply ethical principles and commit to professional Ethics and responsibilities and norms of the engineering practice.
9	**PO 9**	**Individual and Team Work**	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10	**PO 10**	**Communication**	Communicate effectively on complex engineering activities with the engineering community and with society at large. Some of them are, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11	**PO 11**	**Project Management and Finance**	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12	**PO 12**	**Life Long Learning**	Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

ANNEXURE-III

Knowledge Profile, Complex Engineering Problem and Complex Engineering Activities

Knowledge Profile (WK/K)- CHARACTERISTIC

WK1	**Natural Sciences**	A systematic, theory-based understanding of the natural sciences applicable to the discipline
WK2	**Mathematics**	Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline
WK3	**Engineering fundamentals**	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline
WK4	**Specialist knowledge**	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	**Engineering design**	Knowledge that supports engineering design in a practice area
WK6	**Engineering practice**	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline
WK7	**Comprehension**	Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability
WK8	**Research literature**	Engagement with selected knowledge in the research literature of the discipline

Complex Engineering Problem (WP/P)

WP	**Preamble**	**COMPLEX PROBLEMS have characteristic of WP1 and some or all of WP2 to WP7**
WP1	**Depth of Knowledge**	**In-depth engineering knowledge** at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamental based, first principles analytical approach
WP2	**Conflicting requirement**	Wide-ranging or **conflicting** technical, engineering and other issues
WP3	**Depth of analysis**	**no obvious solution** and require abstract thinking, originality in analysis to formulate suitable models
WP4	**Familiarity of issues**	**infrequently** encountered issues
WP5	**Extent of applicable codes**	outside problems encompassed by standards and codes of practice for professional engineering
WP6	**Extent of stakeholder**	**diverse groups** of stakeholders with widely varying needs
WP7	**Interdependence**	high level problems including **many component parts** or sub-problems

Complex Engineering Activities (EA)

Activ ities	Preamble	**Complex activities** means (engineering) activities or projects that have **some or all** of the following characteristics listed below
EA1	**Range of resources**	**Diverse resources** (people, money, equipment, materials, information and technologies).
EA2	**Level of interaction**	Require resolution of significant problems arising from interactions between **wide ranging** or **conflicting** technical, engineering or other issues.
EA3	**Innovation**	Involve creative use of engineering principles and **research-based** knowledge in **novel** ways.
EA4	**Consequences to society and the environment**	Have **significant consequences** in a **range of contexts**, characterised by **difficulty** of prediction and mitigation.
EA5	**Familiarity**	Can extend **beyond previous** experiences by applying **principles-based** approaches.

The End