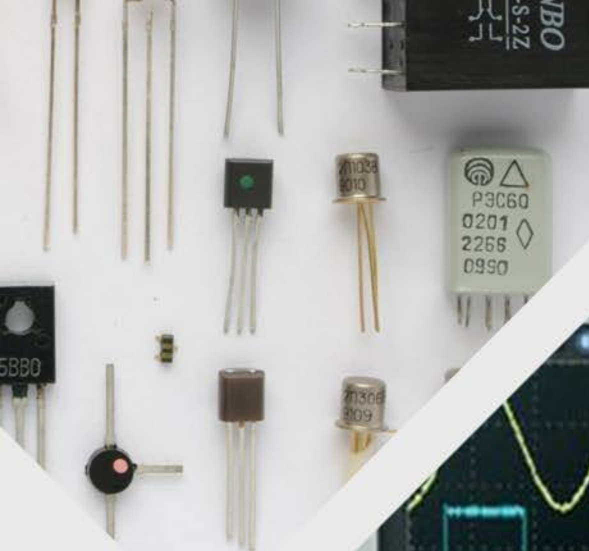
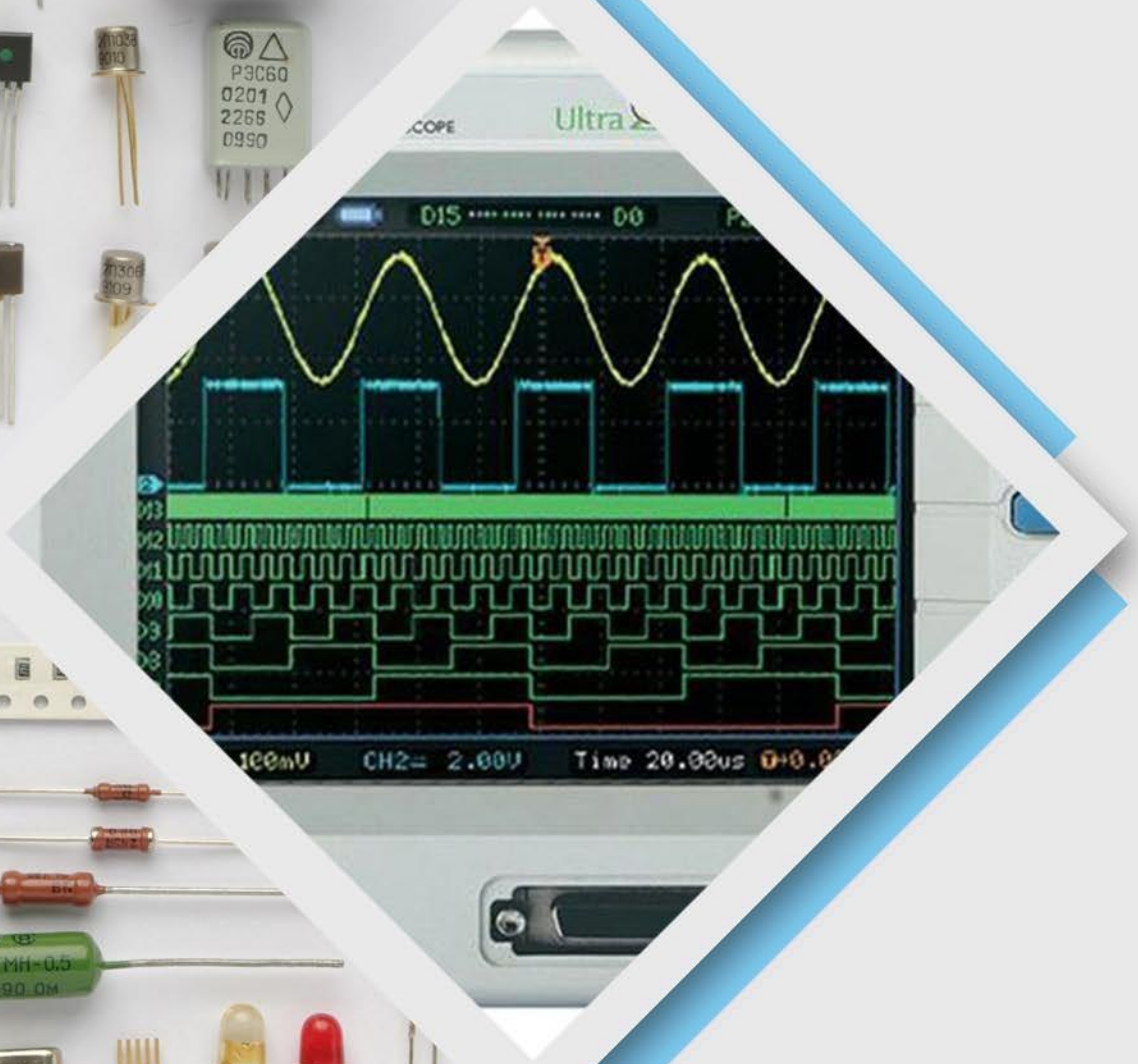
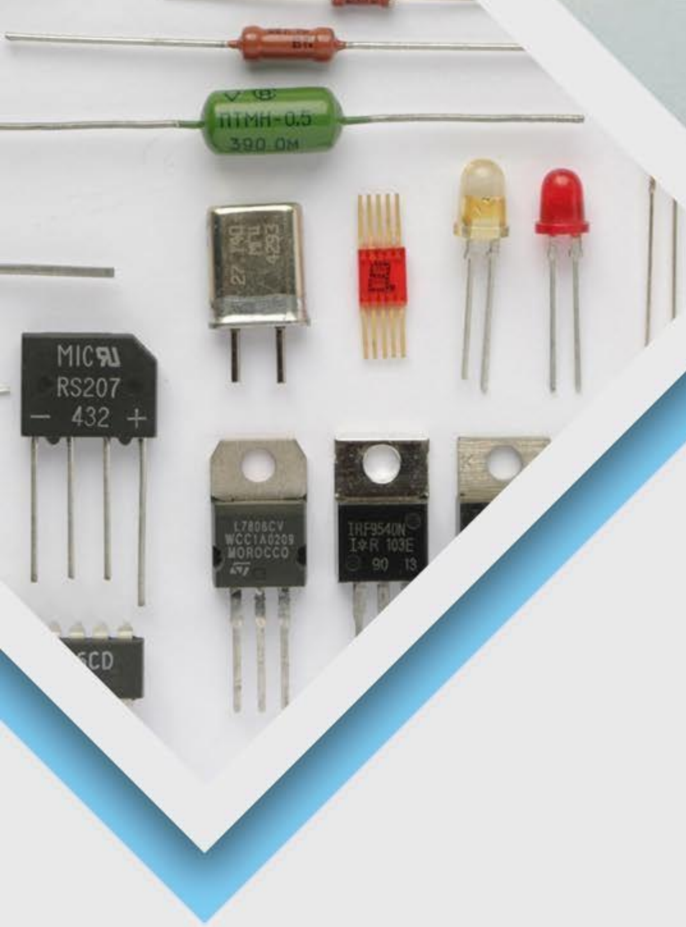
Team of Lecturers







ELECTRONIC PRACTICAL GUIDEBOOK

PHYSICS STUDY PROGRAM
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
UNIVERSITAS NEGERI JAKARTA
2018

PRACTICAL GUIDEBOOK

ELEKTRONIKA

SUBMITTED BY

Electronics Lecturer Team

ELECTRONIC LABORATORY

FACULTY OF MATHEMATICS AND NATURAL SCIENCES

UNIVERSITAS NEGERI JAKARTA

2018

PREFACE

Thanks to the blessings of the Almighty God, the Basic Electronics practicummodule can finally be completed.

This module contains technical instructions for the implementation of Basic Electronics practicum. This book is prepared in accordance with the Basic Electronics lecture material for both the Physics Education Study Program and the Physics Study Program. The purpose of this module is so that students who take Basic Electronics lectures can better understand the material that has been taught based on their own experience in the laboratory. Hopefully, students who take Basic Electronics lectures can better understand the electronics material they learn and can also develop it in making practical electronic circuits that are used in their daily lives.

The author realizes that this module is far from perfect, therefore if there are errorsin this module, it is hoped that criticism and suggestions can be submitted to the author tobe corrected in order to achieve perfection.

Finally, the author congratulates students on practicing to understand lecture material that initially seemed abstract, perhaps with this module it can be more tangible inits understanding.

Jakarta August 2018

Author,

Electronics Lecturer

Team

RULES OF CONDUCT FOR PRACTICUM IN ELECTRONICS LABORATORY OF ELECTRONICS FMIPA UNJ

1. Practitioners must be present 10 minutes before the practicum begins. Practitioners who are late (15 minutes after the practicum starts) cannot take part in the practicum on that day and are declared a failure (ZERO score).
2. Practitioners should dress neatly and wear dry closed shoes while in the laboratory.
3. While in the laboratory, practitioners must be calm, orderly and polite.
4. Bags, books, jackets and other equipment not needed during the practicum must be placed in the lockers.
5. Practitioners can take part in practicum if they have fulfilled the requirements:
   a. bring a practicum report in the form of:
      - preliminary report of the experiment to be conducted
      - final report on the previous week's experiment
   b. practitioners who do not meet the requirements are declared failed practicum that day and the score is ZERO
6. Practitioners who cannot attend are declared a failure except for those who are sick and stated with a sick certificate from an authorized doctor, the letter must be submitted a maximum of 3 days after the practicum day.
7. When the practicum is about to begin, each group must fill in the tool loan list on the tool and material bon sheet.
8. Each group must test the appropriateness of the loaned equipment and if there is damage, it should be reported to the supervisor so that it is repaired or replaced with a better one.
9. All practitioners are responsible for the equipment loaned, if there is damage during the practicum due to negligence of the practitioner, it is the responsibility of the group to repair or replace it.
10. After the practicum, the equipment is tidied up and returned to the supervisor along with the equipment receipt sheet.
11. Practitioners may leave the room if all loaned equipment has been returned and has been checked by the supervisor that it is in good condition (not damaged).
12. Practitioners who do not attend 75% of the practicum do not pass the Basic Electronics course.

REPORT CONDITIONS

1. The report is written on A4 paper
2. Report format:
   a. Practicum Title
   b. Practicum Objectives
   c. Basic Theory
   d. Tools and Materials
   e. Introduction Task Answer
   f. Trial Data
   g. Data Processing
   h. Data analysis + Graphs
   i. Answering the final assignment
   j. Discussion and conclusion
   k. Reading List
3. The report is submitted 1 week after the day of the practicum. Every 1-day delay issubject to a minus five (-5) fine from the grade given, except for practitioners who are sick are given a maximum of 3 days additional time.
4. Students who do not participate in practicum have no report submitted
5. On the cover of the report, the name of the practitioner is written and followed by the names of the other members.

TABLE OF CONTENTS

MODULE I

OPERATION OF MEASURINGINSTRUMENTS

A. PURPOSE

1. Students can use Multimeter and Oscilloscope measuring instruments appropriatelyand correctly
2. Students can test electronic components precisely and correctly

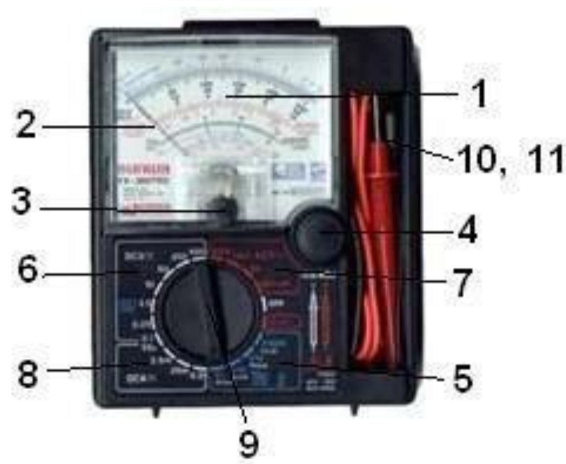
B. BASIC THEORY

1. MULTIMETER

A multimeter is an electronic measuring instrument used to test or measure acomponent, determine the position of the component's legs, and determine the value of the component being measured. Components that can be measured with a multimeter are: the value of the resistor, the value of the capacitor, the position of the transistor legs,diodes, DC or AC voltage, DC current and so on.

Multimeters can be divided into two, namely digital multimeters and analog (needle) multimeters. Multimeters have important parts, including:

1. Measurement scale board
2. Scale pointer needle
3. Scale needle adjuster
4. Ohmmeter ZERO adjustment dial
5. Ohmmeter measuring bar
6. DC volt (DCV) measuring limit
7. AC volt (ACV) measuring limit
8. DC Ammeter (DCA) measuring limit
9. Switch regulator measurement and measuring limit
10. Positive hole
11. Negative hole



The skill and suitability of the use of measuring instruments will determine thesuccess and accuracy of the measurement.

a. Voltmeter (Voltage measurement)

1) The use of a voltmeter is installed in parallel with the component to be measured.
2) Adjust the voltage type of the circuit with a multimeter, AC or DC
3. If the voltage region to be measured is unknown, use the largest measuring limit anduse a voltmeter that has a high input impedance.

b. Ampere meter (strong current measurement)

1) The use of an ammeter is installed in series on the line to be measured.
2) If the current area to be measured is unknown, use the largest measuring limit.

c. Ohmmeter (resistor measurement)

Resistors or resistance can break due to usage or age. If the resistor breaks then the electronic circuit that we make will not be able to work or experience defects.

1) Turn the selector switch to the Ohmmeter position.
2) Take a measurement scale that is expected to measure the resistance value you want to measure. The X1 scale means that the result indicated by the needle isthe measured value of the resistance. The X10 scale means that the measured resistance value is 10 times the value indicated by the needle. If the needle points to a scale of 100, it means that the resistance value is 10 x 100 so it is worth 1000.Likewise for X100, X1K or X1000
3) Before measuring the resistance value of the resistor, first zero the starting point of measurement by connecting the positive pole probe (red) and the negative pole probe (black) then set the needle pointer to be right at the zero point.
4) Every replacement of the scale value of the measuring limit is always zero point calibrated

5) Attach each *probe to* the ends of the resistor. Practitioner's hands should not touch both ends of the resistor wire (One end of the resistor may be touched butnot both).
6) If the needle moves then the resistor is good, if the needle does not move the resistor is broken. Observe the end point pointed by the needle and calculate the value of the resistor expressed from the measurement results.

d. Testing Transistors

In transistors, the collector leg is usually located on the edge and marked with a dot orsmall circle. While the base foot is usually located between the collector and emitter

1) PNP transistor
   - The select switch on the multimeter should point at the ohm meter.
   - Practitioners must make sure that the collector, base, and emitter legs are
   - Place the positive probe (red color) on the base and the negative probe(black color) on the emitter. If the needle moves, move the negative probe on the collector. If in both measurements above the needle moves then the transistor is in good condition, whereas if in one of the measurements the needle does not move, then the transistor is damaged,

2) NPN transistor

   Attach the *negative probe* on the base and *positive probe* on the collector, If the needle moves move the positive *probe* on the emitter. If in both measurements the needle moves, then the transistor is in good condition Whereas if in one of themeasurements the needle does not move then the transistor is in a damaged state.

e. Testing Elco Condensers

Before being installed in the capacitor circuit, it must be tested first or when buyingat the store you must make sure that the elco is in good condition. How to test it isas follows:

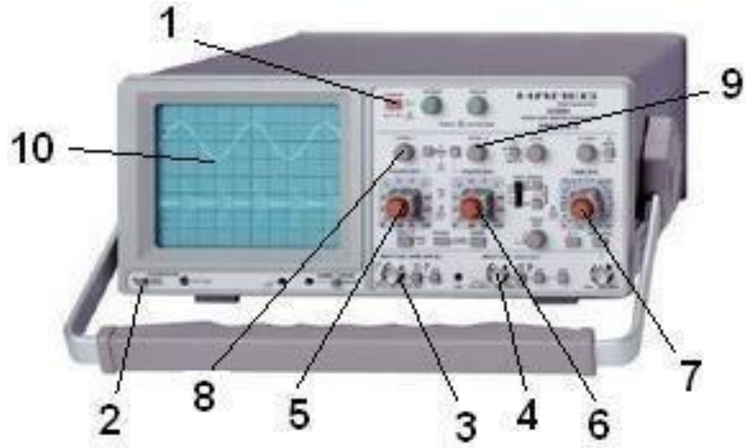
- *Turn the* selector switch to the ohm meter position
- Note the negative or positive sign on the elco body and straighten one of thelegs,
- Attach the negative probe to the positive leg (+) and the positive probe to the negativeleg *(-*). *)* . Watch the movement of t h e needle.
  - ❖ If the needle moves to the right and then back to the left, the elco condenser isgood.
  - ❖ If the needle moves to the right and then back to the left but is not full, theelco condenser is damaged.
  - ❖ If the needle moves right and then does not return to the left (stops),it means that the elco condentsator is leaking.
  - ❖ If the needle does not move at all, the elco condenser is broken.

f. Testing Diodes

- o Turn the selector switch to the ohm meter position
- o Attach the positive *probe* to the cathode pole and attach the negative *probe* to the anode pole. Watch the needle, if it moves it means the diode is good while ifit is stationary it means it is broken.
- o Next reversed, attach the negative *probe* to the cathode pole and attach the positive probe to the anode pole. Pay attention to the needle, if the needle is stationary it means the diode is good while if it moves it means the diode is damaged.

2. OSILOSKOP

An oscilloscope can measure AC and DC voltages and show their waveforms. The oscilloscope must be calibrated before use.



How to calibrate an oscilloscope is as follows:

- Turn on the oscilloscope.
- Set the focus and brightness level of the image on the oscilloscope,
- Attach the measuring cable to the oscilloscope (either the X or Y channel),
- Set COUPLING to the AC position
- Attach the negative / ground measuring cable (crocodile clip head or black) to theground on the oscilloscope.
- Attach the positive measuring cable (mainor colored head) to the place to calibrate the oscilloscope.
- Turn the VOLT/DIV variable selector switch on 0.5 V
- Turn the SWEEP TIME/DIV Variable selector switch at 0.5 ms
- Adjust the box wave that appears on the monitor to match the box lines on the Oscilloscope monitor screen by moving the red or yellow buttons on the Variable selector switch! VOLT/DIV and SWEEP TIME/DIV selector switches so that the box wave is 0.5 V_{PP}

3. SIGNAL GENERATOR

Signal generators can produce signals in the form of DC voltage or AC voltage whose frequency and amplitude we can set.

The part that generates DC voltage is called DC POWER. Its output consists of +5V, -5V, 0 ~ +15V and 0 ~ -15V

The part that generates the AC signal is called the FUNCTION GENERATOR. The amplitude button is useful for adjusting the amplitude of the output signal. The output signal can be set whether the signal is square, triangular or waveform signal.

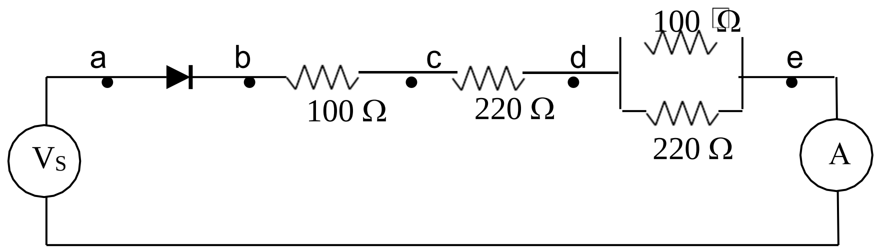
sinusoids via the *function* button.

C. TOOLS AND MATERIALS

1. Multimeter pieces
2. 2 channel oscilloscope
3. Signal Generator
4. Protoboard (circuit board)
5. Capacitors (Ceramic and Elco)
6. Diodes
7. Resistors
8. Transistors (PNP and NPN)
9. Connecting Wire

D. EXPERIMENT PROCEDURE

1. Check that each component to be used is good or damaged.
2. Arrange the circuit as below



3. Apply a DC source voltage of 3 volts
4. Measure the amount of current flowing in the circuit
5. Measure the voltage Vab, Vac, Vad, Vae, Vbc, Vbd, Vbe, Vcd, Vce, Vded using a Voltmeter.
6. Perform steps 2,3,4 for sources with 6 volt, 9 volt DC sources,
7. Remove the ammeter and replace the voltage source with 4-volt AC.
8. Measure the voltage Vab, Vac, Vad, Vae, Vbc, Vbd, Vbe, Vcd, Vce, Vded using a Voltmeter.
9. Measure the voltages Vab, Vac, Vad, Vae, Vbc, Vbd, Vbe, Vcd, Vce, Vded using an oscilloscope and draw the results.

10 Record the VOLT/DIVE and TIME/DIVE from the oscilloscope to help you scale themeasured signal.

11. Perform steps 3-9 for sources with AC sources of 3VPP, 6VPP

E. PRELIMINARY TASK

1. Measure the amount of current flowing in the circuit if a DC source voltage of 6volts is applied.
2. Calculate the voltage Vab, Vac, Vad, Vae, Vbc, Vbd, Vbe, Vcd, Vce, Vde if a silicon diode is used.

F. OBSERVATION DATA FORMAT

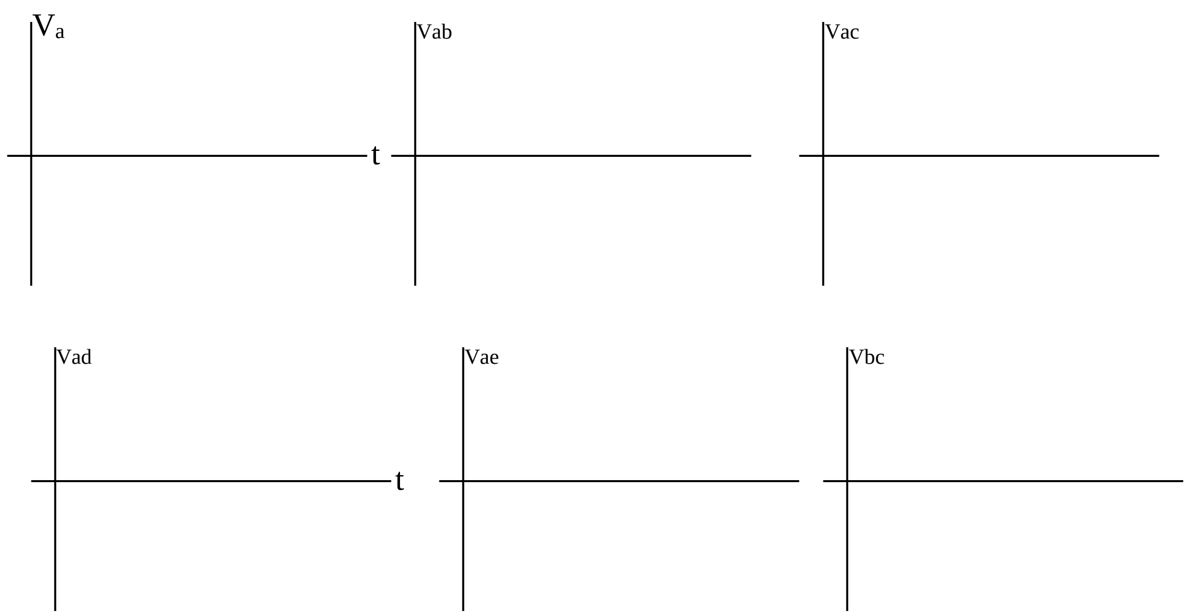
1. DC voltage source experiment

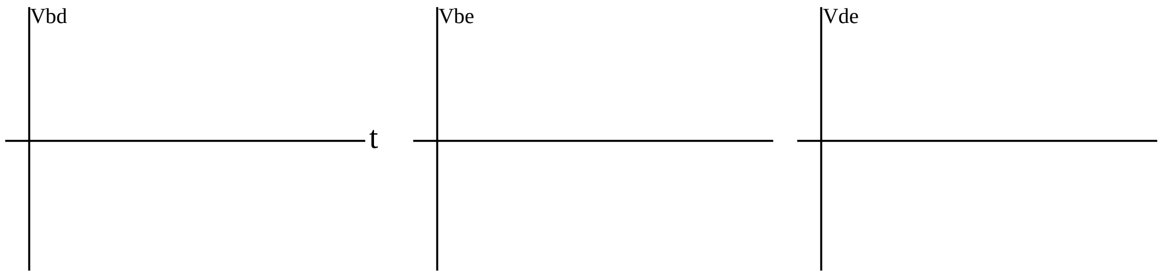
Ebat	I	Vab	Vac	Vad	Vae	Vbc	Vbd	Vbe	Vcd	Vce	Vde
3 volts											
6 volts											
9 volts											

2. AC voltage source experiment

Ebat	Vab	Vac	Vad	Vae	Vbc	Vbd	Vbe	Vcd	Vce	Vde
3 VPP										
6 VPP										
9 VPP										

3. Draw voltage with AC source





G. FINAL TASK

1. Write down the parts of the analog multimeter and explain the function of eachof them
2. Write down the parts of an oscilloscope and explain the function of each.
3. List the parts of a Signal Generator and explain their respective functions
4. Compare the measurement results with a Voltmeter and the measurement resultswith an Oscilloscope for an AC voltage source. Explain why they are different?

MODULE II

RC DIFFERENTIALS AND INTEGRALS

A. PURPOSE

1. Studying RC integrating and differentiating circuits
2. Graph the output of RC integrating and differentiating
3. Determine the effect of R value and C value on the output of integrating and differentiating circuits

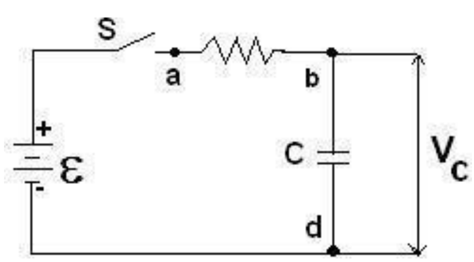
B. BASIC THEORY

Capacitor charging and discharging events are very important in electronics. Thecurrent in charging or discharging a capacitor decreases with time, which is referredto as ***transient current***. This means that this current is only observed for a very short time. In everyday life, this event is useful for changing pulses, processing pulses on television sets, time delays and so on.

In basic physics, we already know that capacitors are made of two layers of conductor plates separated by an insulator or dielectric. If a capacitor with capacitance *C* is connected to a voltage source *V*, then after some time, the capacitor will be filled with as much charge:

$$q = C\,V$$

Once this charge value is reached, it is said that the capacitor is fully charged. This charge will remain stored in the capacitor as long as there is no leakage of charge flowing from one capacitor plate to another.



In the figure above, if switch S is connected, then capacitor C is not immediately fully charged, but requires time to fully charge capacitor C. After switch S is closed, current flows from the voltage source, charging the capacitor. At time *t*, the initially empty capacitor will be filled with as much charge:

$$q(t) = \int_0^t i\,dt \qquad t$$

The voltage difference on capacitor C is equal to:

$$V_C(t) = \frac{q(t)}{C} = \frac{1}{C}\int_0^t i\,dt$$

While the voltage difference between the two ends of the resistor becomes:

$$V_{ab} = \varepsilon - V_C(t)$$
$$= \varepsilon - \frac{1}{C}\int_0^t i\,dt = iR$$

Since the voltage source □ is fixed, while V_c *(t) is* always increasing, V_{ab} will continue to decrease, so the current *i(t)* will also continue to decrease. At time *t=0 the*value of $V_{C}=0$, so the value of i=ε/R. At time t, the value of the current flowing in the circuit is obtained:

$$i(t) = \frac{\varepsilon}{R} e^{-t/RC}$$

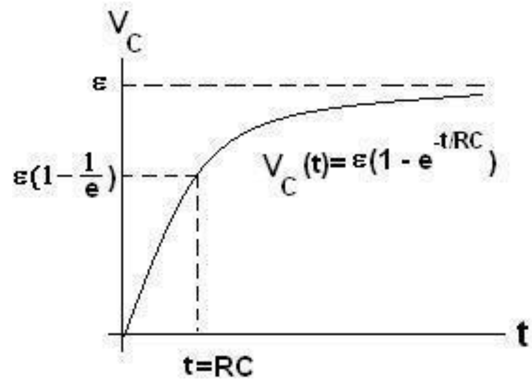
In the above equation, it is found that the decrease in current value decreases exponentially, depending on the values of R and C. The time *t=RC is* referred to as the*constant time* and is expressed as τ which determines the duration of charging ordischarging a capacitor

To find out how the capacitor voltage increases with time when the capacitor ischarged, the equation is used:

$$V_C(t) = \frac{q(t)}{C} = \frac{1}{C}\int_0^t i\ dt$$

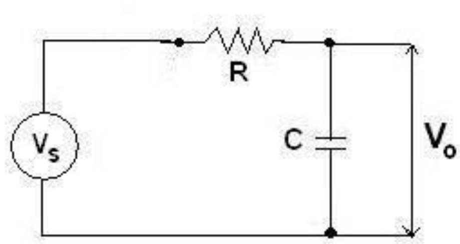
$$V_C(t) = \frac{1}{C}\int_0^t \frac{\varepsilon}{R} e^{-t/RC} dt = \varepsilon\left(1 - e^{-t/RC}\right)$$

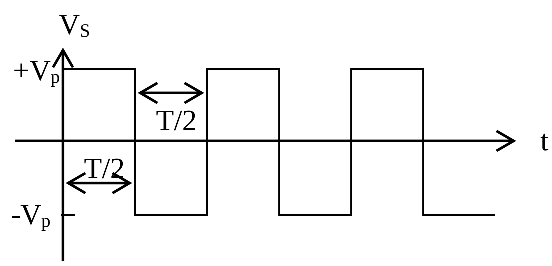
At time *t=0 the* capacitor is not yet charged, based on the above equation $V_C = 0$. The larger the *RC* value, the longer it takes to fully charge the capacitor.



RC integrating circuit

If the input voltage is given in the form of a square alternating voltage, then the input will change direction in a certain interval. Every half-period (*T/2*) the inputvoltage will change direction, so that every *T/2 the* direction of the current flowing in the circuit will change direction. Capacitor charging time is only for *T/2*. After that time there is a change in the direction of the current resulting in capacitors immediately emptied and filled with negative voltage. After *T* there is another change in thedirection of the current so that the capacitor is emptied again and filled with positive voltage. This happens continuously and repeats periodically in line with the shape of the input voltage.



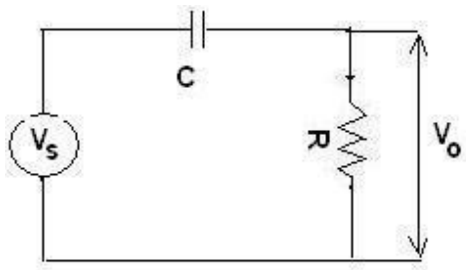


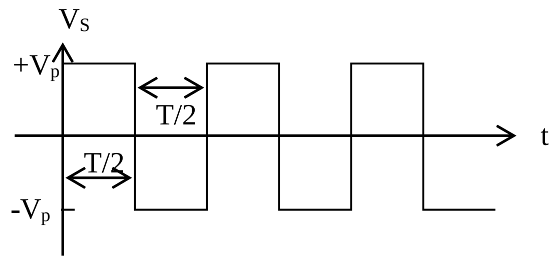
If the time constant τ is much smaller than the input voltage period ($\tau = RC << T$), the capacitor will be fully charged within *T/2*. But if the time constant τ much larger than the input voltage period (τ =RC>>T), then the capacitor is not yet fully charged, the source voltage has reversed to negative, as a result the capacitor is immediately discharged and filled with negative voltage. But before the capacitor is fully charged with negative voltage, the source voltage has reversed to positive voltage, so the capacitor is also immediately discharged and charged with positive voltage. For this second case, the output voltage shape at the capacitor is a triangular wave.

The resulting output voltage form is the integral of the input voltage signal

RC differential circuit

The differentiating circuit is the same as the integrating circuit, but the output voltageis measured at resistor *R*.





If the time constant τ is much larger than the period of the input voltage ($\tau = RC >> T$) or frequency $f >> 1/RC$ then the output signal shape is almost the same as input voltage signal, but the peak is slightly skewed. This means that at time $t=0$ the capacitor is empty, so the output voltage is equal to the input voltage. At time t = T/2 the capacitor is not yet fully charged, but the input voltage has flipped to negative. This means that the current passing through the resistor is not yet zero but the input voltage has changed direction.

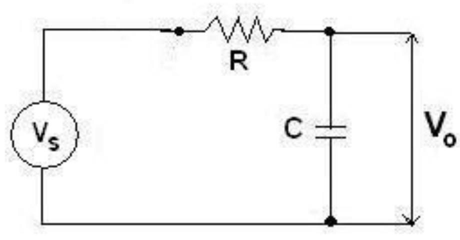
If the time constant τ is much smaller than the input voltage period ($\tau = RC << T$) or $f << 1/RC$ then the capacitor will be fully charged before time T/2, meaning that the current passing through the resistor will be zero before time T/2. The resulting output voltage form is differential from the input voltage signal.

C. TOOLS AND MATERIALS

1. Resistors
2. Capacitors
3. Protoboard
4. Oscilloscope
5. Probe
6. AVOmeter
7. Audiogenerator
8. Red, black, green cable

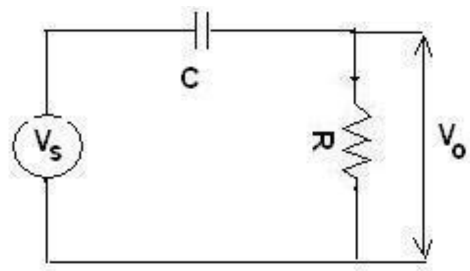
D. EXPERIMENT PROCEDURE

1. Experiment I: RC Integration
   a. Arrange the series of R and C as shown below:



   b. Calculate the time constant τ of the circuit using the equation:
      $\tau = RC$ for R = 3 MΩ and C = 3.3 nF
   c. Use a voltage source whose signal is a square wave and take a source of $6mV_{PP}$ by observing on an oscilloscope
   d. Set the input period to $0.01\,\tau$; $0.1\,\tau$; τ ; $10\,\tau$; $100\,\tau$, respectively, draw the output voltage on the capacitor observed on the oscilloscope.
   e. Perform steps a-d for R_2 = R but C_2 =100 C
   f. Perform steps a-d for R_3 = 10R but C_3 =C

2. Experiment II: RC Differentiation
   a. Arrange the series of R and C as shown below:



   b. Calculate the time constant τ of the circuit using the equation:
      $\tau = RC$ for R = 3 MΩ and C = 3.3 nF
   c. Use a voltage source whose signal is a square wave and take a source of $6mV_{PP}$ by observing on an oscilloscope
   d. Set the input period to *0.01 τ; 0.1 τ ; τ ; 10 τ ; 100 τ*, respectively, draw the output voltage on the resistor observed on the oscilloscope.
   e. Perform steps a-d for R_2 = R but C_2 =100 C
   f. Perform steps a-d for R_3 = 10R but C_3 =C

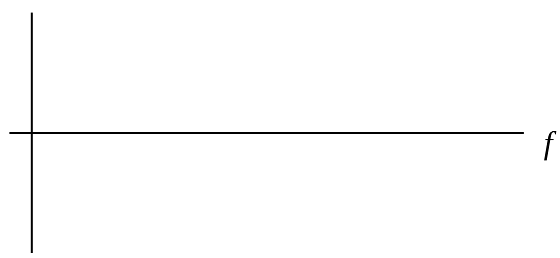
E. PRELIMINARY TASK

1. Determine the value of τ for R = 3 MΩ and C = 3.3 nF
2. Determine the voltage equation at C for time 0 - 0.5T
3. Draw the equation for the values of τ in problem 1 with periods 100ms, 1 ms and 1 s
4. Determine the voltage equation at R for time 0 - 0.5T
5. Draw the equation for the values of τ in problem 1 with periods 100ms 1ms and 1 s

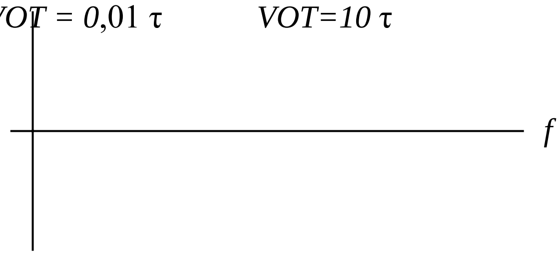
F. OBSERVATION DATA FORMAT

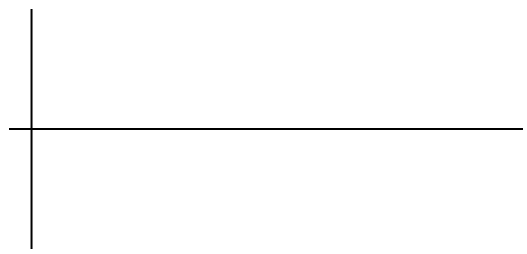
1. Experiment I (preferably drawn on millimeter block paper)

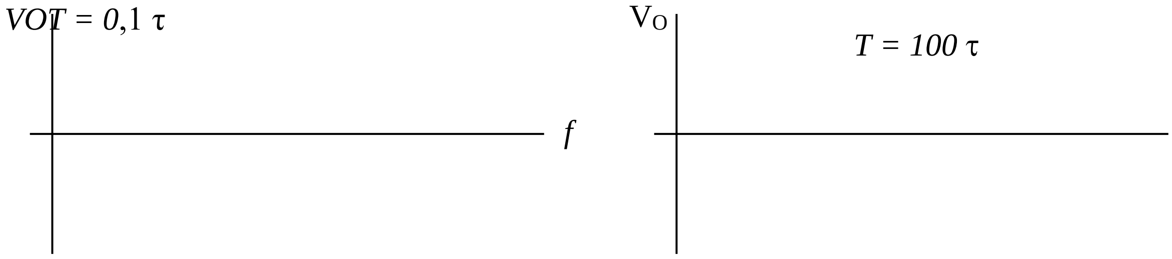
VVOT = τ
s



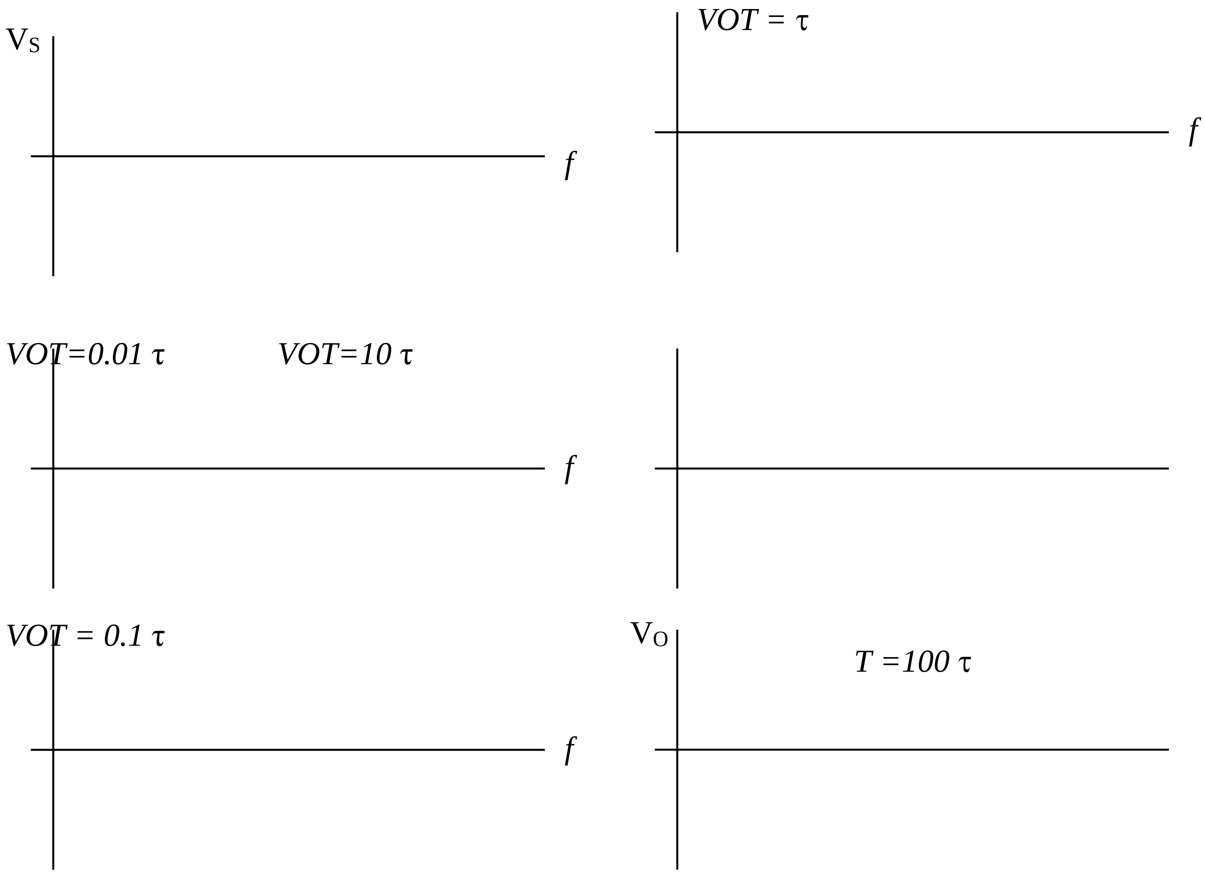
VOT = 0,01 τ *VOT=10* τ







2. Experiment II (preferably drawn on millimeter block paper)



G. FINAL TASK

1. Provide an explanation of the shape of the output graph obtained for both the integrating circuit and the differentiating circuit.
2. Explain the effect of value and the value on the Voltage graph The RC integrating output
3. Explain the effect of value and the value on the Voltage graph RC differentiation output

MODULE III

PASSING TAPES

A. PURPOSE

1. Studying the series of low pass filters and high pass filters
2. Graph the response of voltage amplitude to frequency
3. Graph the phase response to frequency
4. Can conclude that the low pass filter circuit can only pass low frequency signals only
5. Can conclude that the high pass filter circuit can only pass high frequency signals only

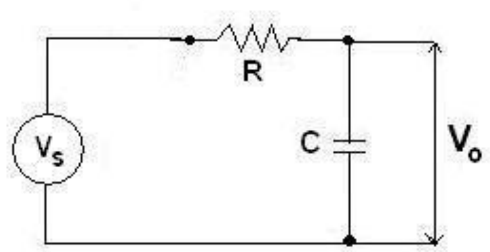
B. BASIC THEORY

1. Low-Pass Filter

A graph that shows the voltage variation or current variation in an electrical circuit is known as a *waveform*. There are many waveforms that will be encountered in electrical circuits, including sine (or sinusoidal), square, triangle, sawtooth (which can be positive or negative, and pulse). **Complex waveforms** such as speech or music generally have many component waves at different frequencies. **Pulse waveforms are** usually categorized as repetitive or non-repetitive. Signals can be conveyed using one or more of the properties of a waveform and transmitted through wires, cables, optical channels, and radio channels. Signals can also be processed in various ways using amplifiers, modulators, filters, etc.
A sinusoidal wave whose equation form:

$$V_S(t) = V_P \sin(\omega t + \phi_{0S})$$

Skipped in the RC series.



Resistance R and capacitance C form a complex voltage divider

$$\overline{V_O}(\omega) = \frac{\overline{Z_2}}{\overline{Z_1} + \overline{Z_2}} \overline{V_i}(\omega)$$

with $\overline{Z_1} = R$ and $\overline{Z_2} = \frac{1}{j\omega C}$

voltage comparison Complex output $\overline{V_O}(\omega)$ and complex input voltage $\overline{V_i}(\omega)$ is called a transfer function

$$\overline{G}(\omega) = \frac{\overline{V_O}(\omega)}{\overline{V_i}(\omega)} = \frac{1}{j\omega RC + 1} = \frac{1}{RC}\frac{1}{j\omega + 1/RC} = \frac{\omega_P}{j\omega + \omega_P}$$

with $\omega_P = 1/RC$ is called as poles.
Based on complex number theory, the magnitude of the complex transfer function,G(ω) is

$$G(\omega) = \frac{\omega_P}{(\omega^2 + \omega_P^2)^{1/2}}$$

The graph of the G(ω) called the amplitude response. For the above circuit when expressed in dB, the transfer function, G(ω) has the value

$$G(\omega)(dB) = 20\log\frac{V_O(\omega)}{V_i(\omega)} = 20\log\frac{\omega_P}{\sqrt{\omega^2 + \omega_P^2}} = 20\log\omega_P - 10\log(\omega^2 + \omega_P^2)$$

For frequencies much smaller than the polar frequency $(\omega << \omega_P)$, $G(\omega)(dB)=0$,

That is, $V_O(\omega) = V_i(\omega)$.

For frequencies much smaller than the polar frequency, then:

$$G(\omega)(dB) \cong 20\log\omega_P - 20\log\omega$$

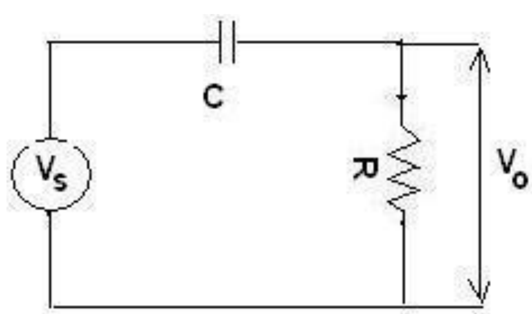
the greater the frequency, the smaller the output voltage
In addition to changing the voltage at the output, the frequency of the input signal alsochanges the phase of the output voltage. A graph expressing the relationship betweenphase difference $\Delta\phi = \phi_O - \phi_i$ between the output signal and the input signal versus frequency is called ***phase response***.

2. **High-Pass Filter**

A sinusoidal wave whose equation form:

$$V_S(t) = V_P \sin(\omega t + \phi_{0S})$$

Skipped in the RC series.



Resistance R and capacitance C form a complex voltage divider

$$\overline{V_O}(\omega) = \frac{\overline{Z_2}}{\overline{Z_1} + \overline{Z_2}}\overline{V_i}(\omega)$$

By $\overline{Z_1} = \frac{1}{j\omega C}$ and $\overline{Z_2} = R$

Complex output voltage $\overline{V_O}(\omega)$ comparison and complex input voltage $\overline{V_i}(\omega)$ is called a transfer function

$$\overline{G}(\omega) = \frac{\overline{V_O}(\omega)}{\overline{V_i}(\omega)} = \frac{R}{\frac{1}{j\omega C} + R} = \frac{j\omega}{j\omega + 1/RC} = \frac{j\omega}{j\omega + \omega_P}$$

With $\omega_P = 1/RC$ is called poles.

Based on complex number theory, the magnitude of the complex transfer function, *G*(ω) is

$$G(\omega) = \frac{\omega}{(\omega^2 + \omega_P^2)^{1/2}}$$

The graph of the transfer function *G*(ω) is called the amplitude response. For the above

Circuit, when expressed in dB, tansfer function $G(\omega)$, has the value:

$$G(\omega)(dB) = 20\log\frac{V_O(\omega)}{V_i(\omega)} = 20\log\frac{\omega}{\sqrt{\omega^2 + \omega_P^2}} = 20\log\omega - 10\log(\omega^2 + \omega_P^2)$$

For frequencies much smaller than the pole frequency $(\omega << \omega_P)$,the voltage amplitude response is

$$G(\omega)(dB) \cong 20\log\omega - 20\log\omega_P$$

That is, the smaller the frequency is from the pole frequency, the smaller the output voltage will be For frequencies much greater than the polar frequency, then:

In theory, it is found that at frequencies below the pole frequency, voltage attenuation occurs, while at frequencies above the pole frequency, the output voltage is equal to the input voltage.

In addition to changing the voltage at the output, the frequency of the input signal alsochanges the phase of the output voltage. A graph expressing the relationship between phase difference $\Delta\phi = \phi_O - \phi_i$

between the output signal and the input signal with respect to the do frequency is called ***phase response***

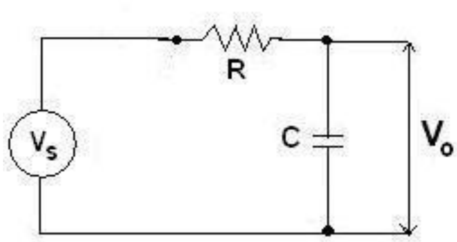
C. TOOLS AND MATERIALS

1. Resistors
2. Capacitors
3. Protoboard
4. Oscilloscope
5. Probe
6. AVOmeter
7. Audiogenerator
8. Red, black, green cable

D. TRIAL PROCEDURE

Low-pass filter

1. Arrange the series of R and C as shown below:



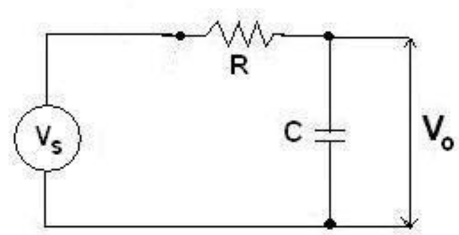
2. Calculate the peak frequency of the circuit using the equation:

$$f_P = \frac{1}{2\pi RC}$$ for R = 4700 Ω and C = 3.3 nF

3. Use a voltage source whose signal is a sinusoidal wave and take a *6 V* source$_{PP}$ by observing on an oscilloscope
4. Set the input frequency to *0.001* f_P *; 0.01* f_P *; 0.1* f_P *;* f_P *; 10* f_P *; 100* f_P , respectively measure the output voltage on the capacitor using a Voltmeter and draw the output voltage wave pattern observed on the oscilloscope.

High-pass filter

1. Arrange the series of R and C as shown below:



2. Calculate the peak frequency of the circuit using the equation:

$$f_P = \frac{1}{2\pi\ RC} \quad \text{for R = 4700 □ and C = 3.3 nF}$$

3. Use a voltage source whose signal is a sinusoidal wave and take a *6 V* source$_{PP}$ by observing on an oscilloscope
4. Set the input frequency to *0.001* f_P *; 0.01* f_P *; 0.1* f_P *;* f_P *; 10* f_P *; 100* f_P , respectively measure the output voltage on the capacitor using a Voltmeter and draw the output voltage wave pattern observed on the oscilloscope.

E. INTRODUCTION Tapis

Low-pass filter

1. Explain what is called cut-off frequency
2. Calculate f_P for values of $R = 4700\ \Omega$ and $C = 3.3\ nF$
3. Prove the equation $G(\omega)(dB) = 20\log f - 10\log(f^2 + f_P^2)$
4. Graph the amplitude response to the input frequency
5. Calculate the output voltage for an input frequency of *0.001* f_P *; 0.01* f_P *; 0.1* f_P *;*f_P *; 10* f_P *; 100* f_P ; for an input of 12 V_P .

High-pass filter

1. Calculate f_P for values of $R = 470\ \Omega$ and $C = 3.3\ nF$
2. Prove the equation $G(\omega)(dB) = 20\log f - 10\log(f^2 + f_P^2)$
3. Graph the amplitude response to the input frequency
4. Calculate the output voltage for an input frequency of *0.001* f_P *; 0.01* f_P *; 0.1* f_P *;*f_P *; 10* f_P *; 100* f_P ; for an input of 12 V_P .

F. OBSERVATION DATA FORMAT

1. Low-pass filter

R=......... *Ω* C=............F f_P = ...*Hz*

Input signal	V_{in} *(volts)*	f_{in} *(Hz)*	V_{out} = *volts*	Output signal

2. High-pas filter

R=......... Ω C=............F f_P = ...*Hz*

Input signal	V_{in} *(volts)*	f_{in} *(Hz)*	V_{out} = *volts*	Output signal

G. FINAL TASK

1. Calculate $G(\omega)(dB) = 20\log\frac{V_{out}(\omega)}{V_{in}(\omega)}$ for each of the above experimental results for low-pas filters and high-pass filter.
2. Graph the amplitude response of $G(\omega)$ to the input frequency for both low passand high pass filters.
3. Calculate the phase change for each of the above experimental results for boththe low pass filter and the high pass filter.
4. What are your conclusions about the results of this experiment?

MODULE IV
DIODE CHARACTERISTICS

A. PURPOSE

1. Learn how diodes work
2. Make a diode characteristic graph between the current and voltage of the diode
3. Determining the working point of a diode
4. Can determine the current and voltage values of a diode on its working line
5. Can distinguish how ordinary diodes and Zener diodes work

B. BASIC THEORY

Diodes include electronic components made from semiconductor materials. Diodes have a unique function that can only flow current in one direction only. The structure of the diode is nothing but a P and N semiconductor connection. One side is a semiconductor with type P and the other side is type N. With this structure, the current will only be ableto flow from the P side to the N side.

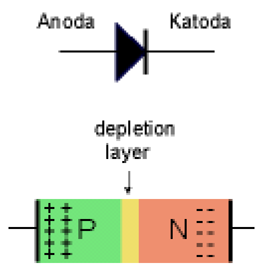


Figure 5.1. Diode symbol and structure

Figure 5.1. above shows a PN junction with a small portion called the *depletion layer*, where there is a balance of *holes* and electrons. As is well known, on the P side many *holes are* formed that are ready to receive electrons while on the N side there are many electrons that are ready to be free. Then if given a positive bias, in the sense of giving thepotential voltage of the P side greater than the N side, then the electrons from the N side will immediately be moved to fill the *hole* on the P side. Of course, if the electrons fill the *hole on the P* side, a *hole* will be formed on the N side because the electrons are left behind. This is called the flow of *holes* from P to N. If using the terminology of electric current, it is said that there is an electric flow from the P side to the N side.

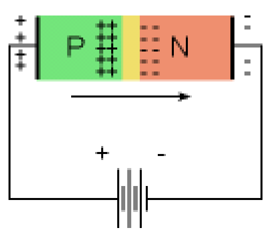


Figure 5.2. Diodes with forward bias

Conversely, what happens if the voltage polarity is reversed, namely by giving a negative bias (*reverse bias*). In this case, the N side gets a voltage polarity greater than the P side.

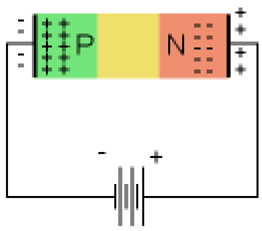


Figure 5.3. Diodes with negative bias

Of course, the answer is that there will be no electron transfer or *hole* flow from P to N or vice versa. Because both *holes* and electrons are attracted to the opposite side of the lid. In fact, the *depletion layer* is getting bigger and blocking the current.

That's a little bit of how a diode can only flow current in one direction. With only a small forward bias voltage, the diode has become a conductor. Not necessarily above 0 volts, but indeed a voltage of several volts above zero can only occur conduction. This is due tothe *depletion* wall (*depletion layer*). For diodes made of Silicon, the conduction voltage is above 0.7 volts. Approximately 0.2 volts is the minimum limit for diodes made of Germanium.

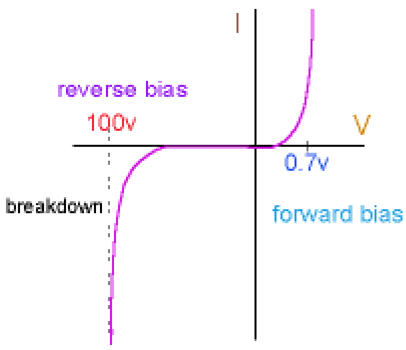


Figure 5.4. Diode current graph

Conversely, for negative bias, the diode cannot flow current, but there is a limit. Up to several tens or even hundreds of volts, *breakdown* occurs, where the diode can no longerwithstand the flow of electrons formed in the depletion layer.

Zener

This diode *breakdown* voltage phenomenon inspired the manufacture of another electronic component called Zener. Actually, there is no difference in the basic structureof the zener, but it is similar to a diode. But by giving a greater amount of doping to the P and N connections, it turns out that the breakdown voltage of the diode can be reached faster. If the diode usually only *breaks down* at a voltage of hundreds of volts, the Zener can occur in the tens and units of volts. In the datasheet there are zeners that have a Vz voltage of 1.5 volts, 3.5 volts and so on.

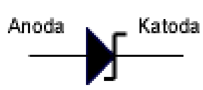


Figure 5.5. Zener symbol

This is a unique characteristic of zeners. If a diode works on forward bias then a zener isusually useful on negative bias (*reverse bias*).

LED

LED stands for *Light Emitting Diode*, which is a component that can emit light. LED is another invention after the diode. The structure is also the same as a diode, but it was later discovered that electrons that hit the P-N connection also release energy in the formof heat energy and light energy. LEDs are made to be more efficient when it comes to emitting light. To get light emission in semiconductors, the doping used is gallium, arsenicand phosphorus. Different types of doping produce different colors of light.

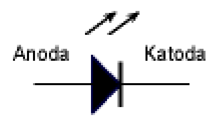


Figure 5.6. LED Symbol

Currently, the most common LED light colors are red, yellow and green. Blue LEDs are very rare. Basically, all colors can be produced, but it will be very expensive and inefficient. In selecting LEDs in addition to color, it is necessary to consider the working voltage, maximum current and power dissipation. The LED housing (*chasing*) and shape also vary, there are rectangular, round and oval.

Application

Diodes are widely applied in power supply *rectifier* circuits or AC to DC converters. In the market, there are many diodes such as 1N4001, 1N4007 and others. Each type is different depending on the maximum current and also the breakdown voltage. Zener is widely used for *voltage regulator* applications. Zener on the market is of course many types depending on the *breakdown* voltage. In the datasheet, this specification is usually called Vz (*zener voltage*) complete with tolerances, and also power dissipation capabilities.

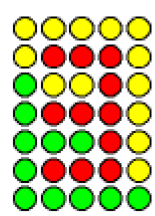


Figure 5.7. LED array

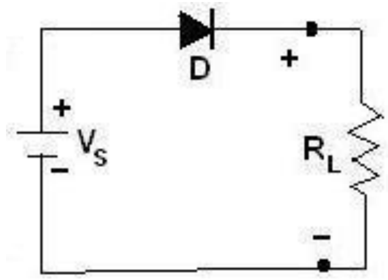
LEDs are often used as indicators where each color can have a different meaning. On,off and blinking can also mean different things. LEDs in the form of an *array* can be a large display. LEDs are also known in the form of 7 *segments* or there are also 14 *segments*. Usually used to display numeric and alphabetical numbers.

C. TOOLS AND MATERIALS

1.	Resistor	220Ω , 1KΩ
2.	potentiometer	5 KΩ
3.	Diodes	IN4001
4.	Diode	
5.	AVOmeter	2V7 4V7 6V2
6.	Battery or DC power	
7.	Red, black, green cable	
8.	Protoboard	

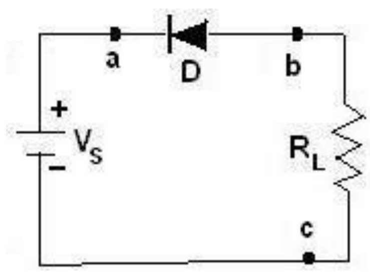
D. EXPERIMENT PROCEDURE

1. Studying the characteristics of diodes on **forward bias** (*Forward*)
   a. Arrange the circuit as shown below on the circuit board with diode IN4001and R_L = 1KΩ



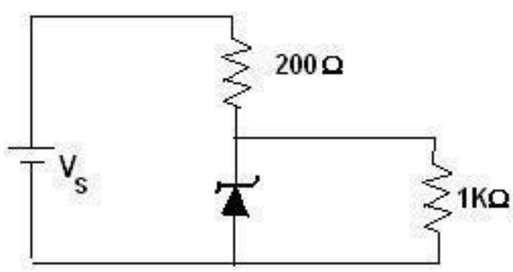
   b. Set the source voltage between 0 and 1 Volt at 0.1 volt intervals
   c. Measure the current flowing through the diode at each input value.
   d. Also measure the voltage on the diode
   e. Perform steps b, c and d again for inputs between 1 and 5 volts at 1 volt intervals.

2. Studying the characteristics of diodes on *reverse* **bias**
   a. Arrange the circuit as shown below on the circuit board with diode IN4001and R_L = 1KΩ



   b. Set the source voltage between 0 and 10 Volts at 1 volt intervals
   c. Measure the current flowing through the diode at each input value.
   d. Also measure the voltage on the diode

3. Zener Regulator Circuit
   a. Make the circuit as shown below with zener 2V7



   b. Set the input voltage between 0 and 12 volts at 1 volt intervals.
   c.Record the voltage at the resistance parallel to the zener, and also recordthe amount of current flowing in the zener.
   d. do steps a, b, and c for zener 4V7
   e. do steps a, b, and c for zener 6V2

E. PRELIMINARY TASK

1. Explain what is known as the Cut off point
2. Determine the cut-off voltage for germanium diodes
3. Determine the cut-off voltage for Silicon diodes
4. Explain why there is a cut-off voltage on germanium diodes and silicon diodes
5. Explain the difference between a bias diode and a zener diode
6. Why are zener diodes installed on reverse bias?

F. OBSERVATION DATA FORMAT

1. Diode characteristic data on **forward bias** (*Forward*)

Source voltage (DC) (volts)	Diode Current (I_D) (A)	Diode Voltage (V_D) (volts)
0,1		
0,2		
0,3		
0,4		
0,5		
0,6		
0,7		
0,8		
0,9		
1,0		
2,0		
3,0		
4,0		
5,0		

2. Diode characteristic data on *reverse* **bias**

Source voltage (DC) (volts)	Diode Current (I_D) (A)	Diode Voltage (V_D) (volts)
1,0		
2,0		
3,0		
4,0		
5,0		
6,0		
7,0		
8,0		
9,0		
10,0		

3. Zener Reguletor

Source Voltage	2V7		4V7		6V2	
	ID	VL	ID	VL	ID	VL
0						
1,0						
2,0						
3,0						
4,0						
5,0						
6,0						
7,0						
8,0						
9,0						
10,0						
11,0						

G. FINAL TASK

1. Based on tables 1 and 2, draw a graph between diode current and diode voltage.
2. Based on the resulting graph, determine the cutting voltage of the diode used
3. Draw your conclusions on the resulting diode characteristic graphs
4. Determine the working line of the diode for R_L = 1 □□ and V_{DD} = 3 volts. Determine the working point of the diode in this state what is the value of I_D and V_D.
5. How is a zener diode different from a regular diode?

MODULE V

WAVE RECTIFIERS

A. PURPOSE

1. Study the characteristics of a single-phase rectifier circuit for half-wave
2. Study the characteristics of single-phase rectifier circuits for full waves
3. Can summarize the role of resistors and capacitors in wave rectifiers

B. BASIC THEORY

Semiconductor diodes are usually used to convert alternating current (ac) into direct current (dc). In this case the diode circuit is referred to as a *rectifier*. The simplest form of rectifier has a single diode. Since it only works on the positive or negative half cycle of the source, the circuit is known as a half-wave rectifier.

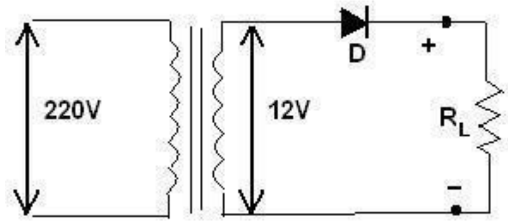


Figure 6.1. Half-Wave Rectifier

The 220 V PLN voltage is fed to the primary side of a step down transformer. The secondary side of the transformer lowers the rms voltage from 220V to 12V rms. Diode D will only allow current to flow from the cathode to the anode. Diode D will be forward biased for the duration of each positive half-cycle and will effectively work like a closing switch. When the circuit current attempts to flow in the opposite direction,the voltage bias on the diode will reverse, causing the diode to act like an open switch.

Half-wave rectifiers are relatively inefficient, as the transmission only occurs during each positive half-cycle. A better rectifier arrangement would utilize both the positive half-cycle and the negative half-cycle. Full-wave rectifiers are not only more efficient, but also require fewer smoothing components and reservoir components. There are two types of full-wave rectifiers: (1) the two-phase type, and (2) the bridge rectifier type.

In a **two-phase rectifier**, a 220V source voltage is applied to the primary side of a step-down **transformer** that has two identical secondary windings, each providing a12V rms voltage. This type of travo is known as a center type (CT) travo.

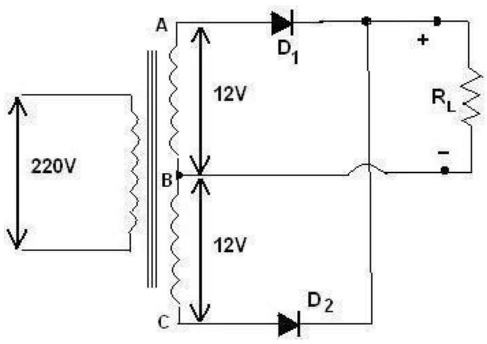


Figure 6.2. 2-Phase Full Wave Rectifier

In the positive half cycle, point A will be positive to point B and point B will be positive to point C. In this condition, D1 will conduct (its anode will be positive to the cathode), while D2 will not conduct (its anode will be negative).

against the cathode). Only D1 will conduct in the positive half cycle, while D2 will act as an open switch.

In the negative half cycle, point C will be positive to point B and point B will be positive to point A. In this condition, D2 will conduct (its anode will be positive to the cathode), while D1 will not conduct (its anode will be negative to the cathode). Only D2 will conduct in the negative half cycle, while D1 will act as an open switch.

As a result, the current is applied to the load in the same direction in each successive half cycle. Unlike the half-wave rectifier, which has the same output frequency as the primary frequency of 50 Hz. In this full-wave rectifier, the voltage pulses arising at RL have twice the frequency at 100 Hz. This doubling of the ripple frequency allows us to use smaller reservoir capacitors or smoothing capacitors to achieve the same level of ripple reduction.

The same result can also be achieved using a four-diode bridge rectifier, with both pairs of diodes on opposite sides conducting at each alternating half-cycle. This system avoids the use of a center type transformer (CT).

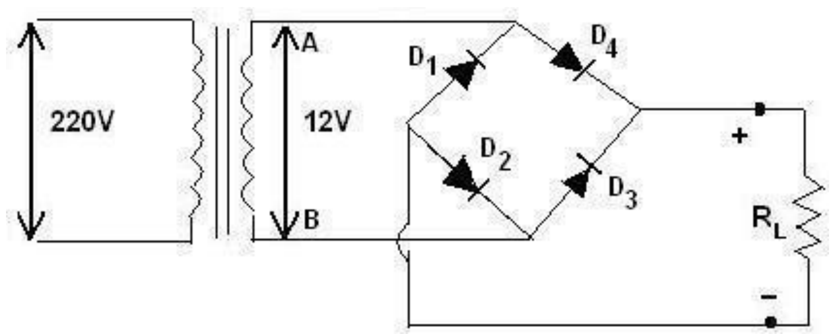


Figure 6.3. 4-Bridge Full Wave Rectifier

In the positive half cycle, point A will be more positive towards point B. In this condition, diodes D4 and D2 will conduct, while D1 and D2 do not conduct or act as an open switch. In the negative half cycle, point B will be more positive towards point A.In this condition, diodes D3 and D1 will conduct, while D2 and D4 do not conduct or act as an open switch. The results obtained are the same as using a travo with two secondary coils (CT), that is, the current is flowing through the load in the same direction in each successive half cycle.

C. TOOLS AND MATERIALS

1. Resistors
2. Diodes
3. Protoboard
4. Oscilloscope
5. Probe
6. AVOmeter
7. CT and ZERO transformers
8. Red, black, green cable

D. EXPERIMENT PROCEDURE

1. Experiment I Half-Wave Rectifier
   a. Make a half-wave rectifier circuit using IN4001 diode as shown in Figure 6.1.,with RL = 10
   b. Set circuit input from 6 volt step down travo secondary voltage
   c. Draw the input waveform of the transformer based on observations with an oscilloscope.
   d. Measure and draw the output waveform at RL
   e. Perform the above steps for a 9 volt input
   f. Perform the above steps for 12 volt input

2. Experiment II: Two-phase Full Wave Rectifier
   a. Make a full-wave rectifier circuit using IN4001 diode as shown in Figure 6.2.,with R_L = 10 □□
   b. Set circuit input of 6-volt peak-peak step down travo secondary voltage
   c. Draw the input waveform of the transformer based on observations with an oscilloscope.
   d. Measure and draw the output waveform at R_L
   e. Perform the above steps for 9 volts peak-peak input
   f. Perform the above steps for a 12-volt peak-peak input

3. experimentIII: Four-bridge full-wave rectifier
   a. Make a full-wave rectifier circuit using IN4001 diodes as shown in Figure 6.3.,with R_L = 10 □□
   b. Set circuit input from 6 volt step down travo secondary voltage
   c. Draw the input waveform of the transformer based on observations with an oscilloscope.
   d. Measure and draw the output waveform at R_L
   e. Pair a 100 nF capacitor parallel to R_L
   f. Measure and draw the output waveform at R_L

E. PRELIMINARY TASK

1. Determine the wave equation of the input voltage with V_{rms} of 6 volts, 9 volts and12 volts respectively with a source voltage frequency of 50 Hz and a phase constant of zero initially.
2. Draw the output voltage waveform for a half-wave rectifier with an rms input voltage of 9 volts
3. Whether the amplitude height of the input voltage waveform is equal to the amplitude height of the output waveform

F. OBSERVATION DATA FORMAT

1. Experiment I Half-Wave Rectifier

Input Voltage	Input Signal	Output Signal
6 Volts	V t	V t
9 Volts	V t	V t
12 volts	V t	V t

2. Experiment II: Two-phase Full Wave Rectifier

Input Voltage	Input Signal	Output Signal
6 VPP	V … t	V … t
9 VPP	V … t	V … t
12 VPP	V … t	V … t

3. Experiment III: Four-bridge full-wave rectifier

Input Voltage	Input Signal	Output Signal	Output (RL/XC)
6 Volts	V … t	V … t	V … t
9 Volts	V … t	V … t	V … t
12 volts	V … t	V … t	V … t

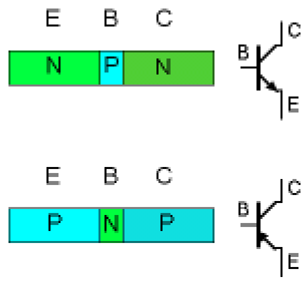
G. FINAL TASK

1. Explain the role of IN4001 diode for half-wave rectifier
2. Describe the process of output voltage signal formation in a two-phase rectifier
3. Describe the process of output voltage signal generation in a four-bridge rectifier
4. Why is the output voltage amplitude lower than the input voltage amplitude? What is the difference?
5. Determine the output signal frequency for a full-wave rectifier
6. Explain the function of a reservoir capacitor installed in parallel with RL.

MODULE VI
TRANSISTOR APPLICATIONS

A. PURPOSE
1. Studying the input characteristics of grounded base transistors
2. Studying the output characteristics of grounded transistors
3. Make a graph of the characteristics of the grounded base transistor

B. BASIC THEORY
The transistor is a diode with two connections (*junction*). The connection forms a PNP orNPN transistor. The ends of the terminals are called emitter, base and collector, respectively. Base is always in the middle, between the emitter and collector. This transistor is called a bipolar transistor, because its structure and working principle depends on the displacement of electrons in the negative cap filling the lack of electrons(holes) in the positive cap. bi = 2 and polar = cap. It was William Shockley in 1951 who first discovered the bipolar transistor.



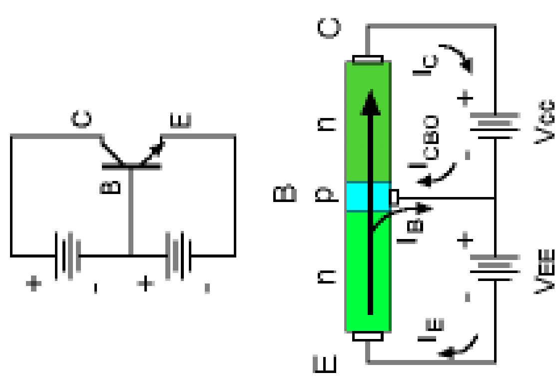
npn and pnp transistors

To be explained later, a transistor is a component that works as an *on/off switch* and also as an *amplifier*. The bipolar transistor is an innovation that replaces the tube transistor (*vacuum tube*). In addition to the relatively smaller dimensions of the bipolar transistor, itspower dissipation is also smaller so that it can work at cooler temperatures. In some applications, tube transistors are still used, especially in audio applications, to get good sound quality, but their power consumption is very large. Because to be able to release electrons, the technique used is heating the filament like in incandescent lamps.

DC Bias

The bipolar transistor has 2 junctions which can be equated to the combination of 2 diodes. Emitter-Base is one junction and Base-Collector the other junction. As in diodes, current will only flow only if given a positive bias, that is, only if the voltage on material Pis more positive than material N (*forward bias*). In the following illustration of an NPN transistor, the base-emitter junction is given a positive bias while the base-collector gets anegative bias (*reverse bias*).

npn transistor electron current

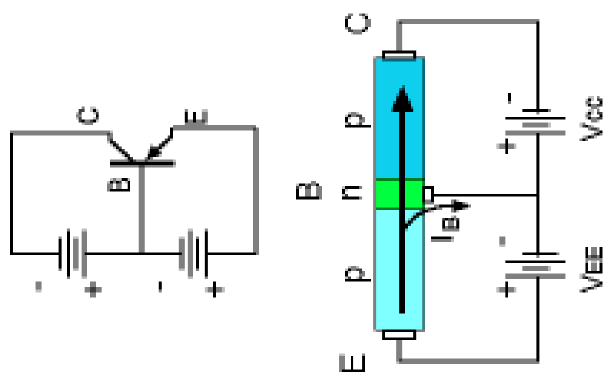


Because the base-emitter gets a positive bias then as in a diode, electrons flow from the emitter to the base. The collector in this circuit is more positive because it gets positive voltage. Since the collector is more positive, the electron flow moves towards thiscap. Suppose there is no collector, the flow of electrons will all go to the base like in a diode. But since the width of the base is very thin, only some of the electrons can combine with the holes in the base. Most will pass through the base layer towards the collector. This is the reason why if two diodes are combined it cannot be a transistor, because the requirement is that the base width must be very thin so that it can be penetrated by electrons.

If for example the base-emitter voltage is reversed (*reverse bias*), there will be no electron flow from the emitter to the collector. If slowly the base 'tap' is given a *forward* bias (*forward bias*), electrons flow towards the collector and the amount is proportional to the amount of base bias current given. In other words, the base current regulates the number of electrons flowing from the emitter to the collector. This i s called the transistorgain effect, because a small base current produces a larger emitter-collector current. The term *amplifier* (strengthening) to be misunderstood, because with the above explanation actually happens not strengthening, but rather a smaller current controls the flow of largercurrents. It can also be explained that the base regulates the opening and closing of the emitter-collector current flow (*on/off switch*).

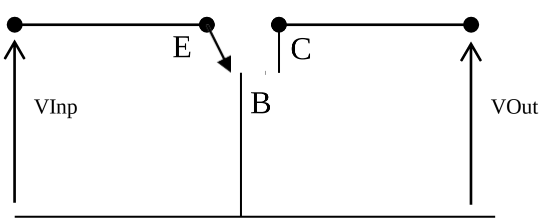
In PNP transistors, the same phenomenon can be explained by providing a bias as in thefollowing figure. In this case, the so-called current transfer is the hole current.

hole current of pnp transistor



To facilitate further discussion of the transistor bias principle, here is the terminology of transistor parameters. In this case the current direction is from a larger potential to a smaller potential.

In order for the transistor to function as an amplifier, it must be sought connection between the emitter-base (emitter connection or JE) must get a forward voltage and the connection between the base-collector (collector connection or JC) must get a reverse voltage. An amplifier circuit with a grounded base transistor is as follows:



The input is tapped from the base-emitter terminal and the output is tapped from the base-collector terminal. So the base terminal is shared as a base, so this type of amplifieris known as an amplifier with a grounded base.

Static input characteristics can be studied through measuring the input voltage, namely the voltage between the emitter-base (VEB) and the input current strength, namely the current strength entering through the emitter (IE) at a certain output voltage (VCB).

The input properties of a PNP transistor in an all-base configuration are shown by graphing IE (mA) against VBE (volts). The resulting graph characteristics will be different fordifferent VCB values. This characteristic graph is identical to the characteristics of a forward biased diode.

The nature of the transistor input in the CB configuration which is affected by the VCB voltage is due to the thickening of the empty region (depletion region) at the JC connection because the VC connection voltage is increasingly negative if VCB is increasingly negative. With the thickening of the empty region means that the base thickness is effectively reduced. There are two consequences caused by the reduced base thickness. First,
□ becomes larger, because the hole injection in the base region that performs recombination is reduced in number. Second, because the effective distance between JE and JC is getting smaller, the decrease in the concentration of minority hole injection in the base region is getting sharper. Note that when the collector-base junction is subjected to reverse voltage, the concentration of hole injection at this junction is close to zero. With a sharper decrease in concentration, the IE price becomes larger. So to summarize, as VCB becomes more negative, if VEB remains fixed, the IE price becomes larger.

Static output characteristics can be studied through measuring the output voltage, namely the voltage between the base collector (VCB) and the output current strength, namely the current strength that comes out through the terminal collector (IC) at a certain input current (IE).
The nature of the PNP transistor output in a shared base configuration can be described from the characteristics generated by the collector current (IC) against the base collector voltage (VCB) at a certain current value IE. From the resulting graph can be observed threeregions of output properties, namely: dead area, active area and saturated area.

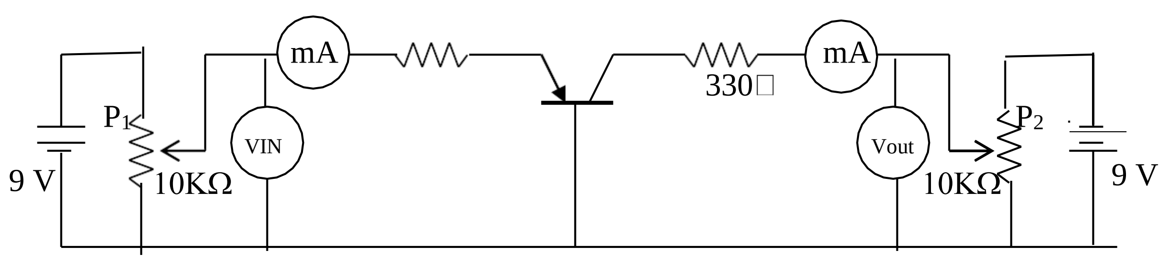
C. TOOLS AND MATERIALS

1. Voltmeter
2. Ammeter
3. Power suplay (bateray)
4. Protoboard
5. Resistor □□□□
6. Potentiometer 10K

D. TRIAL PROCEDURE

Static Characteristics Input

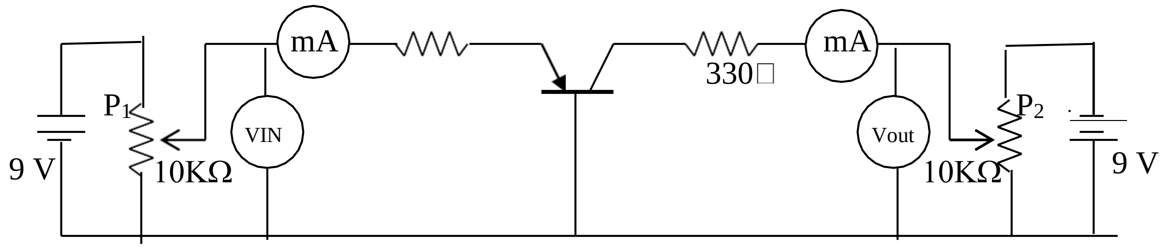
1. Create a circuit as shown in the diagram below with both voltage sources in an open state



2. After the circuit has been checked by the supervisor and is correct, change the potentios P1 and P2 to the minimum position, then connect them to the voltage source.
3. Change the potentio P1 so as to obtain VEB (input voltage) 0.5 volts, while P2 remainsminimum, so that VCB = Vout = 0. Record the current strength at the emitter (IE).
4. Perform step 3 for voltages VEB to 6 volts at 0.5 volt intervals
5. Perform steps 3 and 4 for 3-volt, 6-volt and 9-volt VCBs

Output Static Characteristics

1. Make a circuit like the scheme below with both voltage sources in the openstate



2. After the circuit has been checked by the supervisor and is correct, changethe potentios P1 and P2 to the minimum position, then connect them to the voltage source.
3. Change the potentio P_1 so that the current $I_E = 1mA$ *is* obtained. Set P_2 so asto get V_{CB} = 1volt, record the amount of current on the collector (I_C)
4. Perform step 3 for V_{CB} voltages up to 9 volts at 1 volt intervals
5. Perform steps 3 and 4 for I_E 5 mA, 10 mA, 15 mA, 20 mA and 25 mA

E. PRELIMINARY TASK

1. Make a graph of the input characteristics of the grounded base transistor, where theemitter current strength (I_E) is the Y axis and the base-emitter voltage (V_{EB}) is the X axis.
2. Make a characteristic graph ofoutput grounded base transistor, where the strong collector current (I_C) as the Y axis and the collector-base voltage (V_{CB}) as the X axis.

F. FORMAT DATA Observation

Static Characteristics Input

No.	V_{CB} = 0 volts		V_{CB} = 3 volts		V_{CB} = 6 volts		V_{CB} = 9 volts	
	V_{EB} (volts)	I_E	V_{EB} (volts)	I_E	V_{EB} (volts)	I_E	V_{EB} (volts)	I_E
1	0,5		0,5		0,5		0,5	
2	1,0		1,0		1,0		1,0	
3	1,5		1,5		1,5		1,5	
4	2,0		2,0		2,0		2,0	
5	2,5		2,5		2,5		2,5	
6	3,0		3,0		3,0		3,0	
7	3,5		3,5		3,5		3,5	
8	4,0		4,0		4,0		4,0	
9	4,5		4,5		4,5		4,5	
10	5,0		5,0		5,0		5,0	
11	5,5		5,5		5,5		5,5	
12	6,0		6,0		6,0		6,0	

Output Static Characteristics

No.	I_E = 1 mA		I_E = 5 mA		I_E = 10 mA		I_E = 15 mA		I_E = 20 mA		I_E = 25 mA	
	V_{CB} (volts)	I_C	V_{CB} (volts)	I_C	V_{CB} (volts)	I_C	V_{CB} (volts)	I_C	V_{CB} (volts)	I_C	V_{CB} (volts)	I_C
1	1,0		1,0		1,0		1,0		1,0		1,0	
2	2,0		2,0		2,0		2,0		2,0		2,0	
3	3,0		3,0		3,0		3,0		3,0		3,0	
4	4,0		4,0		4,0		4,0		4,0		4,0	
5	5,0		5,0		5,0		5,0		5,0		5,0	
6	6,0		6,0		6,0		6,0		6,0		6,0	
7	7,0		7,0		7,0		7,0		7,0		7,0	
8	8,0		8,0		8,0		8,0		8,0		8,0	
9	9,0		9,0		9,0		9,0		9,0		9,0	

G. FINAL TASK

1. Graph the input characteristics of a grounded base transistor, where the emitter current strength (I_E) is the Y-axis and the base-emitter voltage (V_{EB}) is the X-axis.Draw it for different values of V_{CB} on the same cartesian plane.
2. Graph the output characteristics of a grounded base transistor, with the collector current (I_C) as the Y-axis and the collector-base voltage (V_{CB}) as the X-axis. Draw itfor different values of I_E on the same cartesian plane.
3. Compare the input characteristic curve of a transistor with the characteristic curveof a forward biased diode, give your explanation!
4. For the output characteristic curve of the transistor, determine the dead region,active region and saturated region of the grounded base transistor

MODULE VII
CHARACTERISTICS OF GROUNDED EMITTER TRANSISTORS

A. PURPOSE
1. Observe the characteristics of transistor amplifier with grounded emitter
2. Observe the linking process on grounded emitter transistors
3. Determines the voltage gain value at the output of a grounded emitter transistor

B. BASIC THEORY

Has been discussed in class about the bias current that allows electrons and holesdiffuse between the collector and emitter across the thin base layer. To summarize, the working principle of the transistor is a small base-emitter bias current regulates the large collector-emitter current. The next important part is how to give the right bias current so that the transistor can work optimally.

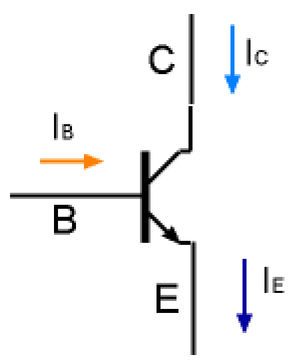
Bias current

There are three common ways to give bias current to the transistor, namely the circuit CE(Common Emitter), CC (Common Collector) and CB (Common Base). But this time willbe more detailed explained bias transistor CE circuit. By analyzing the CE circuit will be able to know some important parameters and useful especially for selecting the right transistor for a particular application. Of course for audio frequency signal processing applications should not use power transistors, for example.

Emitter Current

From Kirchhoff's law it is known that the amount of current entering a point will be equalto the amount of current coming out. If the theorem is applied to the transistor, then the law explains the relationship:

$$I_E = I_C + I_B \quad (1)$$



emitter current

Equation (1) says the emitter current IE is the sum of the collector current I_C with the base current I_B. Because the I_B current is very small or mentioned $I_B << I_C$, it can be stated:

$$I_E = I_C \quad (2)$$

Alpha (α)

In the transistor data table (*databook*) often found alpha dc specifications (α_{dc}) which isnone other than :

$$\alpha_{dc} = I / I_{CE} \ldots\ldots\ldots\ldots\ldots(3)$$

Its definition is the ratio of collector current to emitter current.

Because the large collector current is generally almost equal to the large emitter current then ideally large α_{dc} is = 1 (one). But generally existing transistors have α_{dc} approximately between 0.95 to 0.99.

Beta (β)

Beta is defined as the ratio between collector current and base current.

$$\beta = I / I_{CB} \ldots\ldots\ldots\ldots\ldots(4)$$

In other words β is a parameter that indicates the current gain capability of a transistor. This parameter is listed in the transistor *databook* and is very helpful for electronic circuit designers in planning the circuit.

For example, if a transistor is known to be large β= 250 and the desired collector current of 10 mA, then what is the required base bias current. Of course the answer is very easy,namely:

$$I_B = I_C / \beta = 10mA/250 = 40\ \mu A$$

The current that occurs at the collector of a transistor that has β = 200 if given a basebias current of 0.1mA is :

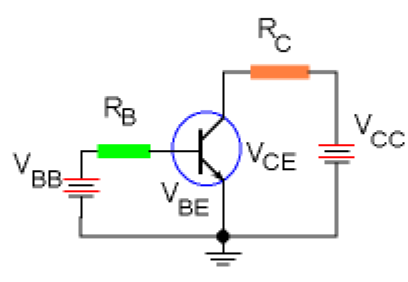
$$I_C = \beta\ I_B = 200 \times 0.1mA = 20\ mA$$

From this formulation, the definition of transistor current gain is more visible, which is again, a small base current becomes a larger collector current.

Common Emitter (CE)

The CE circuit is the most commonly used circuit for various applications that usetransistors. Named CE circuit, because the ground point or the point of 0 volt voltage is connected at the emitter point.

CE circuit



Notation at a Glance

There are several notations that are often used to indicate the amount of voltage at a point or between points. Notation with 1 subscript is to indicate the amount of voltage atone point, for example VC = collector voltage, VB = base voltage and VE = emitter voltage.

There is also a notation with 2 subscripts used to indicate the amount of stress between 2points, which is also called pinch stress. Among them are :

VCE = collector-emitter pinch voltage

VBE = base - emitter pinch voltage

VCB = collector - base pinch voltage

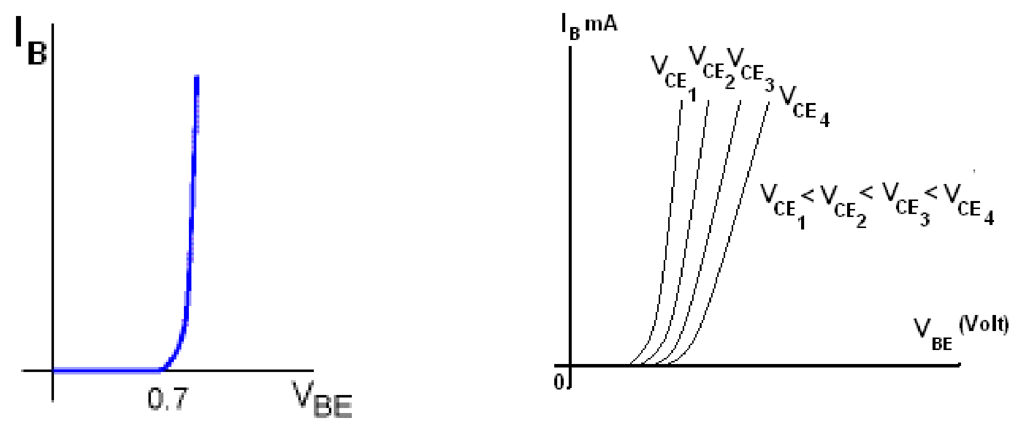
Notations such as VBB, VCC, VEE are the voltage sources that enter the base, collector andemitter points, respectively.

Base Curve

The relationship between IB and VBE will of course be a diode curve. Because it is known that the base-emitter junction is nothing but a diode. If Ohm's law is applied to the base loop, it is known to be:

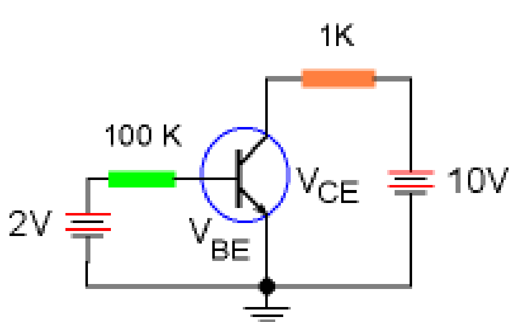
$$IB = (VBB - VBE) / RB \text{ .... } (5)$$

VBE is the pinch voltage of the base-emitter junction diode. Current will only flow if the voltage between the base-emitter is greater than VBE. So that IB current begins to actively flow when a certain VBE value.



curve I_B -V_{BE} (*CE Input Characteristics)*

The amount of VBE is generally listed in the *databook*. But for simplification it is generally known that VBE = 0.7 volts for silicon transistors and VBE = 0.3 volts for germanium transistors. The ideal value of VBE = 0 volts.



At this point it will be very easy to know the IB current and IC current of the following circuit, if known to be large □ = 200. Let's say that is used is a transistor made of silicon material.

circuit-01

$I_B = (V_{BB} - V_{BE}) / R_B$

$= (2V - 0.7V) / 100\ K$

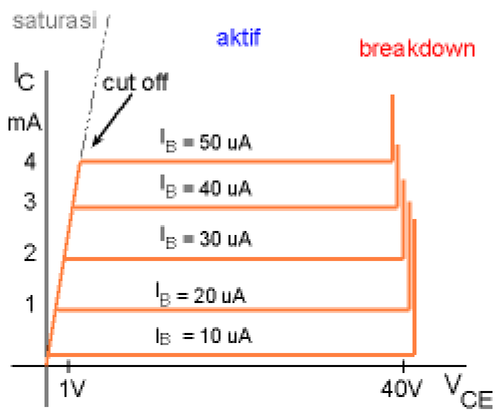
$= 13\ uA$

With = 200, the collector current is :

$I_C = $ $I_B = 200 \times 13uA = 2.6\ mA$

Collector Curve

Now we know the concept of base current and collector current. Another interesting point is the relationship between base current I_B, collector current I_C and collector-emittervoltage V_{CE}. By using *circuit-01*, the voltages V_{BB} and V_{CC} can be adjusted to obtain a plotof the collector curve lines. In the following figure, several collector curves of current I_C versus V_{CE} have been plotted where current I_B is held constant.



collector curve(CE Output Characteristics)

From this curve there are several regions that show the working area of the transistor. First is the *saturation* region, then the *cut-off* region, then the *active* region and then the *breakdown* region.

Active Region

The normal working area of the transistor is in the active region, where the I_C current is constant against any value of V_{CE}. From this curve is shown that the current I_C depends only on the amount of current I_B. This working area is also called the linear region (*linear region*).

If Kirchhoff's law of voltage and current is applied to the collector loop (CE circuit), the relationship can be obtained:

$$V_{CE} = V_{CC} - I_C R_C \text{..............................} (6)$$

It can be calculated that the power dissipation of the transistor is:

$$P_D = V_{CE} . I_C \text{................................} (7)$$

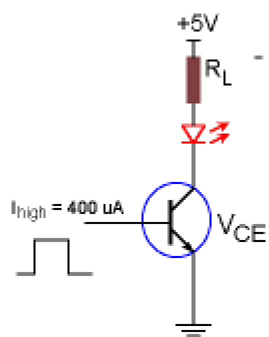
This formula says the amount of transistor power dissipation is the collector-emitter voltage multiplied by the amount of current through it. This power dissipation is in theform of heat which causes an increase in transistor temperature. Generally for power transistors it is necessary to know the P_{Dmax} specification. This specification indicates the maximum working temperature allowed for the transistor to still work normally. Because ifthe transistor works beyond the P_{Dmax} power capacity, the transistor can be damaged or burned.

Saturation Region

The saturation region is from $V_{CE} = 0$ volts to approximately 0.7 volts (silicon transistors), which is due to the collector-base diode effect where the V_{CE} voltage is insufficient to cause electron flow.

Cut-Off Region

If then the V_{CC} voltage is raised slowly, until a certain V_{CE} voltage suddenly I_C current starts to constant. At the time of this change, the working area of the transistor is in the cut-off region that is from the saturation state (OFF) and then become active (ON). This change is used in digital systems that only recognize binary numbers 1 and 0 which can be represented by the status of the transistor OFF and ON.



LED driver circuit

Suppose that in the LED driver circuit above, the transistor used is a transistor with β =50. LED ignition is regulated by a *logic gate* with a *high output* current = 400 μA and known LED forward voltage, $V_{LED} = 2.4$ volts. Then the question is, what should be theresistance R_L used.

$I_C = \beta I_B = 50 \times 400\ \mu A = 20$ mA

This amount of current is enough to light the LED at the transistor *cut-off*. The voltage V_{CE} at *cut-off* should ideally = 0, and this approximation is sufficient for this circuit.

$R_L = (V_{CC} - V_{LED} - V_{CE}) / I_C$

= (5 - 2.4 - 0)V / 20 mA

= 2.6V / 20 mA

= 130 Ohm

Breakdown Area

From the collector curve, it can be seen that if the V_{CE} voltage is more than 40V, the I_C current rises rapidly. Transistors in this area are called in the breakdown area. The transistor should not work in this area, because it will be able to damage the transistor. For various types of transistors, the value of VCEmax voltage allowed before breakdown varies. V_{CEmax} on the transistor databook is always listed as well.

Transistor datasheet

Earlier we mentioned some transistor specifications, such as voltage VCEmax and P_D max. Often also listed on the datasheet other information about the current ICmax V_{CBmax} and V_{EBmax}. There is also P_{Dmax} at T_A = 25° and P_{Dmax} at T_C = 25° . For example, the transistor 2N3904 listed data such as:

V_{CB} max = 60V
VCEOmax = 40V
V_{EBmax} = 6 V
ICmax = 200mAdc
PDmax = 625 mW T_A = 25°
P_{Dmax} = 1.5W T_C = 25°

T_A is ambient temperature, which is room temperature. While T_C is the temperature of the transistor cashing. Thus if the transistor is equipped with a *heatshink*, then the transistor can work with greater power dissipation capabilities.

□ or h_{FE}

In the circuit analysis system, the parameter h is also known, stating h_{FE} as $\square_{dc}$ to say thecurrent gain.

$$\square_{dc} = h_{FE} \quad \ldots\ldots\ldots\ldots (8)$$

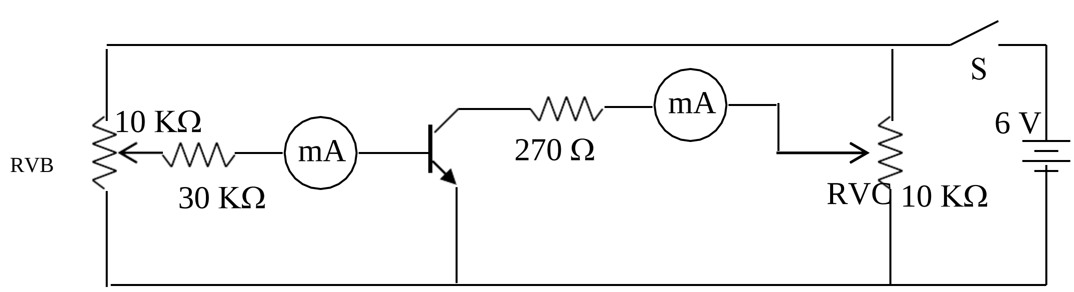
Just like the inclusion of theidc value, the datasheet generally lists the minimum h_{FE} value (h_{FE} min) and the maximum value (h_{FE} max).

C. TOOLS AND MATERIALS

1. Voltmeter
2. Ammeter
3. Power suplay (bateray)
4. Protoboard
5. Resistor 270Ω, 30KΩ
6. Potentiometer 10K

D. EXPERIMENT PROCEDURE

1. Make the circuit as below



2. Set R_{VB} and R_{VC} in the minimum position, after the circuit is declared correct by the supervisor and connect the switch S
3. Change the resistance R_{VB}, while the potentio R_{VC} is in the minimum position (V_{CE}=0).Measure and record the base emitter voltage (V_{BE}) and base current strength (I_B) every time VBE = 0.1 volt changes.
4. Repeat step 3 for different V_{CE}s by rotating R_{VC}, e.g. 1 volt, 2 volt, and 4 volt V_{CE}s.
5. Attach a milliampere (mA) to the collector to measure the collector current (I_C). Set R_{VB} to obtain a current at the base of 10 A, then change the magnitude of the

R_{VC}. Measure and record the collector-emitter voltage (V_{CE}) and collector current strength (I_C) every time VCE = 1 volt changes.

6. Repeat step 5 for different base current strengths by rotating the R_{VB}, e.g. I_B 20 µ A, 30 µ A, and 40 µ A

E. OBSERVATION DATA FORMAT

1. Static Characteristics of Common Emitter Input

No.	V_{CE} = 0 volts		V_{CE} = 1 volt		V_{CE} = 2 volts		V_{CE} = 4 volts	
	V_{BE} (volts)	I_B	V_{BE} (volts)	I_B	V_{BE} (volts)	I_B	V_{BE} (volts)	I_B
1	0,0		0,0		0,0		0,0	
2	0,1		0,1		0,1		0,1	
3	0,2		0,2		0,2		0,2	
4	0,3		0,3		0,3		0,3	
5	0,4		0,4		0,4		0,4	
6	0,5		0,5		0,5		0,5	
7	0,6		0,6		0,6		0,6	
8	0,7		0,7		0,7		0,7	
9	0,8		0,8		0,8		0,8	
10	0,9		0,9		0,9		0,9	
11	1,0		1,0		1,0		1,0	
12	1,5		1,5		1,5		1,5	

Common Emitter Output Static Characteristics

No.	I_B = 10 □A		I_B = 20 □A		I_B = 30 □A		I_B = 40 □A	
	V_{CE} (volts)	I_C	V_{CE} (volts)	I_C	V_{CE} (volts)	I_C	V_{CE} (volts)	I_C
1	0,0		0,0		0,0		0,0	
2	0,5		0,5		0,5		0,5	
3	1,0		1,0		1,0		1,0	
4	1,5		1,5		1,5		1,5	
5	2,0		2,0		2,0		2,0	
6	2,5		2,5		2,5		2,5	
7	3,0		3,0		3,0		3,0	
8	3,5		3,5		3,5		3,5	
9	4,0		4,0		4,0		4,0	
10	4,5		4,5		4,5		4,5	
11	5,0		5,0		5,0		5,0	
12	5,5		5,5		5,5		5,5	

F. FINAL TASK

1. For steps 1-4 make a graph of the input characteristics of the grounded emitter transistor, with the strong base current (I_B) as the Y axis and the base emitter voltage (V_{BE}) as the X axis for each price of the collector emitter voltage (V_{CE}) in one axis.
2. For steps 5-6 make a graph of the output characteristics of the grounded emitter transistor, with the strong collector current (I_C) as the Y axis and the emitter collector voltage (V_{CE}) as the X axis for each base current price (I_B) in one axis.
3. Compare curve no. 1 with the graphical curve of the forward diode.
4. Why does the slope of the graph change when the collector-emitter voltage (V_{CE}) changes?
5. From graph no. 2, determine the dead region, active region and saturated region of the grounded emitter transistor
6. From graph no. 2, give an interpretation of the angle of inclination for different base currents (I_B), in relation to the output resistance of the grounded emitter transistor amplifier.

LITERATURE LIST

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