Hall Ticket Number: | | | | | | | | | |

20EE401

II/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

July/August, 2023 — **Electrical & Electronics Engineering**

Fourth Semester — **Analog Electronics**

Time: Three Hours — **Maximum:** 70 Marks

Answer question 1 compulsory. **(14X1 = 14Marks)**

Answer one question from each unit. **(4X14=56 Marks)**

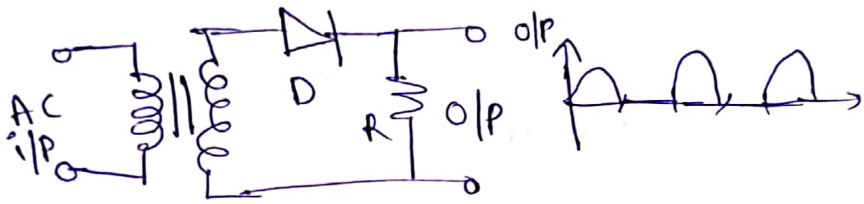
			CO	BL	M
1	a)	Compare PN diode and zener diode.	CO1	L1	1M
	b)	Draw the circuit diagram for half wave rectifier.	CO1	L1	1M
	c)	Define avalanche break down.	CO1	L1	1M
	d)	What is meant by clamping?	CO1	L1	1M
	e)	What is early effect?	CO2	L1	1M
	f)	Draw the circuit diagram for switch using BJT.	CO2	L1	1M
	g)	Compare JFET and MOSFET.	CO2	L1	1M
	h)	What are the advantages of FET over BJT?	CO2	L1	1M
	i)	Mention the advantages of Negative feedback.	CO3	L1	1M
	j)	What are the applications of oscillators?	CO3	L1	1M
	k)	What is op-amp.	CO4	L1	1M
	l)	Draw the circuit diagram for non-inverting amplifier.	CO5	L1	1M
	m)	What are the applications of Schmitt trigger.	CO5	L1	1M
	n)	Define virtual ground concept.	CO5	L1	1M
		Unit-I			
2	a)	Illustrate How temperature effects the I-V characteristics of PN diode.	CO1	L3	7M
	b)	Explain the operation of rectifier with L section filter and also derive expression for ripple factor.	CO1	L2	7M
		(OR)			
3	a)	Write short notes positive clippers.	CO1	L2	7M
	b)	Derive the expression for the ripple factor of capacitor filter when used with half wave rectifier. Make necessary approximations.	CO1	L4	7M
		Unit-II			
4	a)	Explain the characteristics of CE configuration of BJT.	CO2	L2	7M
	b)	Describe the operation of NPN and PNP transistor.	CO2	L4	7M
		(OR)			
5	a)	Illustrate the volt-ampere characteristics of JFET.	CO2	L3	7M
	b)	How MOSFET acts as an amplifier? Describe.	CO2	L3	7M
		Unit-III			
6	a)	Draw the basic block diagram for feedback amplifier and Explain.	CO3	L2	7M
	b)	Derive the expression for frequency of Wien bridge oscillator using BJT.	CO3	L4	7M
		(OR)			
7	a)	Derive the expression for slew rate equation and explain its significance	CO4	L4	7M
	b)	Design RC phase shift oscillators using BJT to produce a frequency of 1KHz	CO3	L3	7M
		Unit-IV			
8	a)	Derive the expression for gain of both inverting and non-inverting amplifiers.	CO5	L4	7M
	b)	Explain about voltage to current converter using op-amp.	CO5	L2	7M
		(OR)			
9	a)	Design a square wave generator using op-amp for a frequency of 1KHz.	CO5	L3	7M
	b)	Derive the expression for frequency of triangular-wave generator using op-amp.	CO5	L4	7M

2/4 B.Tech Regular Degree Examination
Department Of EEE
Analog Electronics
(20EE401)
Scheme of Evaluation

1)

a) PN diode is designed to operate forward bias only whereas zener diode is in reverse biased condition. Doping is very high in zener diode

b)

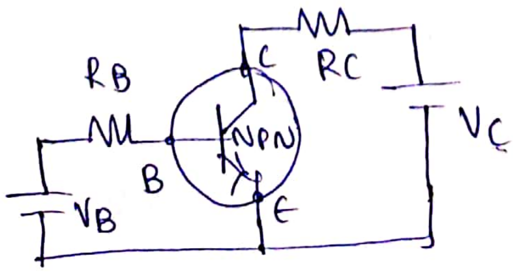


c) It is a phenomenon that can occur in lightly doped materials due to rapid collision of electrons with other atoms with increase in reverse voltage.

d) The process of shifting the i/p signal to a particular value on amplitude axis (vertically) is known as clamping.

e) The variation in effective base width of the base in a BJT due to a variation in applied base to collector voltage is known as early effect.

f)



g)

JFET	MOSFET
1. operated in depletion mode	1. Operates in both depletion and enhancement mode
2. High i/p impedance	2. very high i/p impedance
3. Gate is not insulated from channel	3. Gate is insulated from channel

h) FET advantages over BJT

1. more temperature stable
2. easier to fabricate
3. Not as sensitive to radiation
4. high i/p Z permit them to store charge long enough to use them as storage elements

i) advantages of -ve feedback

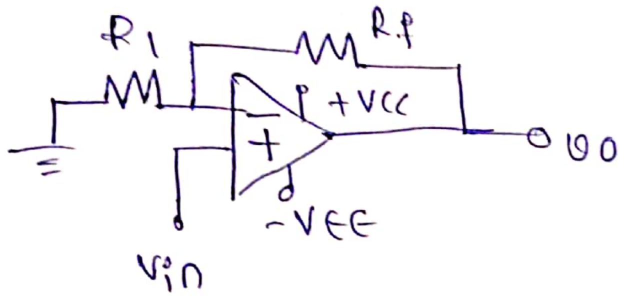
1. gain stabilization
2. Noise reduction
3. Distortion reduction
4. increase in Bandwidth

j) Applications of oscillator

① It is used in TV, radio and communication devices
② computers, metal detectors
③ ultrasonic, radio frequency
④ Microprocessors and Microcontrollers

K) An operational amplifier is a DC-coupled high gain electronic voltage amplifier with a differential i/p and usually a single ended o/p.

l) ckt diagram of Non-inverting amplifier



m) Schmitt trigger devices are used in signal conditioning applications to remove noise from signals used in digital circuits

n) Virtual ground is a node of a circuit that is maintained at a steady reference potential, without being connected directly to the reference potential

Unit - 1

2. a) Temparature effect of V-I charauteristics of P-N diode

The diode current is expressed as

$$I = I_0 \, e^{\left(\frac{V}{\eta V_T} - 1\right)}$$ → 2M

where I = diode current (+ve when forward bias
−ve when reverse bias)

I_0 = diode reverse saturation current at T

V = diode voltage (+ve forward bias
− ve reverse bias)

$\eta = 1$ for Ge
$= 2$ for Si

V_T = volt equivalent of temperature

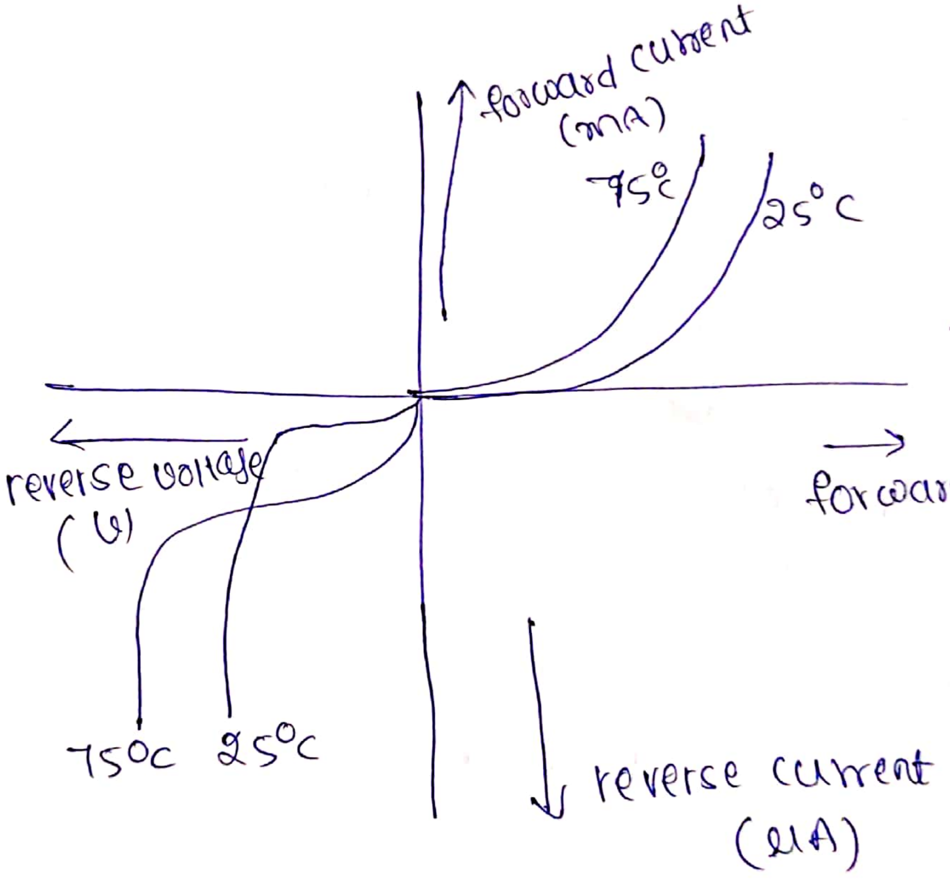
$= \frac{KT}{e}$ where K = boltzmann's constant
T = temperature in ^oK
e = electron charge

at room temperature
22^oC $T = 295K$

$$V_T = \frac{T}{11,600} = 0.025\,V$$

$$I = I_0\left(e^{40V} - 1\right) \text{ for Ge}$$
$$= I_0\left(e^{20V} - 1\right) \text{ for Si}$$

with increase in temperature, the exponential term reduces and hence diode current should also reduce. However, the reverse saturation current is also temperature dependent. It can be shown that it increases 7% per °c for both Ge and Si. This represents a doubling for every 10°c rise. Ge is more temperature dependent than Si because its saturation current approximately 1000 times larger. ⟶ 2M

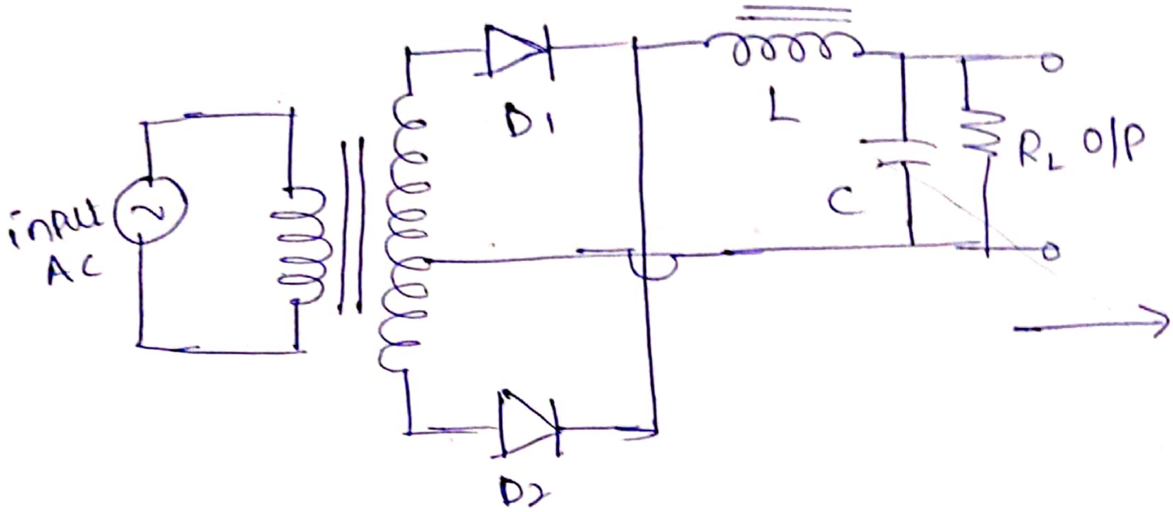


⟶ 3M

V-I characteristics

2.
b) L-C filter

A combination of series inductor and shunt capacitor results L-type choke input filter. A combination of these two filters may be selected to make the ripple independent of load resistance.



→ 2M

The action of choke input filter is like low pass filter. The capacitor shunting the load by passes the harmonic current because it offers very low reactance to a.c. ripple current while it appears as an open circuit to d.c. current. On other hand the inductor offers a high impedance to harmonic current terms. In this way most of the ripple voltage is eliminated from the load voltage → 1M

ripple factor : The main aim of filter is to supress the harmonic components. So the reactance of the choke must be large as compared with combined parallel impedance of capacitor and resistor.

$$X_L >> X_C$$

rms value of ripple current is

$$(I_r)_{rms} = \frac{4V_m}{3\pi\sqrt{2}} \cdot \frac{1}{X_L} = \frac{2}{3\sqrt{2}X_L}\left(\frac{2V_m}{\pi}\right)$$

$$= \frac{\sqrt{2}}{3X_L} \cdot V_{dc}$$

The a.c. voltage across the load is voltage across capacitor. Hence

$$(V_r)_{rms} = (I_r)_{rms} X_C$$

$$= \left(\frac{\sqrt{2}}{3X_L} V_{dc}\right) X_C$$

ripple factor → $r = \frac{(V_r)_{rms}}{V_{dc}} = \frac{\sqrt{2}\, V_{dc} X_C}{3X_L V_{dc}}$

$$= \frac{\sqrt{2}\, X_C}{3\, X_L} = \frac{\sqrt{2}}{3(2\omega L)(\omega C 2)}$$

$$= \frac{\sqrt{2}}{3\omega^2 LC(2)(2)} = \frac{\sqrt{2}}{6\sqrt{2}\cdot\sqrt{2}\cdot\omega^2 LC}$$

$$= \frac{1}{6\sqrt{2}\,\omega^2 LC}$$ → **4m**

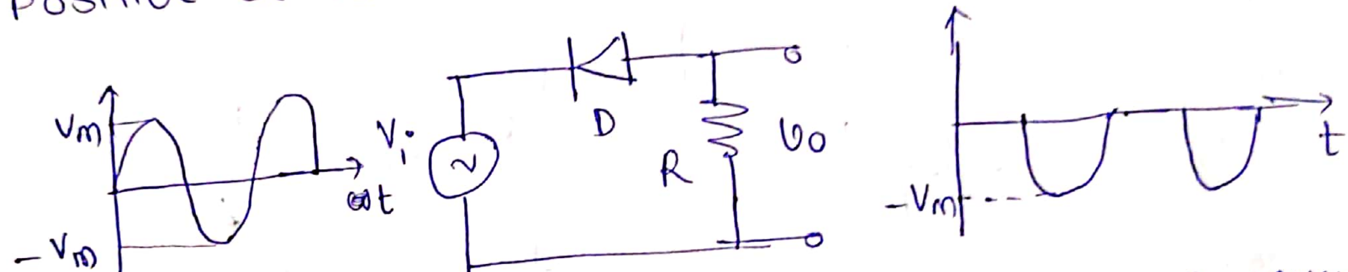
This shows that ripple factor is independent of load resistance (R_L).

3\. a. Positive clippers :

The circuits intended to attenuate positive portions of input signals can be termed as positive clipper. ⟶ 1M

① positive series clipper ⟶ 3M

A clipper circuit in which diode is conneceed in series with the input signal and that attenuates positive portions of wave form is termed as positive series clipper.

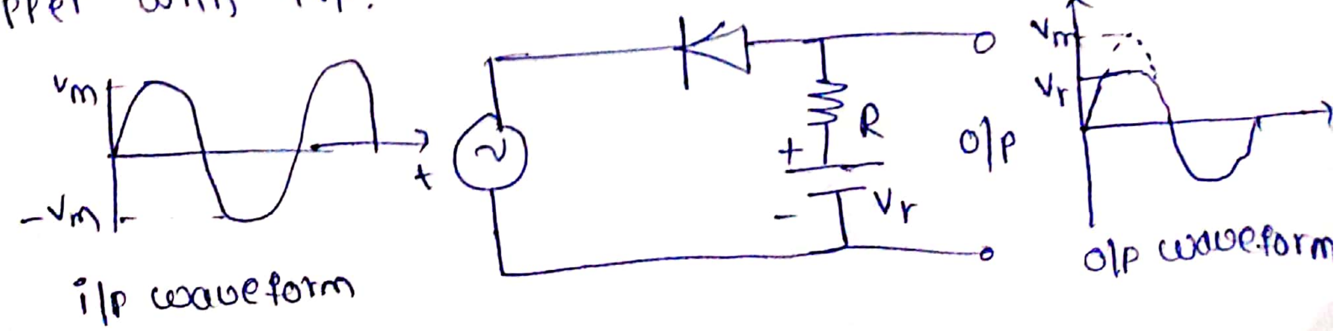


During +ve half cycle of i/p signal diode gets reverse biased and hence it behaves like an open switch. thus voltage across load is zero.

During -ve half cycle of i/p signal diode gets forward biased and hence it behaves like an closed switch. Thus voltage across load equl to i/p voltage

② positive series clipper with positive reference voltage

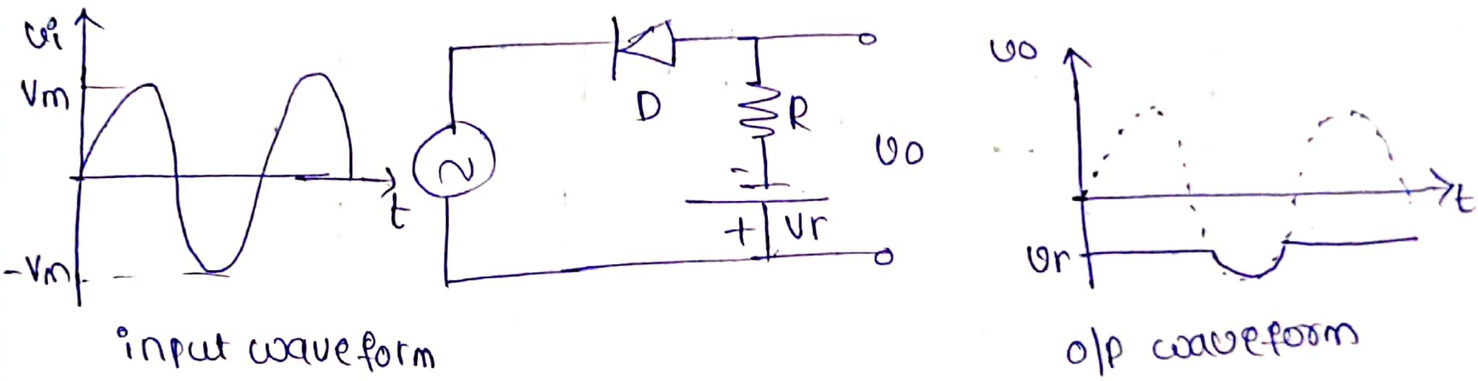
The following ckt gives positive series clipper with +Vr.



During +ve cycle of input the diode gets reverse biased and the reference voltage appears at the output. During its -ve cycle diode gets forward biased and conducts like a closed switch. Hence output wave-form appears as input wave form.

Positive series clippers with negative V_r : → 3M

Diagram shown below. A clipper ckt in which diode is connected in series to the i/p signal and biased with -ve reference voltage and attenuates positive portions of the wave form

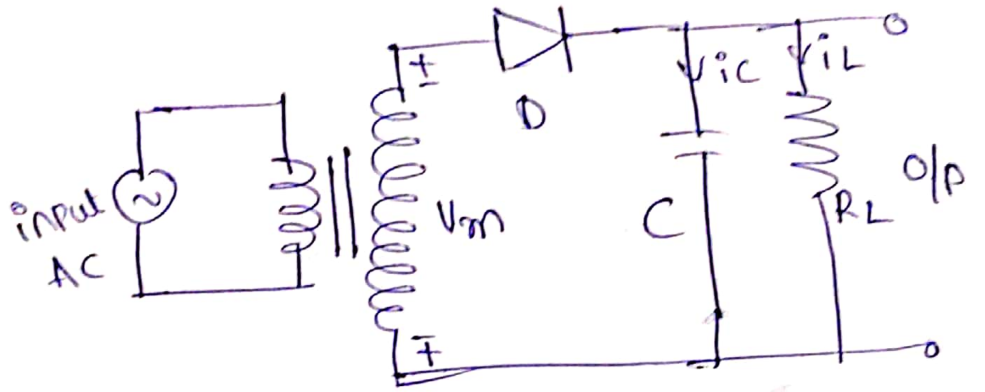


During +ve cycle of i/p the diode gets reverse biased and reference voltage appears at the o/p. During its -ve cycle below reference voltage diode gets forward biased v_o follows the i/p voltage.

$$v_o = v_i$$

3 b) Shunt capacitor filter:

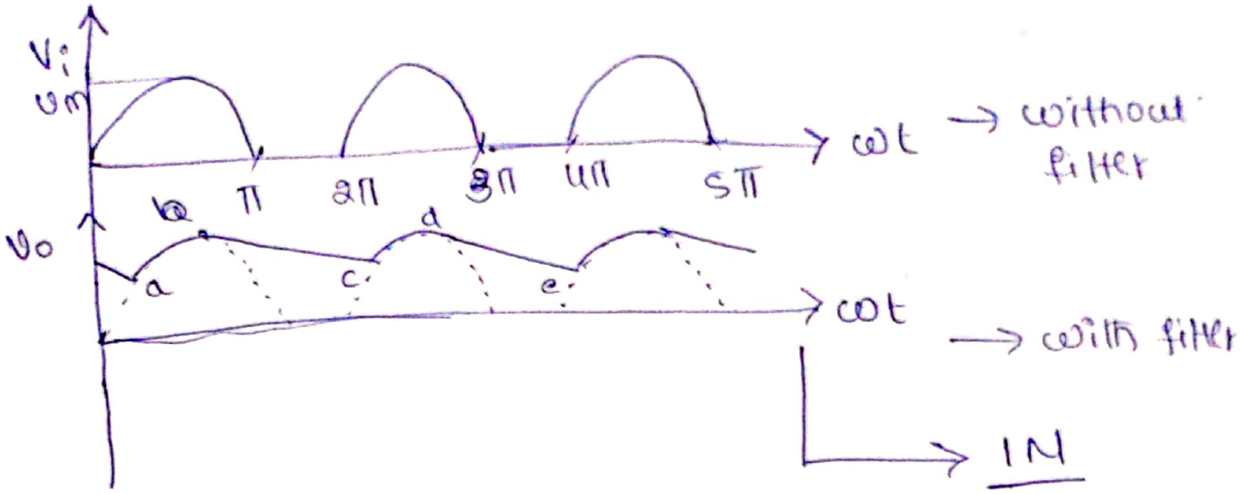
Rectifier o/p is pulsating in nature i.e. it contains a large number of ripple components. these ripple components are filtered by shunting the load with capacitor. This type of filter is known as capacitor input filter. The action of filter depends on the fact that capacitor stores energy when conducting and delivers energy to load during non-conduction. through this process, the ripple components are considerably reduced. ⟶ 1M



⟶ 1M

Operation :-

During +ve half cycle of a.c. input the diode D forward biased and hence it conducts. This quickly charges the condenser c to a voltage Vm. During -ve half cycle diode D is reverse biased it does not conduct. So the capacitor c discharges through RL. As discharging time constant is 1000 times larger, hence condenser does not have sufficient time to discharge appreciably ⟶ 1M



Expression for ripple factor: → 3M

From Fourier Analysis

$$i = I_{dc} + 2I_d \cos\omega t + 2I_d \cos 2\omega t + \dots$$

$$V_{ac} = \sqrt{V_1^2 + V_2^2 + V_3^2 + \dots}$$

$$V_1 = \frac{2I_{dc}/\sqrt{2}}{X_C}$$

$$V_2 = \left(\frac{2I_{dc}}{\sqrt{2}}\right) \cdot \frac{1}{2\omega C}$$ → second harmonic ripple

$$V_{ac} = \sqrt{\left(\frac{2I_{dc}}{\sqrt{2}} \cdot \frac{1}{\omega C}\right)^2 + \left(\frac{2I_{dc}}{\sqrt{2}} \cdot \frac{1}{2\omega C}\right)^2 + \dots}$$

$$= \frac{2I_{dc}}{\sqrt{2}\omega C}\sqrt{1 + \left(\frac{1}{2}\right)^2 + \left(\frac{1}{3}\right)^2 + \dots}$$

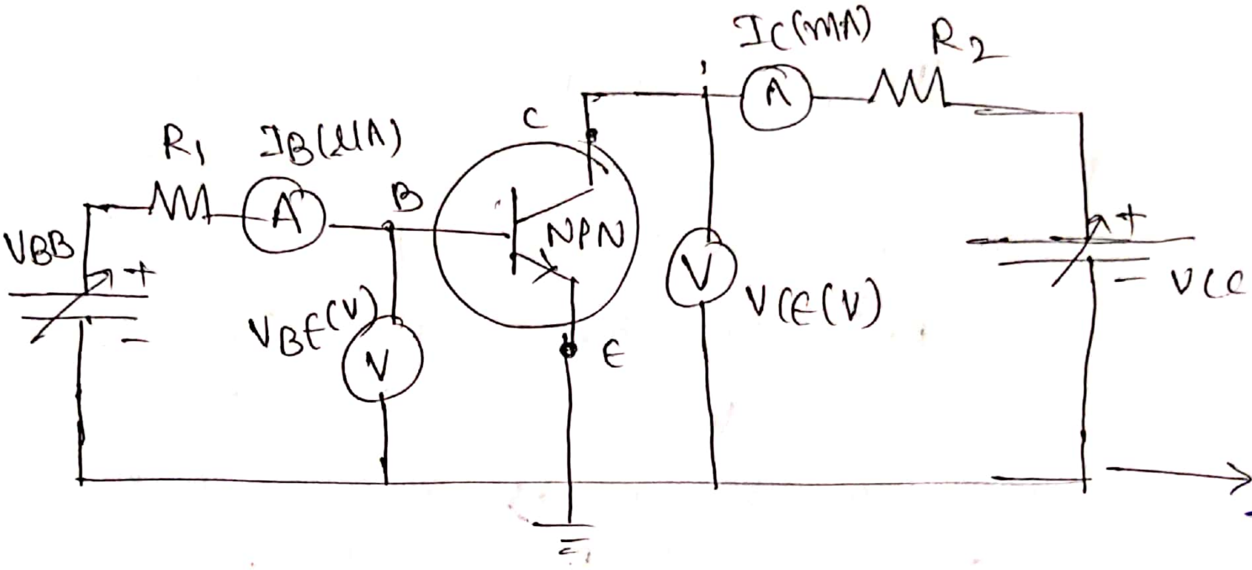
$$= \frac{2I_{dc}}{\sqrt{2}\omega C}\sqrt{1.36} = \frac{\sqrt{2} I_{dc}\sqrt{1.36}}{\omega C} = \frac{1.64 I_{dc}}{\omega C}$$

$$r = \frac{V_{ac}}{V_{dc}} = \frac{1.64\, I_{dc}/\omega C}{I_{dc} R_L} = \frac{1.64}{\omega C R_L} = \frac{1}{2\sqrt{3} f C R_L}$$

From above equation ripple factor is inversly proportional to road resistor i.e. filter is effective when load is high.

4
a) Characteristics of CE configuration of BJT.

In common emitter configuration the emitter is common terminal. Hence the i/p is applied between Base and emitter while output is between collector and emitter.

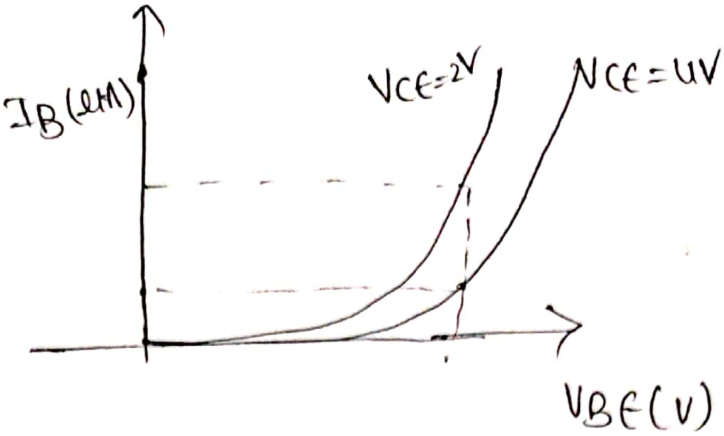


→ 1M

Input characteristics : → 3M

It is drawn between input voltage (V_{BE}) and i/p current I_B (μA) for different constant values of o/p voltage (V_{CE})

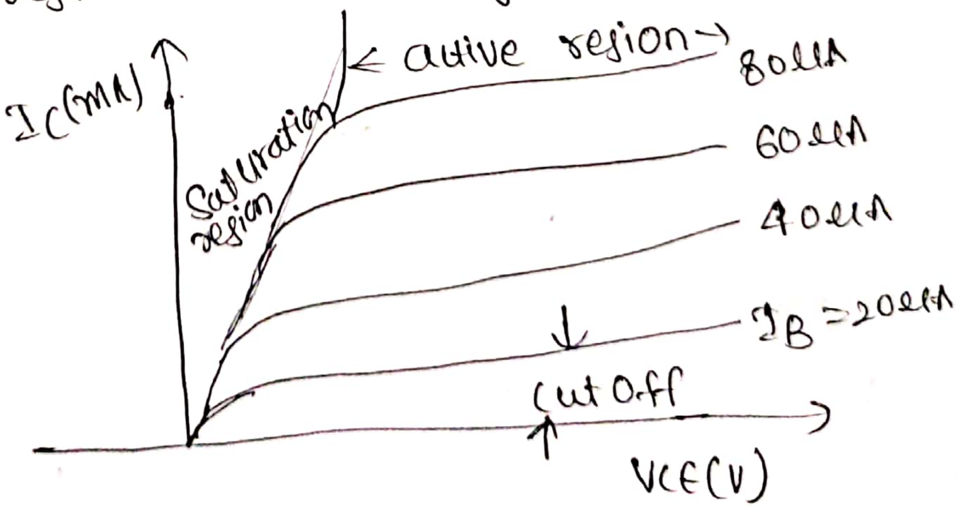
In active state the V_{CE} has to be maintained at a value much larger than 0.7eV. If we increase ~~tev~~ V_{CE} reverse bias across collector junction increase which leads modulation in base width i.e. it decreases due to which base current reduces. this is called early effect.



Output characteristics : → 3M

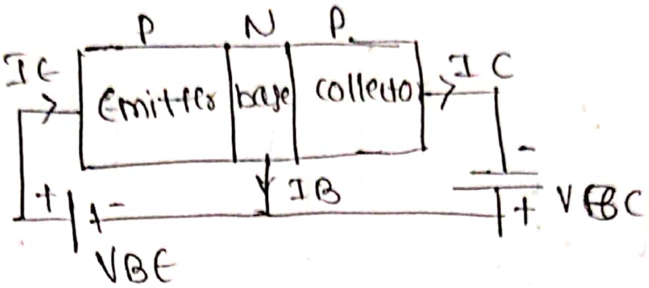
It is drawn between output voltage VCE and o/p current IC(mA) for different constant values of i/p current IB(μA).

First keep base current IB(μA) at a steady value. if VBE is increased by a small amount we can observe an increase in emitter current consequently Base current. output characteristic devided into three regions cutoff, saturation region and active region.



4 b) Operation of PNP transistor → 4M

The PNP transistor consists of two p-type semiconductors that sandwitch an n-type semiconductor. Here holes are the majority charge carriers while electrons are minority charge carriers.



The emitter bas (VBE) battery connects P-type emitter which is forward biased whereas collector base (VBC) battery connects P-type collector which is reverse biased.

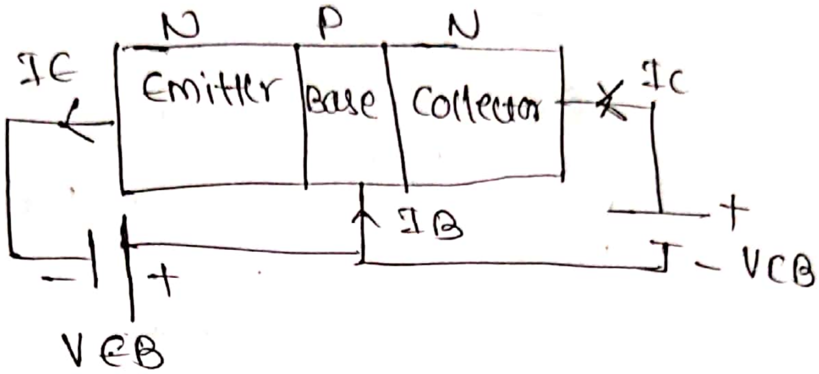
In this case, the majority charge carriers in emitter are holes which are repelled towards the base. As the base layer is thin, thus only litter interaction occurs when electrons and holes combine. most of the holes reach collector. the current is carried by holes in PNP transistor.

Emitter current = Base current + collector current

$$I_E = I_B + I_C$$

Operation of NPN transistor : → 3M

The NPN transistor consists of two N-type semiconductors that sandwich a P-type semiconductor. Here, electrons are the majority charge carriers while holes are minority charge carriers.



From above circuit it is seen that emitter base circuit is forward biased while the collector emitter circuit is reverse biased. Due to forward bias the majority of charge carriers in the emitter are repelled towards the base. The electron-hole recombination is very small in the base region because the base lightly doped. Most of electrons cross into the collector region. A small amount of current at the base terminal causes large amount of current to flow from emitter to collector.

Emitter current = Base current + Collector current

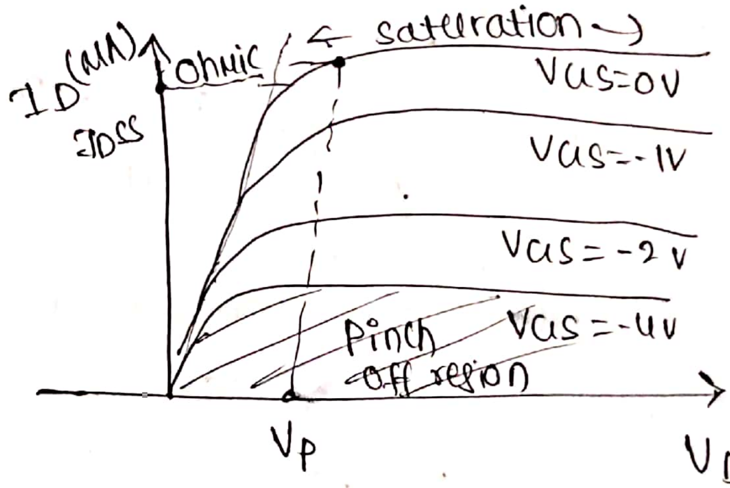
$$I_E = I_B + I_C.$$

5.

a) V-I characteristics of JFET

The V-I characteristics of N-channel JFET are discussed below. In this structure the gate source voltage (V_{GS}) controls the current flow between the source drain. The JFET is a voltage controlled device so no current flows through gate, then the source current (I_S) is equal to drain current (I_D) i.e. $I_D = I_S$.

In this V-I characteristic the voltage V_{GS} represents the voltage applied between the gate and source and the voltage V_{DS} represents the voltage applied between drain and source



→ 2M

The JFET has different characteristics at different stages of operation depending on i/p voltages.

Ohmic region: if $V_{GS}=0$ then the depletion region of channel is very small and in this region JFET acts as voltage controlled resistor. → 1M

Pinched off ⇒ region : also called cut off region.
The JFET enters into this region when gate voltage is large negative, then channel closes i.e. no current flows through the channel → 1M

Saturation (or) active region : In this region the channel acts as good conductor which is controlled by gate voltage (V_{GS}). → 1M

Breakdown region : If the drain to source voltage (V_{DS}) is high enough, then the channel of the JFET breaks down and in this region uncontrolled max. current passes through the device → 1M

The drain current I_D flowing through the channel is zero when applied voltage V_{GS} is equal to pinchoff voltage.

$$I_D = I_{DSS}\left(1-\left(\frac{V_{GS}}{V_P}\right)\right)^2 \rightarrow 1M$$

I_{DSS} ↓ Maximum Saturation current

The drain-source resistance equl to ratio of rate of change in drain-source voltage to current.

$$R_{DS} = \frac{\Delta V_{DS}}{\Delta I_D} = 1/g_m$$

g_m ↓ transconductance gain.

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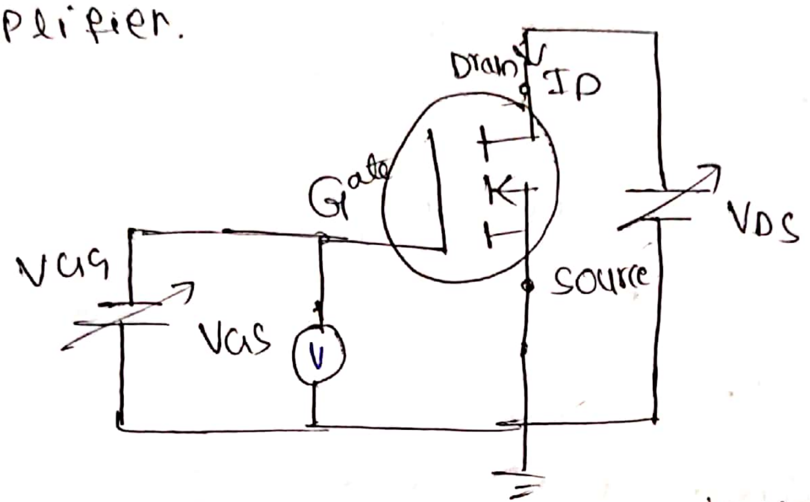
5 b) MOSFET amplifier :

An amplifier is an electrical device used to enhance the amplitude of i/p signal. An amplifier that uses metal oxide semiconductor field effect transistor (MOSFET) technology is known as MOSFET amplifier.



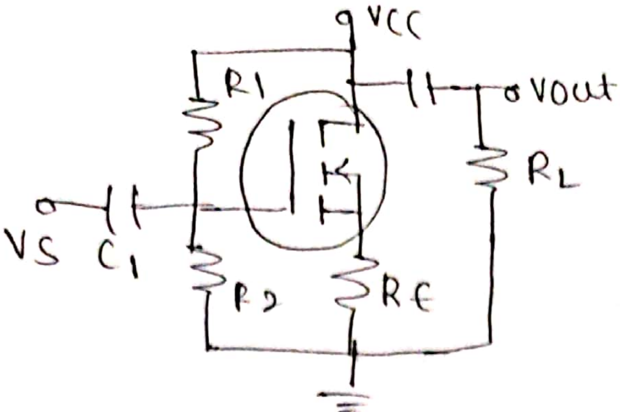
→ 1M

In above circuit drain voltage (V_D) and drain current I_D (mA) and Gate to source voltage (V_{GS}) and three terminals of MOSFET gate, source, drain are mentioned.

Generally MOSFET should operate in ohmic region when it is used as amplifier. In MOSFET amplifier small change within gate voltage will generate large change in drain current.

In a complete MOSFET amplifier ckt biasing circuit and load resistor, coupling capacitor are designed. The coupling capacitor protect the biasing dc voltage from the ac signal to be amplified.

$$V_G = V_S \cdot \left(\frac{R_2}{R_1 + R_2}\right)$$



→ 2M

Biasing circuit of MOSFET amplifier

Acc. to transconductance (g_m) the ratio of I_D to V_{GS} once a constant V_{DS} is applied

$$g_m = I_D / V_{GS}$$

$$V_{in} = V_{GS} \times (1 + g_m R_S)$$

O/p voltage is given by

$$V_o = -R_D I_D = -g_m V_{GS} R_D \quad \rightarrow 2M$$

The voltage gain is ratio of input voltage and output voltage

$$A_v = \frac{V_o}{V_{GS} \text{ (or) } V_{in}} = -g_m R_D =$$

$$= \frac{V_o}{V_{in}} = \frac{V_o}{V_{GS}(1+g_m R_S)}$$

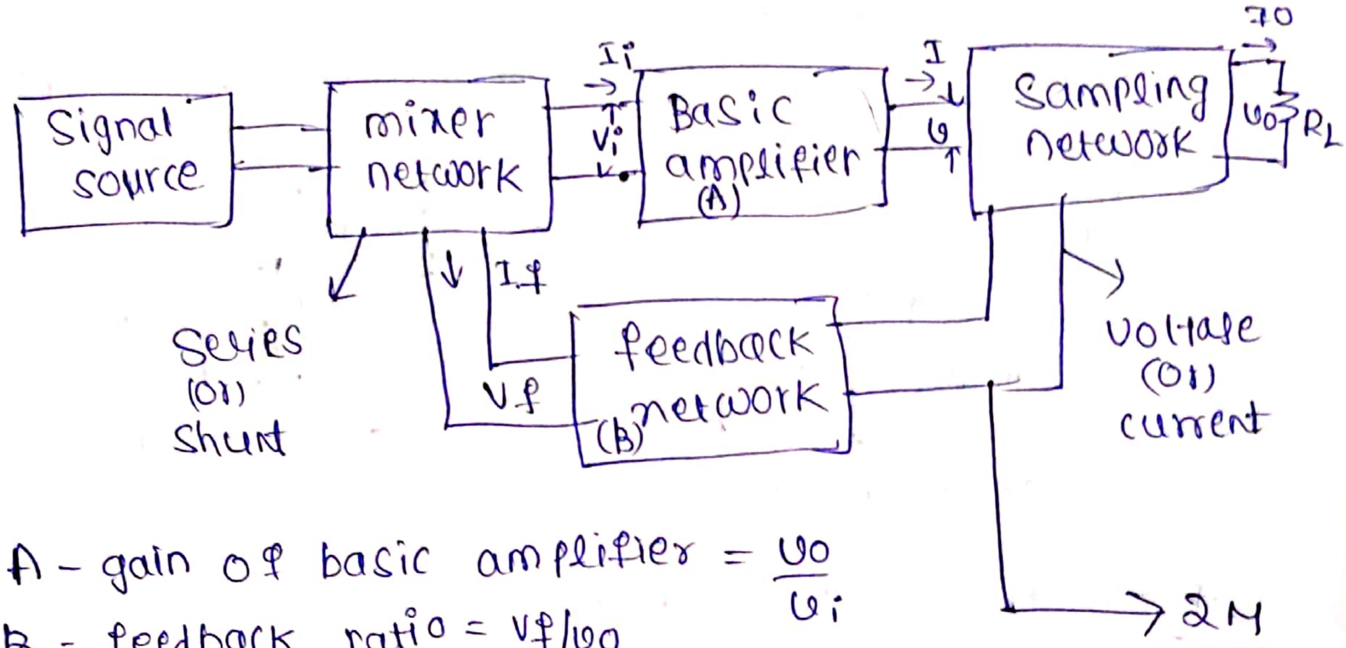
$$= \frac{-g_m V_{GS} R_D}{V_{GS}\, g_m R_S} = \frac{-R_D}{R_S}$$

$$= 1/g_m \quad \rightarrow 2M$$

In above equation - sign comes from the fact that MOSFET amplifier inverts the o/p signal in equivalent with BJT CE amplifier.

6.
a. Block diagram for feedback amplifier

Block diagram of an amplifier with feedback shown below, the o/p Quantity either voltage (or) current is sampled by suitable sampler and fed to feedback n/w. The output of feedback n/w which has fraction of output signal is combined with external source signal Vs through mixer and fedback to basic amplifier mixers are also known as comparators, are of two types namely, series and shunt mixer.



A - gain of basic amplifier = V_o / V_i

B = feedback ratio = V_f/V_o

Af - gain of feedback amplifier = V_o/V_s

feedback network :- feedback of two types → 1M

1. positive (or) regenerative feedback

If the feedback signal V_f is in phase with the i/p signal Vs this type of feedback is said to be +ve.

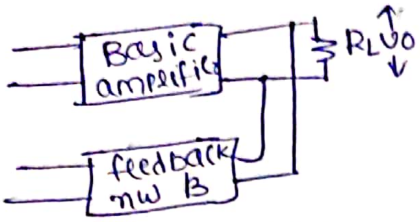
$$A_f = A/1+AB$$

2. Negative (or) Degenerative feedback

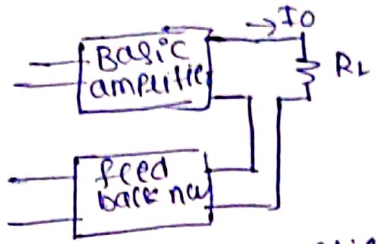
If the feedback signal V_f is out of phase with the i/p signal V_s this type of feedback is said to be -ve.

$$A_f = \frac{A}{1+AB}$$

Sampling network : There are two types sampling the signal at the output . ① voltage sampling ② current sampling



Voltage sampling

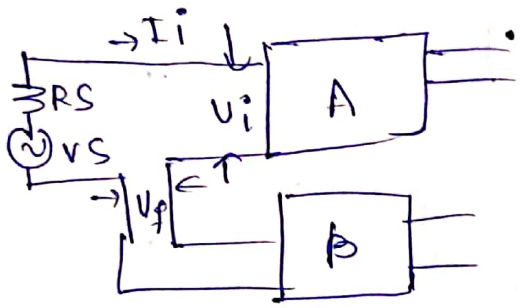


current sampling

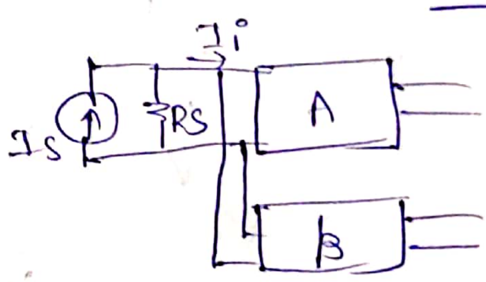
⟶ 1 M

Mixer network : There are two ways of mixing the feedback signal with the input signal namely

① series mixing ② shunt mixing ⟶ 1M



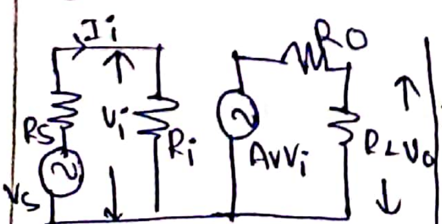
series mixing



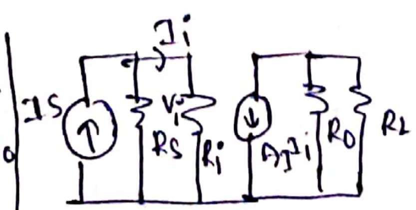
shunt mixing

Basic Amplifier : there are four types of Basic amplifier ⟶ 2M

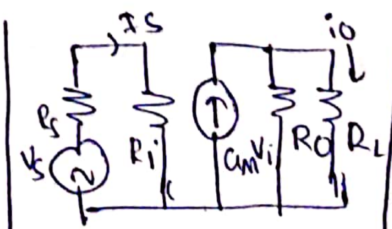
① voltage amplifier ② current amplifier ③ Transconductance amplifier ④ transresistance amplifier



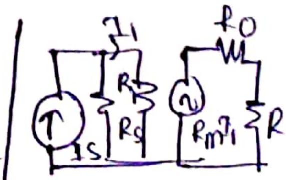
voltage amplifier



current amplifier



Transconductance amplifier

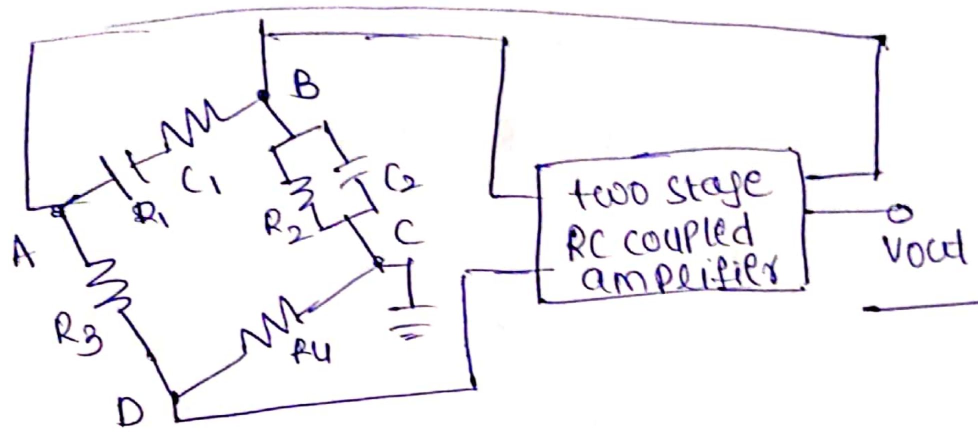


Transresistance amplifier

6.

b) frequency of oscillations of wein bridge oscillator

The circuit consists of a two-stage RC coupled amplifier which provides phase shift of 360° (or) 0°. A balanced bridge is used as feedback network which has no need to provide any additional phase shift.



→ 2M

If bridge is balanced

$$\frac{R_3}{R_4} = \frac{R_1 - jX_{C_1}}{R_2 \,||\, (-jX_{C_2})}$$

$$\frac{R_3}{R_4} = \frac{R_1 - jX_{C_1}\,(R_2 - jX_{C_2})}{R_2(-jX_{C_2})}$$

$$-R_3 R_2 jX_{C_2} = R_4 (R_1 - jX_{C_1})(R_2 - jX_{C_2})$$

$$-\frac{jR_3R_2 \cdot 1}{\omega C_2} = R_4\left(R_1R_2 - jX_{C_2}R_1 - jX_{C_1}R_2 - X_{C_1}X_{C_2}\right)$$

equating real parts on both sides

$$R_4R_1R_2 - R_4X_{C_1}X_{C_2} = 0$$

$$R_1R_2 - X_{C_1}X_{C_2} = 0$$

$$R_1R_2 = X_{C_1}X_{C_2}$$

$$R_1R_2 = \frac{1}{\omega C_1} \cdot \frac{1}{\omega C_2}$$

$$\omega^2 C_1 C_2 = \frac{1}{R_1R_2}$$

$$\omega^2 = \frac{1}{R_1R_2C_1C_2}$$

if $R_1 = R_2 = R$ and $C_1 = C_2 = C$

$$\omega^2 = \frac{1}{R^2C^2}$$

$$\omega = \frac{1}{RC}$$

$$\boxed{f = \frac{\omega}{2\pi} = \frac{1}{2\pi RC}} \longrightarrow \underline{5M}$$

7.

a) Slew rate equation.

slew rate is an important parameter because it limits the bandwidth for large signals. It is defined as maximum rate of change in input voltage per unit of time and is expressed in volt per microsecond

$$SR = \frac{dv_o}{dt}\Big|_{max} \; V/\mu s \longrightarrow \underline{2M}$$

slew rate indicates how fast the output of an op-amp can change in response to change in the i/p frequency. For example the op-amp 741 has a slew rate of 0.5 V/μs i.e. for 0.5 volts change it takes 1 microsecond therefore for 10 volt change it takes 20 microseconds for the o/p to change from 0 to 10V. It is impossible for 741 to change faster than this. ⟶ 1M

generally slew rate is specified for unity gain

$$V_s = V_m \sin\omega t$$

with no slew rate limitations, the output voltage of voltage follower is

$$V_o = V_m \sin\omega t$$

rate of change of output

$$\frac{dv_o}{dt} = \frac{d}{dt}(V_m \sin\omega t)$$

$$\frac{dv_o}{dt} = \omega V_m \cos\omega t$$

The maximum rate of change of o/p occurs when $\cos\omega t = 1$ i.e. $\omega t = 0°$

$$\left.\frac{dv_o}{dt}\right|_{max} = \omega V_m$$

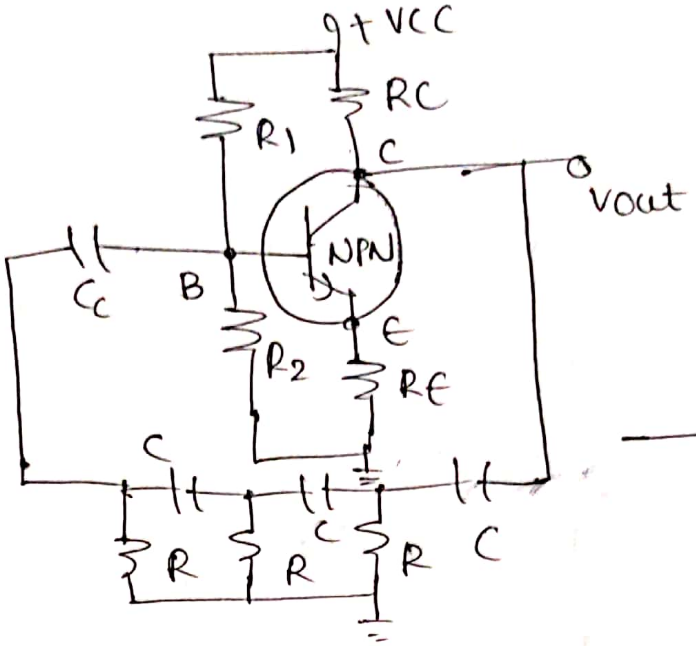
$$SR = \left.\frac{dv_o}{dt}\right|_{max} = 2\pi f v_m \ V/s$$

$$= 2\pi v_m f \times 10^{-6} \ V/\mu s$$

$$= 2\pi f v_m \times 10^{-6} \ V/\mu s$$ → 4m

For distortion less o/p, slew rate determines the maximum frequency of operation, f_{max}, for a desired o/p swing. The frequency f_{max} is called full power bandwidth and is defined as maximum frequency at which an undistorted sinusoidal output can be obtained with peak voltage v_m

7. b) Design RC phase shift oscillator with 1KHZ.



→ 2M

The frequency of oscillation f is given by

$$f = \frac{1}{2\pi RC\sqrt{6}} \quad \rightarrow 1M$$

$$= \frac{0.065}{RC}$$

Let $C = 0.01 \mu f$ → 1M

$f = 1KHZ$

$$1 \times 10^3 = \frac{0.065}{R \times 0.01 \times 10^{-6}}$$

$$R \times 10^3 = \frac{0.065}{10^{-8}} = \frac{65 \times 10^{-3}}{10^{-8}}$$

$$= \frac{65}{10^{-5}}$$

$R \times 10^3 \times 10^{-5} = 65$ → $R = 6500$

$= 6.5 K\Omega$ → 2M

$R = 6.5 K\Omega$

To prevent loading of amplifier because of RC network, it is necessary that

$R_1 \geq 10R$

$R_1 = 10\ (6.5 K\Omega) = 65 K\Omega$

$\frac{R_f}{R_1} = 29$

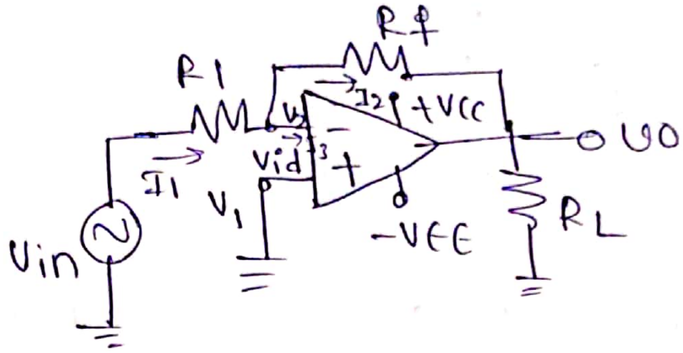
$R_f = 29 R_1$

$R_f = 29 \times 65 K\Omega \longrightarrow 1M$

$= 1.8 M\Omega$

8 a) Gain of Inverting amplifier

The i/p signal drives the inverting i/p of op-amp through resistor R_1.



→ 2M

The op-amp has open loop gain A, because of phase inversion, the o/p signal is 180° out of phase with the i/p signal. From virtual ground

$$v_1 = v_2 = 0$$

$$I_1 = I_2 + I_3$$

$$I_1 = I_2$$

$$\frac{v_{in} - v_2}{R_1} = \frac{v_2 - v_0}{R_f}$$

$$\frac{v_{in} - 0}{R_1} = -\frac{v_0}{R_f}$$

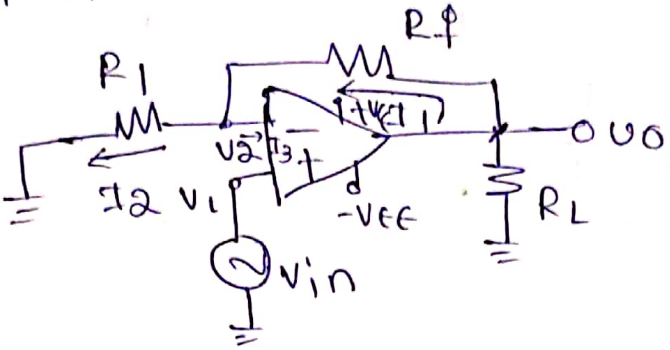
$$v_0 = -\frac{R_f}{R_1} v_{in}$$

$$A_f = \frac{v_0}{v_{in}} = \frac{-R_f}{R_1}$$

→ 1M

gain of Non-inverting amplifier:

The i/p signal drives the Non-inverting terminal of op-amp.



→ 2M

The open loop gain of op-amp is A, this circuit does not provide any phase shift.

$I_1 = I_2 + I_3$

$I_1 = I_2$

$$\frac{V_o - V_2}{R_f} = \frac{V_2 - 0}{R_1}$$

$V_1 = V_2 = V_{in}$

$$\frac{V_o - V_{in}}{R_f} = \frac{V_{in}}{R_1}$$

$$\frac{V_o}{R_f} = V_{in}\left(\frac{R_f + R_1}{R_1 R_f}\right)$$

$$A_f = \frac{V_o}{V_{in}} = \frac{R_f + R_1}{R_1}$$

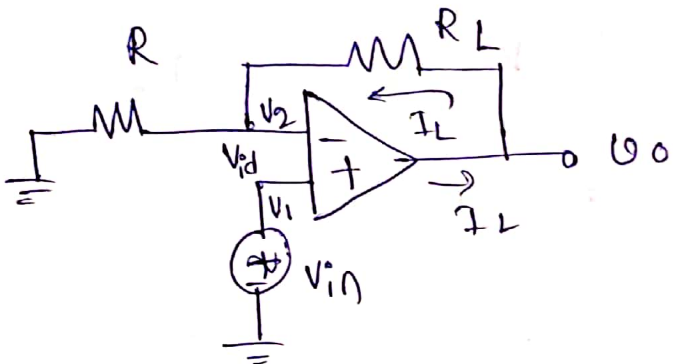
$$= 1 + \frac{R_f}{R_1}$$ → 2M

8.
b) Voltage- current converter

A voltage to current converter is an electronic circuit that takes the current as the i/p and produces voltage as o/p. It can simply change the carrier of electrical data from voltage to current. They are of two types

① floating load voltage current converter

The name indicates the load resistor is floating in this circuit. The resistor is not connected to ground.



→ 2M

$V_1 = V_2 = V_{in}$ → from virtual ground

$$\frac{V_2 - 0}{R} = \frac{V_o - V_2}{R_L} = I_L$$

$$\frac{V_{in}}{R} = I_L$$

$I_L \propto V_{in}$ → 1M

from above eq, it is clear that load current depends on i/p voltage and i/p resistance. the load current is controlled by resistor, R. Here proportionality constant is (1/R).

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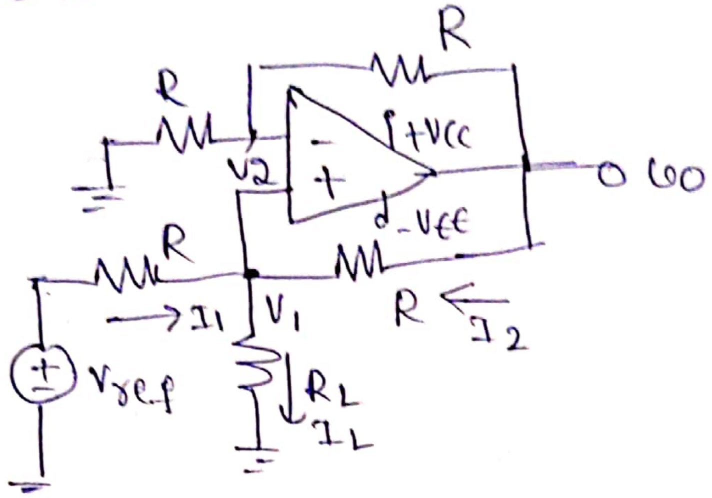
② Ground load voltage to current converter.

This is also known as Howland current converter. One end of load is always grounded.



→ 2M

$$I_1 + I_2 = I_L$$

$$\frac{V_{ref} - V_1}{R} + \frac{V_o - V_1}{R} = \frac{V_1}{R_L} = I_L$$

$$\frac{V_{ref} - 2V_1 + V_o}{R} = I_L$$

$$V_1 = \frac{V_{ref} + V_o - I_L R}{2}$$

$$A = \frac{V_o}{V_1} = 1 + \frac{R_f}{R_1} = 2$$

$$V_o = 2V_1$$

$$= 2\left(\frac{V_{ref} + V_o - I_L R}{2}\right)$$

$$V_{ref} = I_L R$$

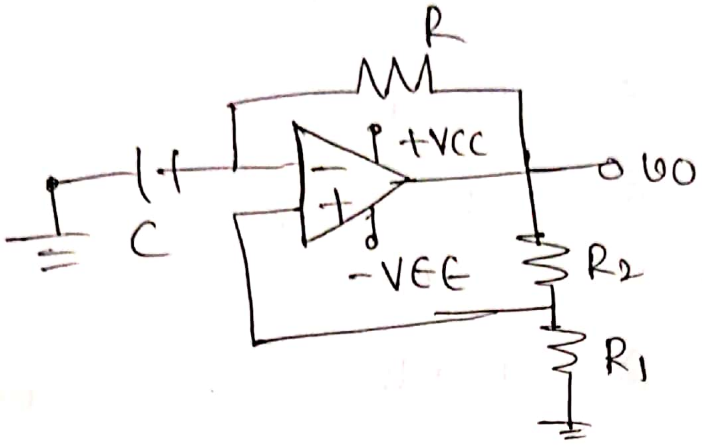
$$I_L = \frac{V_{ref}}{R} \rightarrow I_L \propto V_{ref}$$ → 2M

We can conclude from above equation o/p current is proportional to i/p voltage.

9.

a) Squrare wave generator using op-amp for a frequency of 1KHZ

$f = 1KHZ$



→ 2M

$R_2 = 1.16 R_1$

$$T = 2RC \ln\left(\frac{2R_1 + R_2}{R_2}\right)$$

$$f_0 = \frac{1}{2RC}$$ → 1M

$f = 1KHZ$

assume capacitor = 0.05 µf → 1M

$R_1 = 10K\Omega$ → 1M

$R_2 = 1.16 \times 10 K\Omega$

$= 11.6 K\Omega$ → 1M

$$10^3 = \frac{1}{2RC} = \frac{1}{2R(0.05\times10^{-6})}$$

$$10^3 \cdot 2R \cdot 0.05\times10^{-6} = 1$$

$$0.1\times10^{-6}\times10^3\times R = 1$$

$$10^{-7}\times10^3 R = 1$$

$$R = \frac{1}{10^{-4}} = 10^4$$

$$R = 10K\Omega$$ → 1M

$R = 10K\Omega$

$C = 0.05\mu f$

$f = 1KHz$

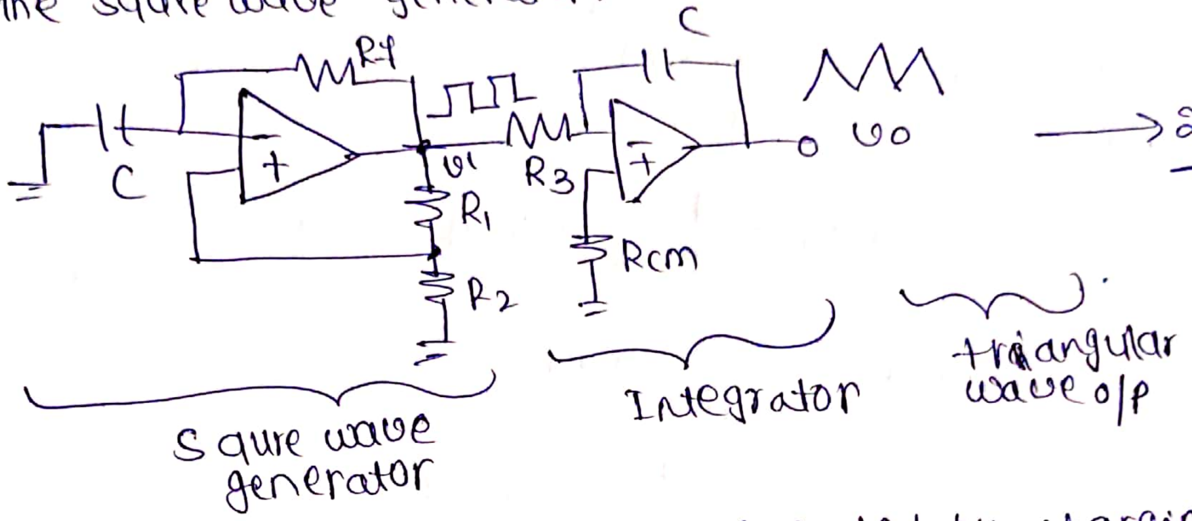
$R_1 = 10K\Omega$

$R_2 = 11.6K\Omega$

9

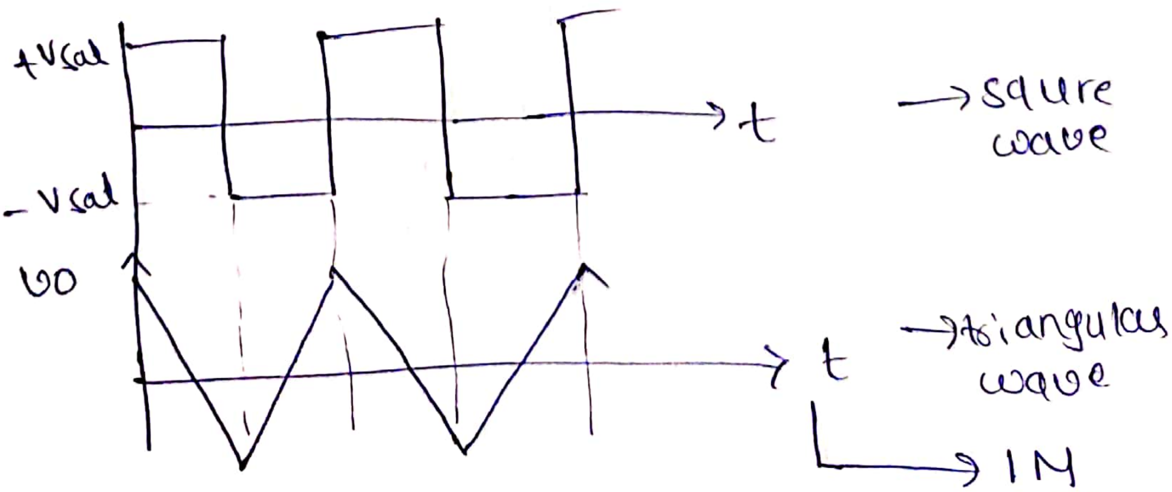
b) Triangular wave generator:

The o/p of Integrator is triangular wave if its i/p is squre wave. Triangular wave generator formed by simply connecting an integrator to the squre wave generator.



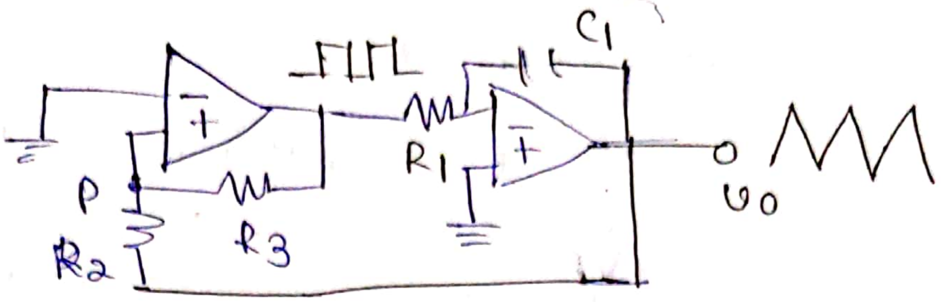
→ 2M

Triangular wave is generated by charging and discharging capacitor through constant current. Assume that v1 is high at +Vsat. This forces a constant current through C to drive vo negative linearly when v1 is low at -Vsat, it forces a constant current through C to drive vo positive linearly. The freq. of triangular wave same as squre wave.



→ 1M

Another triangular wave generator, which requires fewer components is shown below



The frequency and amplitude of the triangular wave generator using op-amp can be determined as follows. when comparator o/p is +Vsat

$$0 = -V_{ramp} + \frac{R_2}{R_2+R_3}\left(V_{sat} - (-V_{ramp})\right) \rightarrow \text{the voltage at point P}$$

$$-V_{ramp} + \frac{R_2}{R_2+R_3} V_{ramp} + \frac{R_2}{R_2+R_3}(V_{sat}) = 0$$

$$\frac{-R_3}{R_2+R_3}(V_{ramp}) = \frac{-R_2}{R_2+R_3}(V_{sat})$$

$$-V_{ramp} = \frac{-R_2}{R_3}(+V_{sat})$$

similarly, when the comparator o/p is $-V_{sat}$

$$V_{ramp} = \frac{-R_2}{R_3}(-V_{sat})$$

$$V_{o(p-p)} = \frac{2R_2 V_{sat}}{R_3}$$

$$V_{o(p-p)} = -\frac{1}{R_1C_1}\int_0^{T/2}(-V_{sat})\,dt$$

$$= \frac{V_{sat}}{R_1C_1}(T/2)$$

$$T = \frac{2R_1C_1 V_{o(p-p)}}{V_{sat}} = \frac{2R_1C_1}{V_{sat}} \cdot \frac{2R_2 V_{sat}}{R_3}$$

$$= \frac{4R_1R_2C_1}{R_3}$$

$$f_o = \frac{1}{T} = \frac{R_3}{4R_1C_1R_2} \rightarrow \text{frequency of oscillations.}$$ $\longrightarrow$ 4M

Signature of HOD.

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