CMR INSTITUTE OF TECHNOLOGY

Analog Electronic Circuits-21EC34

Solution for Internal Assesment Test – II Dec2022

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USN

Internal Assesment Test - II

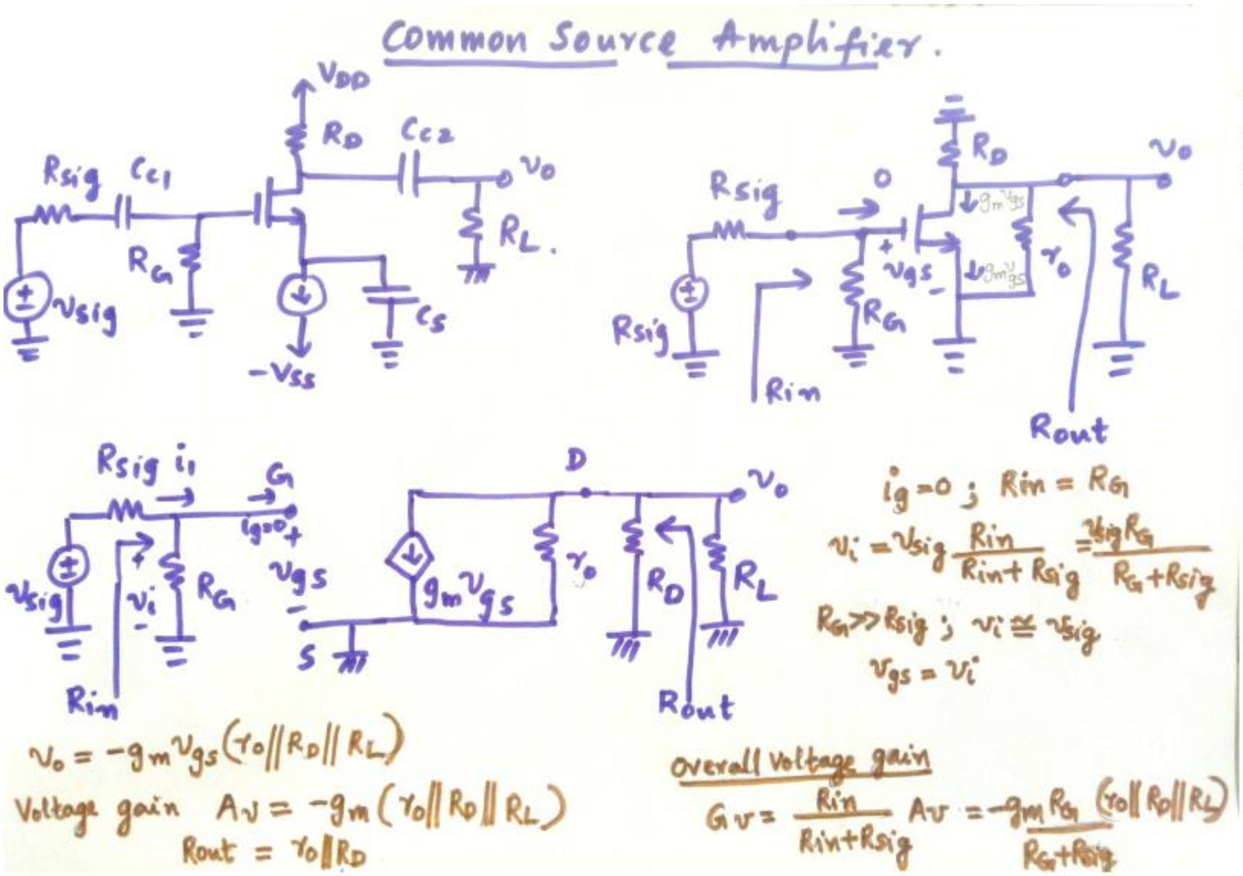
Sub:	Analog Electronic Circuits							Code:	21EC34
Date:	27/ 12/ 2022	Duration:	90 mins	Max Marks:	50	Sem:	3rd	Branch:	ECE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1.	Using small signal model of MOSFET derive the overall gain and output impedance of CS amplifier without source resistance.	[10]	CO2	L3
2.	Draw and explain the complete frequency response of a common source amplifier. Derive the expression for its lower cut-off frequency.	[10]	CO2	L2
3.	Find the midband gain AM , and the upper 3-dB frequency f_H of a CS amplifier fed with a signal source having an internal resistance Rsig = 100 kΩ. Theamplifier has RG = 4.7MΩ, RD = RL = 15 kΩ, , gm=1mA/V, ro=150kΩ , Cgs=1pFand Cgd=0.4pF	[10]	CO2	L3
4	State Barkhausen criteria for oscillation.With relevant circuit diagrams and equations explain the following a) Hartley Oscillator b) Crystal Oscillator.	[10]	CO2	L2

5.	Explain the working of a monostable multivibrator using 555 Timer IC. Design acircuit using 555 Timer to get a monoshot pulse of width 10ms. Choose C = 0.1μF	[10]	CO4	L3
6.	Explain the operation of 4-bit R-2R DAC with neat circuit. For the R-2R DAC,with R=10kΩ and RF=20kΩ and VREF=5V, determine the output voltage when the inputs b2=b1=5V and b0=b3=0V	[10]	CO4	L3
7	a) Derive the expression for gain with feedback for an operational amplifier in noninverting configuration. b) Write short notes on AC and DC amplifiers using opamp	[10]	CO4	L2
8.	A CS amplifier utilizes a MOSFET biased at I_D=0.25mA with V_{OV}=0.25V and R_D=20kΩ. The device has V_A=50V. The amplifier is fed with a source having R_{sig}=100kΩ, and a 20-kΩ load is connected to the output. Find Rin, Avo, Av and Ro and G_V. If to maintain reasonable linearity, the peak of the input sine-wave signal is limited to 10% of ($2V_{OV}$) what is the peak of the sine wave voltage at the output?	[10]	CO2	L3

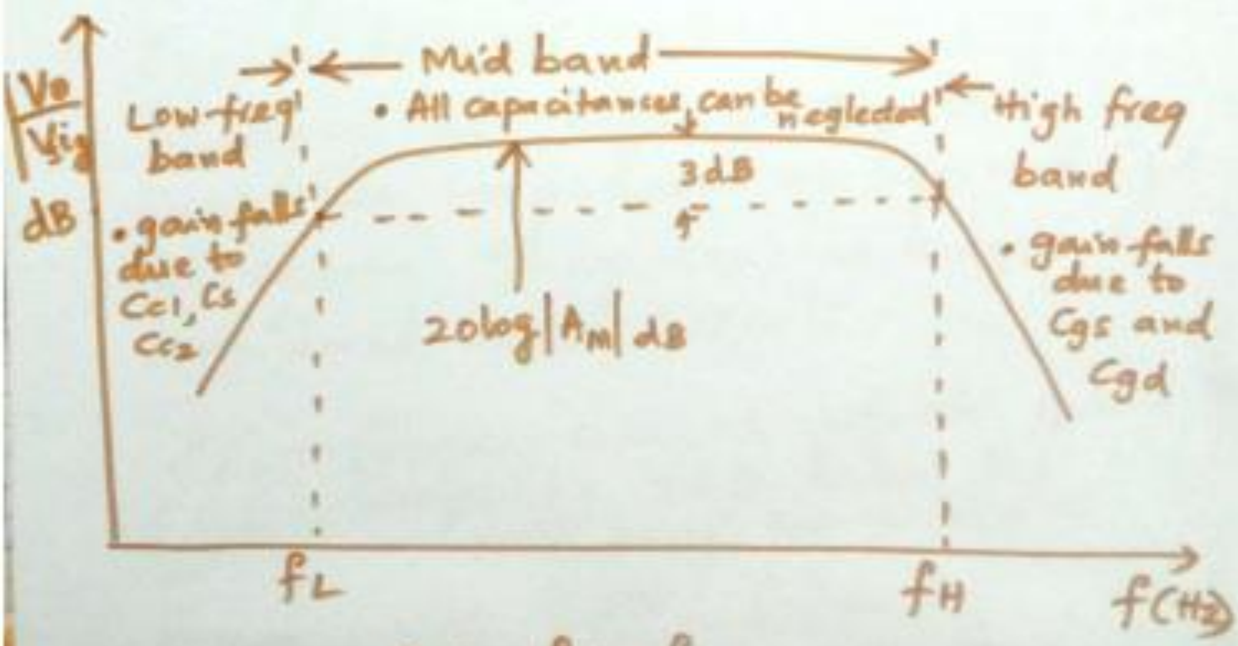
1. Using small signal model of MOSFET derive the overall gain and output impedance of CS amplifier without source resistance.



2. Draw and explain the complete frequency response of a common source amplifier. Derive the expression for its lower cut-off frequency.

FREQ RESPONSE OF CS AMPLIFIER.

- Dependence of the gain of the MOSFET Common Source Amplifier on the frequency of the input signal.
- C_{c1}, C_{c2}, C_s were acting as perfect short ckt when we studied the equivalent ckt model
- Internal capacitances C_{gs} and C_{gd} were neglected.
- These assumptions are valid only in Mid band Region ⇓



$BW = f_H - f_L$

* Mid band gain A_M corresponds to the over all voltage gain G_V

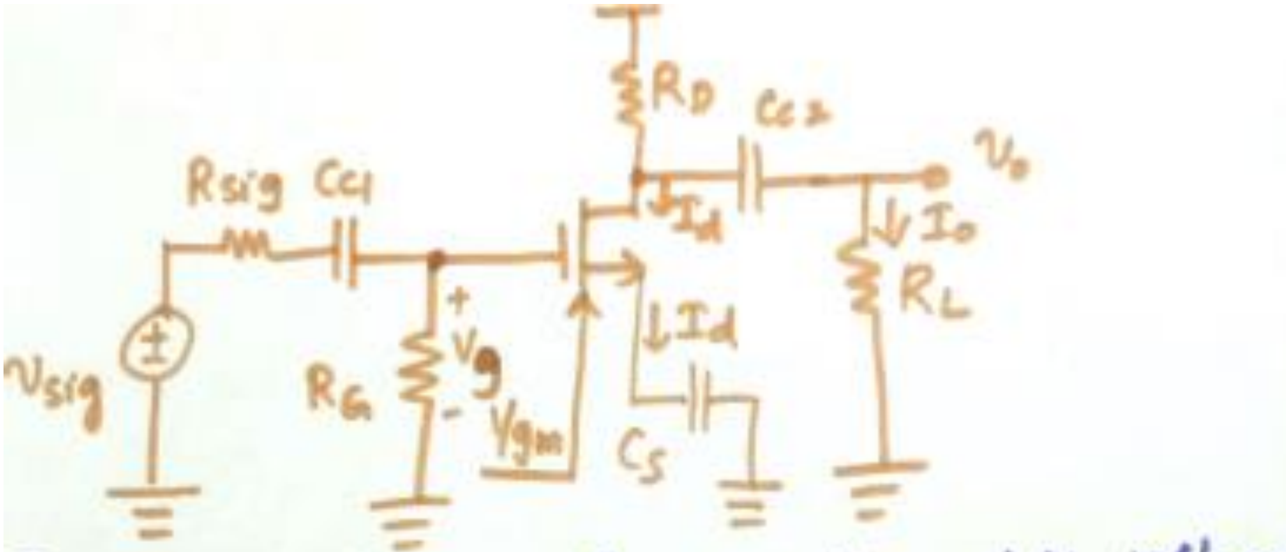
$$A_M = \frac{V_o}{V_{sig}} = -\frac{R_G}{R_G + R_{sig}} g_m (r_o \| R_D \| R_L)$$

* Gain falls off in the <u>low freq band</u> because as freq ↓, capacitive impedance $X_c = \frac{1}{C\omega} = \frac{1}{C \times 2\pi f}$ increases for C_{C1}, C_{C2}, C_S . [of the order of μF). So they no longer act as short circuits
* Gain falls off in the <u>high freq band</u> because at high freq, the capacitive impedance of C_{gs} and C_{gd} decreases. They can no longer be considered open circuits

* $\left.\begin{matrix} f_L \\ f_H \end{matrix}\right\}$ – frequencies at which gain drops by 3dB below the mid band gain value.

* Band width (BW) = $f_H - f_L$

Low Frequency Response



To find the low-freq Response, V_{DD} and V_{SS} voltage Sources are Short circuited, current source I is open circuited. The Coupling capacitors and by pass capacitor is taken into consideration. For Simplicity r_o is neglected (it has minor effect also)

$$V_g = V_{sig} \cdot \frac{R_G}{R_{sig} + \frac{1}{sC_{C1}} + R_G}.$$

In low freq Response, we need to consider the effect of 3 Capacitors. All of them affect the Low frequency Response.

There will be three break frequencies represented as:-

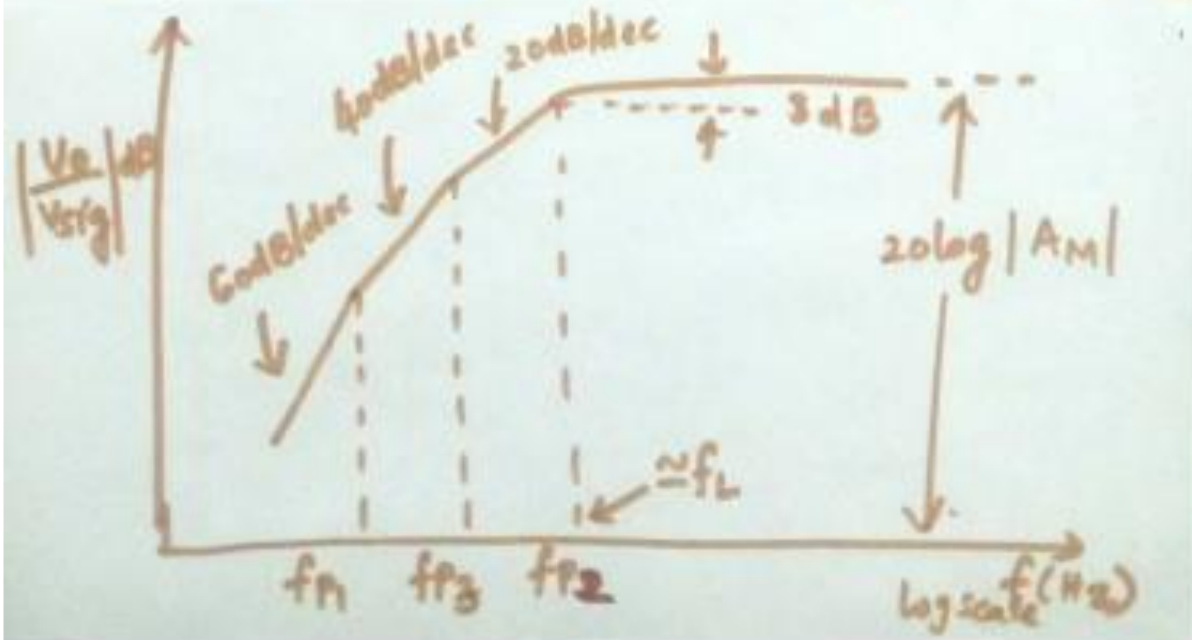
$$\omega_{P_1} = \frac{1}{C_{C_1}(R_G + R_{sig})}$$

$$\omega_{P_2} = \frac{g_m}{C_S}$$

$$\omega_{P_3} = \frac{1}{C_{C_2}(R_D + R_L)}$$

Over all low-frequency transfer function is given by

$$\frac{V_o}{V_{sig}} = -\left[\frac{R_G}{R_G + R_{sig}}\right](g_m R_D \| R_L)\left(\frac{s}{s+\omega_{P_1}}\right)\left(\frac{s}{s+\omega_{P_2}}\right)\left(\frac{s}{s+\omega_{P_3}}\right)$$



3. Find the midband gain AM , and the upper 3-dB frequency f H of a CS amplifier fed with a signal source having an internal resistance Rsig = 100 kΩ. The amplifier has RG = 4.7MΩ, RD = RL = 15 kΩ, gm=1mA/V, ro=150kΩ , Cgs=1pFand Cgd=0.4pF

The equivalent capacitance, C_{eq}, is found as

$$C_{eq} = (1 + g_m R_L')C_{gd}$$
$$= (1 + 7.14) \times 0.4 = 3.26 \text{ pF}$$

The total input capacitance C_{in} can be now obtained as

$$C_{in} = C_{gs} + C_{eq} = 1 + 3.26 = 4.26 \text{ pF}$$

The upper 3-dB frequency f_H is found from

$$f_H = \frac{1}{2\pi C_{in}(R_{sig} \parallel R_G)}$$
$$= \frac{1}{2\pi \times 4.26 \times 10^{-12}(0.1 \parallel 4.7) \times 10^6}$$
$$= 382 \text{ kHz}$$

$$A_M = -\frac{R_G}{R_G + R_{sig}} g_m R_L'$$

where

$$R_L' = r_o \parallel R_D \parallel R_L = 150 \parallel 15 \parallel 15 = 7.14 \text{ k}\Omega$$

$$g_m R_L' = 1 \times 7.14 = 7.14 \text{ V/V}$$

Thus,

$$A_M = -\frac{4.7}{4.7 + 0.1} \times 7.14 = -7 \text{ V/V}$$

4. State Barkhausen criteria for oscillation.With relevant circuit diagrams and equations explain the following a) Hartley Oscillator b) Crystal Oscillator.

[III] Oscillation Criterion (Barkhausen Criterion)

The condition for the feedback loop to provide sinusoidal oscillation

$$1 - A(j\omega_0)\beta(j\omega_0) = 0$$

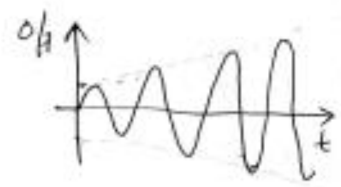
or $|A(j\omega_0)\beta(j\omega_0)| = 1$ and $\angle A(j\omega_0)\beta(j\omega_0) = 0$ or 360°

Cntenon:

To produce sustained oscillation at ω_0 the magnitude of loop gain should be unity and phase of loop gain should be zero.

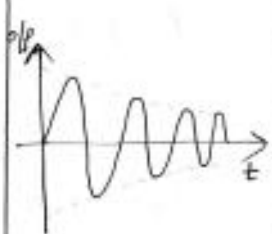
$|A\beta| > 1$

⇒ Oscillation will be growing type



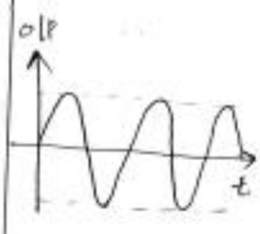
$|A\beta| < 1$

⇒ Decaying oscillation

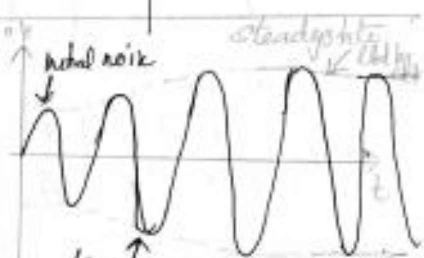


$|A\beta| = 1$

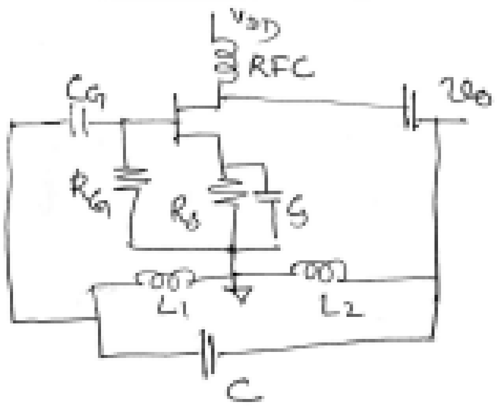
⇒ Sustained Oscillation

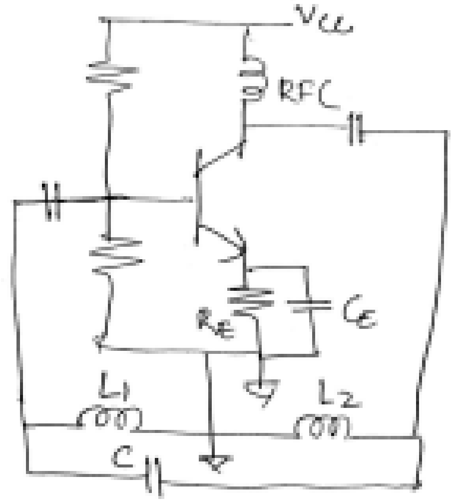


** In practical scenario $|A\beta| > 1$
→ It is not possible to keep $|A\beta| = 1$
then after some time due to non linearity of amplifier the steadystate envelope gives sustained o/p.



Hartley Oscillator:





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see the discussions related to Colpitt's oscillator is valid here too.

Frequency of oscillations

$X_1 + X_2 = X_3$

$\omega L_1 + \omega L_2 = \frac{1}{\omega C}$ $\qquad L_1 + L_2 \Rightarrow L_{eq}$

$(L_1 + L_2)\,\omega = \frac{1}{\omega C}$ $\qquad$ mutual inductance

$\omega^2 = \frac{1}{(L_1+L_2)C}$ $\qquad$ conn $\Rightarrow L_1 + L_2 + 2M \Rightarrow L_{eq}$

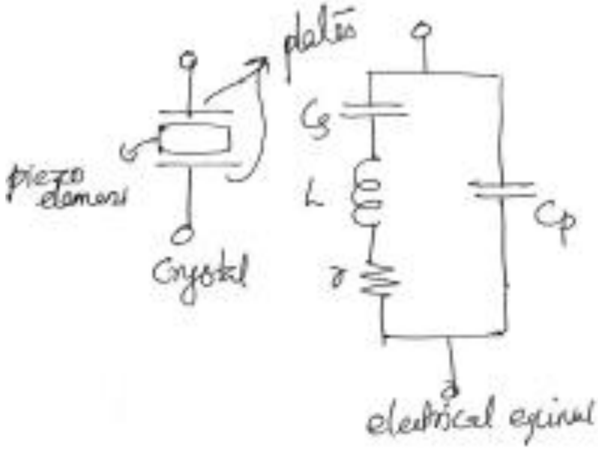
$(2\pi f)^2 = \frac{1}{(L_1+L_2)C} \Rightarrow \boxed{f = \frac{1}{2\pi\sqrt{L_{eq}C}}}$

Note: To obtain sustained oscillations the amplifier gain must be greater than L_1/L_2

$\boxed{A > L_2/L_1}$

Crystal Oscillator:

Piezoelectric crystal such as quartz, exhibits electromechanical resonance that are very stable and highly selective.



$C_p \rightarrow$ capacitance b/w the two plates of the crystal.

① The resonance properties are characterised by large inductance L (100's H), very small series capacitance C_s (0.0005pF) and series resistance r.
[$Q = \omega_0 L / r \Rightarrow$ hundred thousand]
parallel capacitance C_p (few pico farad)

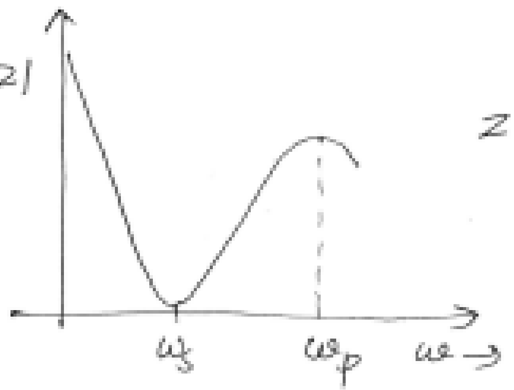
② The crystal will have a series resonance where the arm L, C_s and r will be purely resistive. This will happen when

$$X_L = X_{C_S} \Rightarrow \omega_S L = \frac{1}{\omega_S C_S}$$

$$\boxed{\omega_s = \frac{1}{\sqrt{LC_s}}} \rightarrow \text{Series resonance freq.}$$

Parallel resonance will happen at a freq ω_p when

$$X_L = X_{C_S} + X_{C_P} \Rightarrow \omega_p = \frac{1}{\sqrt{L\left(\frac{C_S C_P}{C_S + C_P}\right)}}$$



Z → impedence.

Piezo electric effect

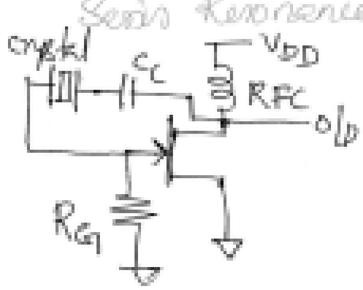
(a) When an alternating voltage is applied across the crystal, mechanical vibrations are setup at a natural frequency

(b) When mechanical stress is applied a difference is potential develops across the plates.

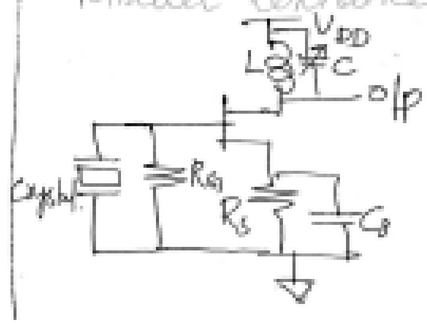
Note: Crystal oscillators are highly stable, so they are used in communication equipments and processor clock circuits.

Crystal Oscillator ckts:

Series Resonance



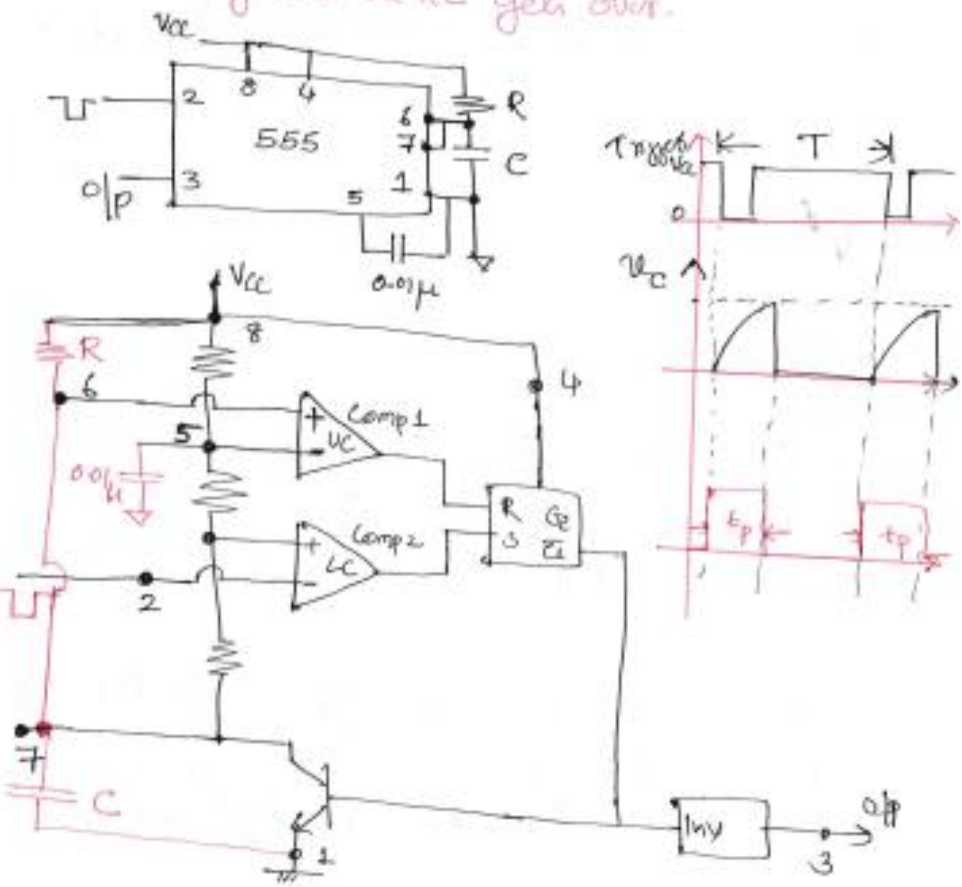
Parallel Resonance



5. Explain the working of a monostable multivibrator using 555 Timer IC. Design a circuit using 555 Timer to get a monoshot pulse of width 10ms. Choose C = 0.1µF

Monostable Multivibrator using 555 IC (5)

* It has one stable state.
* It is also called as one shot, it is a pulse generating circuit.
* The ckt remains in the stable state (normally logic zero). It will switch to quasi stable state once an external Trigger pulse is applied. It goes back to stable state once the time duration determined by external RC gets over.



I] when ckt is s/w ON, no trigger pulse present

capacitor voltage is zero

$V_6 = 0$, $V_2 = V_{CC}$

Upper comparator output will be '0' and lower comparator output will be '0'

* R = 0, S = 0, F/F becomes reset (retains the stable state), Q = 0, $\bar{Q}$ = 1

* 555 timer output zero ∴ Transistor Q is 'ON' capacitor won't be charging.

II] when a -ve trigger pulse is applied at Pin 2

The lower comparator output goes high

S = 1, R = 0, the F/F is set and 'Q' is off. The output will be '1' (555 o/p)

the capacitor starts charging to Vcc thru R.

S=0, R=0 ⇒ The trigger pulse will be removed, S=0, R=0 ⇒ state remains unchanged

once capacitor voltage reaches $\frac{2}{3}V_{CC}$

$V_C > \frac{2}{3}V_{CC} \Rightarrow V_6 > \frac{2}{3}V_{CC}$

the upper comparator state changes

R = 1, S = 0 } F/F is reset, Q is ON

555 output goes low. Capacitor discharge thru Q. (fast discharge) → stable state. Remains here till Next pulse comes.

Time Constant tp (pulse width)

tp → the time taken by capacitor to charge to $\frac{2}{3}V_{CC}$

from capacitor voltage eqn (charging)

$$v_C(t) = v_{final} + (v_{initial} - v_{final})\, e^{-t/RC} \quad \text{--- (2)}$$

$v_C(t_p) = \frac{2}{3} v_{CC}$ $t = t_p$

$v_{final} = v_{CC}$, $v_{initial} = 0$

from (2)

$$\frac{2}{3} V_{CC} = v_{CC} + (0 - V_{CC})\, e^{-t_p/RC}$$

$$\frac{2}{3} - 1 = -e^{-t_p/RC}$$

$$\frac{1}{3} = e^{-t_p/RC}$$

$$3 = e^{t_p/RC}$$

or $\boxed{t_p = (\ln 3) RC = 1.0986 RC = 1.1 RC}$

1.1RC=10m

Given C=0.1uF

R= 10m/1.1*0.1u =9.7kohm

6. Explain the operation of 4-bit R-2R DAC with neat circuit. For the R-2R DAC,with R=10kΩ and RF=20kΩ and VREF=5V, determine the output voltage when the inputs b2=b1=5V and b0=b3=0V

(ii) R-2R Ladder type DAC.

- Fig 5.2 represents a DAC with R and 2R resistors.

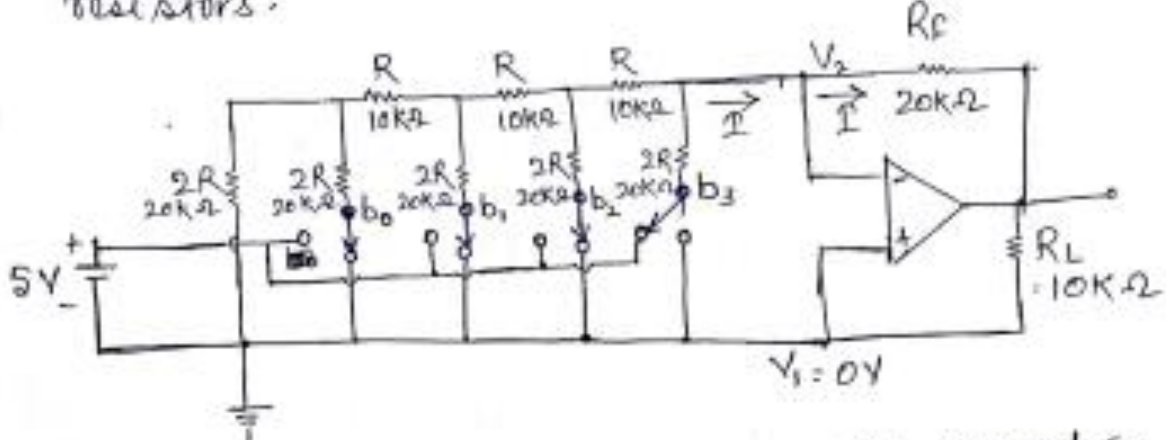


Fig 5.2.a :- D/A converter with R/2R resistor.

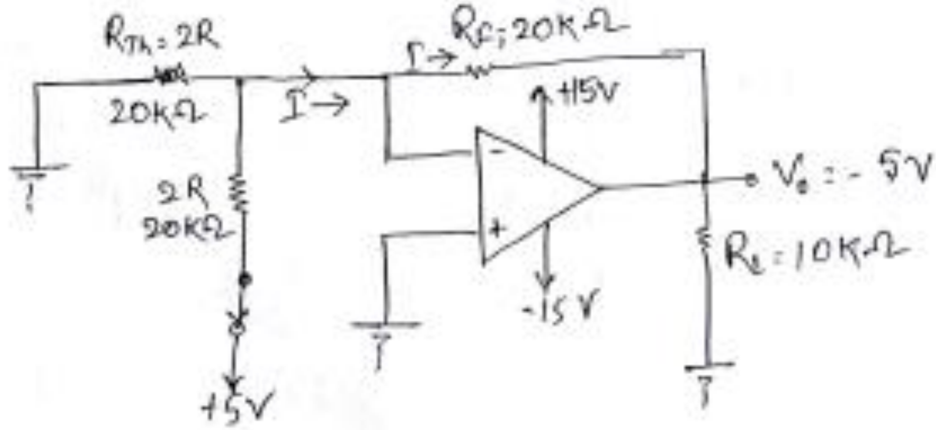


Fig 5.2.b :- Equivalent circuit when b_3 is high and b_0, b_1 & b_2 are low

- $b_0 \rightarrow$ LSB, $b_3 \rightarrow$ MSB (in 4-bit system).
- From figure, switch b_3 is connected to +5V (high) and other switches b_0, b_1 & b_2 are connected to ground, 0V (low).

• For particular set of inputs i.e.

$b_3 \to 1$

$b_2 \to 0$

$b_1 \to 0$

$b_0 \to 0$,

the thevenin equivalent resistance R_T is, to the left of switch b_3.

$$R_{Th} = [\{[(2R||2R+R)||2R]+R\}||2R]+R$$

$$= 2R = 20K\Omega$$

• From Fig 5.2.b, it is clear, that R_{Th} is connected to ground, hence the current through R_{Th} will be zero. But the resistance 2R is connected to +5 V, so the current flowing through 2R will be $5V/20K\Omega = 0.25$ mA. This very same current flows through R_F. So, the output voltage will be.

$$V_o = -(20K\Omega)(0.25\,mA) = -5\,V.$$

. Therefore the output voltage equation can be written as

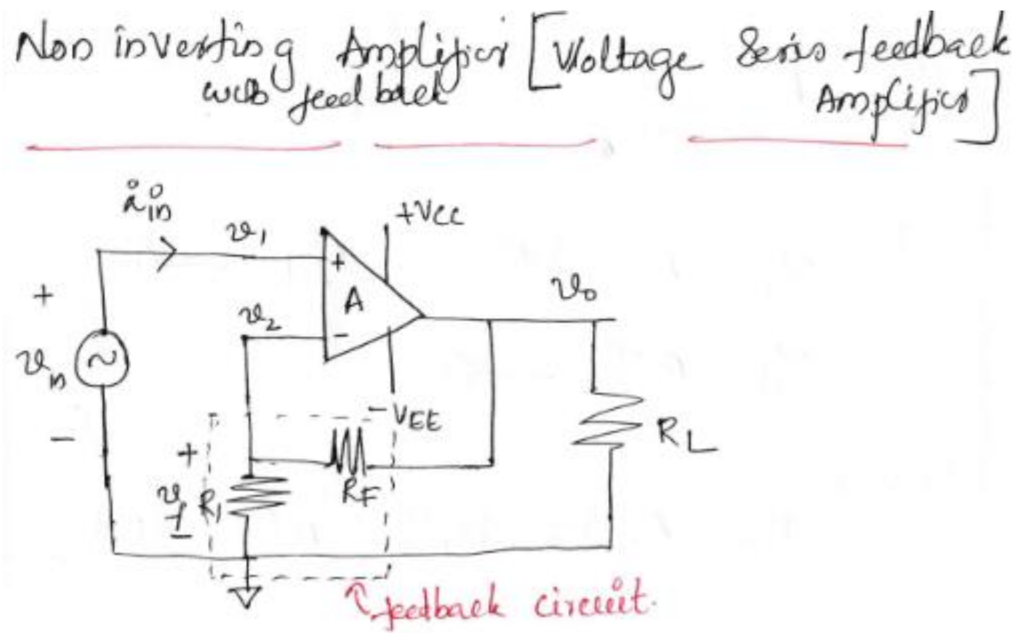
$$\boxed{V_o = -R_F\left(\frac{b_3}{2R} + \frac{b_2}{4R} + \frac{b_1}{8R} + \frac{b_0}{16R}\right)} \quad (5.2)$$

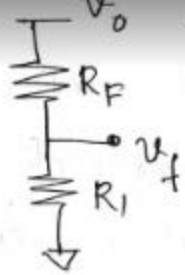
b2=b1=5

Vo= -20*5/10(1/4+1/8) = -3.75V

7. a)Derive the expression for gain with feedback for an operational amplifier in noninverting configuration. b) Write short notes on AC and DC amplifiers using opamp

a)





$$v_f = \frac{v_0 \times R_1}{R_1 + R_F}$$

$$B = \frac{v_f}{v_0} = \frac{R_1}{R_1 + R_F}$$

Substituting value of B in ③

$$A_F = \frac{A}{1 + \frac{AR_1}{R_1 + R_F}} = \frac{A(R_1 + R_F)}{R_1 + R_F + AR_1} \quad \text{—(}$$

<u>Note:</u> In ideal case A >>>. [Typically is the order of] thus if ideal op-amp is considered

$$1 + \frac{AR_1}{R_1 + R_F} \simeq \frac{AR_1}{R_1 + R_F} \quad \text{OR}$$

$$R_1 + R_F + AR_1 \simeq AR_1$$

thus eqn ④ becomes under ideal case.

$$A_F = \frac{A(R_1 + R_F)}{AR_1} = 1 + \frac{R_F}{R_1} \quad \text{— ⑤}$$

b)

DC and AC Amplifiers.

Based on the signal to amplify, the amplifier can be of two types.

- DC Amplifier
- AC Amplifier.

DC Amplifier.

In DC amplifier the output signal changes in response to changes in its dc input levels. A dc amplifier can be inverting, non-inverting or differential.

AC Amplifier.

AC amplifier responds to the ac input. It is used ~~needed~~ when ac response characteristics i.e low and high frequency limits ~~of the~~ is needed. Also if the ac input is riding on some dc level, it is necessary to use an ac amplifier with coupling ~~capact~~ capacitor.

The coupling capacitor not only blocks the dc voltages but also sets but also sets the low frequency cut-off limit, given by

$$f_L = \frac{1}{2\pi C_i (R_{iF} + R_o)}$$

where, f_L = low-frequency cut-off.
C_i = coupling capacitor or dc blocking capacitor.
R_{iF} = ac input resistance
R_o = ac output resistance

8. A CS amplifier utilizes a MOSFET biased at I D =0.25mA with V OV =0.25V and R D =20kΩ. The device has V A =50V. The amplifier is fed with a source having R sig =100kΩ, and a 20-kΩ load is connected to the output. Find Rin, Avo, Av and Ro and G V . If to maintain reasonable linearity, the peak of the input sine-wave signal is limited to 10% of (2VOV) what is the peak of the sine wave voltage at the output?

For CS amplifier

$$R_{in} = R_G$$

$$A_v = -g_m(r_o \| R_D \| R_L)$$

$$R_{out} = r_o \| R_D$$

$$G_v = -\frac{R_G}{R_G + R_{sig}} g_m(r_o \| R_D \| R_L)$$

Here RG=infinity

Rin= infinity

So Av=Avo

gm = $2I_D/V_{ov}$ =0.5mS

$r_0 = V_A/I_D$ =200kohm

A_v = -0.5m*(200||15||15)k

=-7.3V/V

R_{out} = 13.9Kohm

G_v = Av=-7.3V/V