CMR
INSTITUTE OF
TECHNOLOGY

USN

Internal Assesment Test - I

Sub:	Operational Amplifiers and linear Ics							Code:	18EE46
Date:	12/07/2022	Duration:	90 mins	Max Marks:	50	Sem:	4th	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1	Sketch the circuit of 3 input non inverting summing amplifier and derive the expression of output voltage and illustrate how the same can be used as averaging amplifier.	10	CO1	L2
2	Define the following a.Input bias current b.Input offset current c.Slew rate d.CMRR e.Offset Voltage	10	CO1	L1
3	Explain the Instrumentation amplifier circuit and obtain expression for output voltage of a transducer bridge Instrumentation amplifier with a neat circuit diagram.	10	CO1	L2
4	Why are active filters are preferred over passive filters? Derive the expression of gain for first order LPF	10	CO2	L2

P.T.O

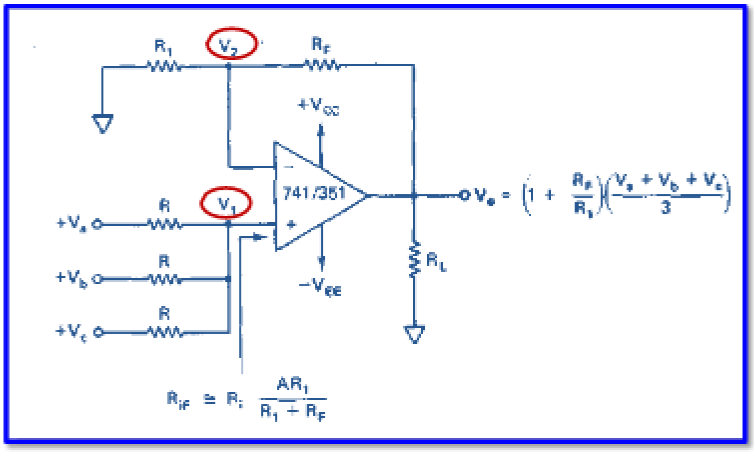
5	Design a Butterworth second order high pass filter circuit to have a cut-off frequency of 6Khz calculate the actual cut-off frequency for the circuit using the selected component values	10	CO2	L3
6	Explain in detail about the all pass filter and derive the magnitude and phase of the same.	10	CO2	L2

CI

CCI

HOD

1.



Non-inverting Summing Amplifier

Therefore, using the superposition theorem, the voltage $V_2 = V_1$

V_b & $V_c = 0$. Net resistance $= R+R/2$

$$V_1 = \frac{R/2}{R + R/2} V_a + \frac{R/2}{R + R/2} V_b + \frac{R/2}{R + R/2} V_c$$

$$V_1 = \frac{R/2}{3R/2} V_a + \frac{R/2}{3R/2} V_b + \frac{R/2}{3R/2} V_c$$

$$V_1 = \frac{V_a}{3} + \frac{V_b}{3} + \frac{V_c}{3} = \frac{V_a + V_b + V_c}{3}$$

If $R_F=2R_1$, $1+R_F/R_1=3$

$V_o= V_a+V_b+V_c$

2.

Input bias current:The dc current required by the inputs of the amplifier to properly operate the first stage.It Is the average of both input currents.

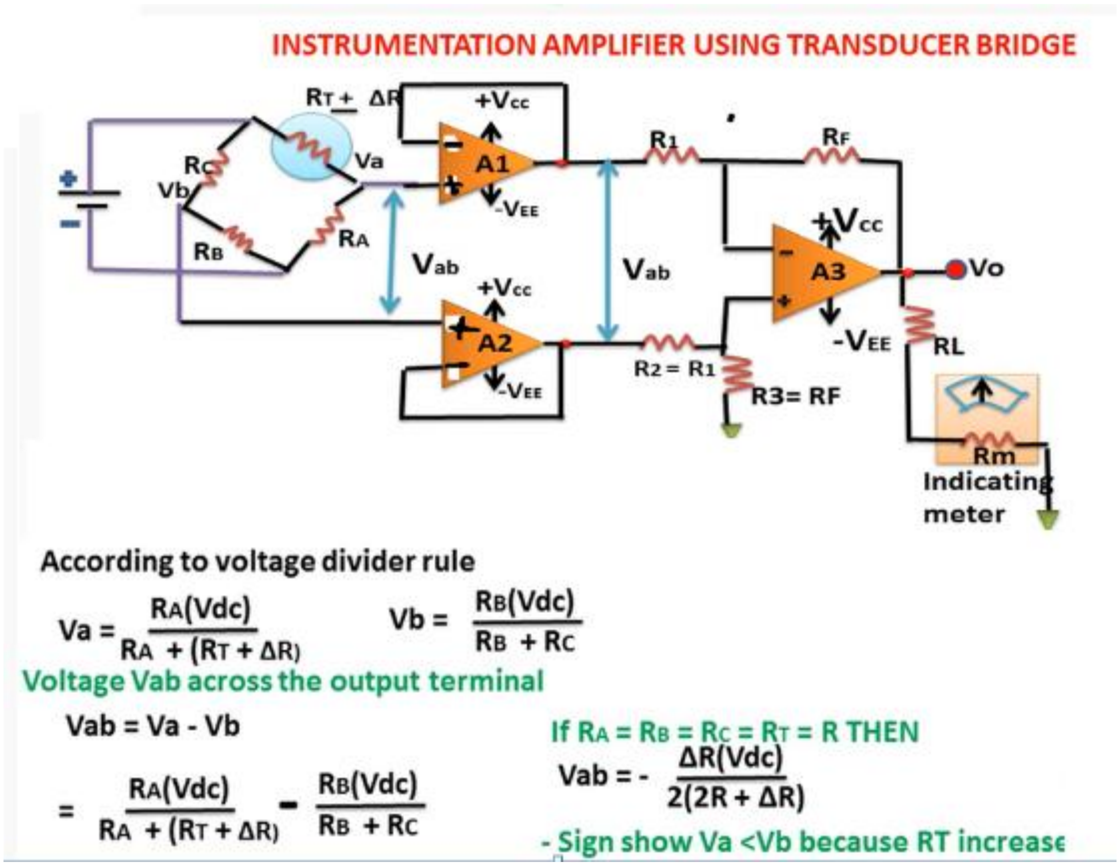
Input Offset Current It is the difference of input bias currents.

Slew Rate It is the maximum rate of change of the output voltage in response to a step input voltage.

COMMON-MODE REJECTION RATIO (CMRR) The ability of amplifier to reject the common-mode signals (unwanted signals) while amplifying the differential signal (desired signal).

The input offset voltage is defined as **the voltage that must be applied between the two input terminals of the op amp to obtain zero volts at the output**. Ideally the output of the op amp should be at zero volts when the inputs are grounded. In reality the input terminals are at slightly different dc potentials.

3.


INSTRUMENTATION AMPLIFIER USING TRANSDUCER BRIDGE
RT + ΔR
+Vcc
A1
-VEE
RC
Vb
Va
RB
RA
Vab
+Vcc
A2
-VEE
Vab
R1
RF
+Vcc
A3
-VEE
Vo
RL
R2 = R1
R3= RF
Rm
Indicating meter
According to voltage divider rule
Va = RA(Vdc) / RA + (RT + ΔR)
Vb = RB(Vdc) / RB + RC
Voltage Vab across the output terminal
Vab = Va - Vb
= RA(Vdc) / RA + (RT + ΔR) - RB(Vdc) / RB + RC
If RA = RB = RC = RT = R THEN
Vab = - ΔR(Vdc) / 2(2R + ΔR)
- Sign show Va <Vb because RT increase

Output voltage Vab of the bridge is applied to differential instrumentation amplifier composed to three op amp .

Gain of the basic amplifier is (-RF/R1) , then Vo is

Voltage Vab across the output terminal

ΔR is small and $2R + \Delta R = 2R$

$$V_o = V_{ab} \cdot \frac{R_F}{R_1} = -\frac{\Delta R(V_{dc})}{2(2R+\Delta R)} \frac{R_F}{R_1}$$

$$V_o = \frac{R_F}{R_1} \frac{\Delta R}{4R} V_{dc}$$

4.

Basis for Comparison	Active Filter	Passive Filter
Composed of	Active components like op-amp, transistor etc.	Passive components like resistor, inductor and capacitor etc.
Cost	High	Comparatively low.
Circuit complexity	More complex	Less complex than active filter.
Weight	Low	Comparatively bulkier due to presence of inductors.
Q factor	High	Very low in comparison to active filters.
External power supply	Required	Not required

First Order Low Pass Filter

- The resistors R_f and R_1 decide the gain of the filter in the pass band.

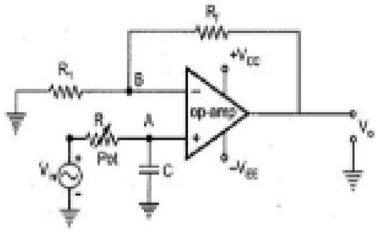
The impedance of the capacitor C is $-jX_C$ where X_C is the capacitive reactance given by $X_C = 1/2\pi fC$.

$$V_A = -\frac{-jXC}{R - jXC} * VIN$$

$$V_A = -\frac{-j\frac{1}{2\pi fC}}{R - j\frac{1}{2\pi fC}} * VIN = \frac{V_{IN}}{1 - \frac{2\pi fRC}{j}}$$

-j = 1/j; j = - 1/j

$$V_A = -\frac{V_{IN}}{1 + j2\pi fRC}$$



First order low pass butterworth filter

$$V_A = -\frac{V_{IN}}{1 + j2\pi fRC}$$

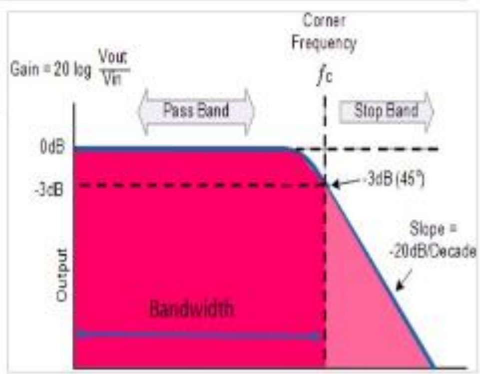
the op-amp is in the non-inverting configuration,

$$V_O = \left(1 + \frac{R_f}{R_1}\right) V_A = \left(1 + \frac{R_f}{R_1}\right) \frac{V_{IN}}{1 + j2\pi fRC}$$

$$\frac{V_O}{V_{IN}} = \frac{A_F}{1 + j\left(\frac{f}{f_H}\right)}$$

Where, $A_F = 1 + \frac{Rf}{R1}$

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



5.

VTU : Aug.-02, July-08,09, Jan.-16, Marks 6

Solution : As decay rate in the stop band is + 40 dB/decade, it is second order high pass filter.

Choose $C_2 = C_3 = C = 1000$ pF

and $f_L = 6$ kHz

$\therefore \quad f_L = \frac{1}{2\pi RC}$ i.e. $6\times10^3 = \frac{1}{2\pi R\times1000\times10^{-12}}$

$\therefore \quad R = 26.525\ k\Omega \approx 27\ k\Omega$

$\therefore \quad R = R_2 = R_3 = 27\ k\Omega$

For Butterworth response,

$$A_F = 1.586 = \frac{R_f}{R_1}+1$$

$\therefore \quad R_f = 0.586\ R_1$

Choose $R_f = 10\ k\Omega$ and $R_1 = 17\ k\Omega$

Hence the designed circuit is,

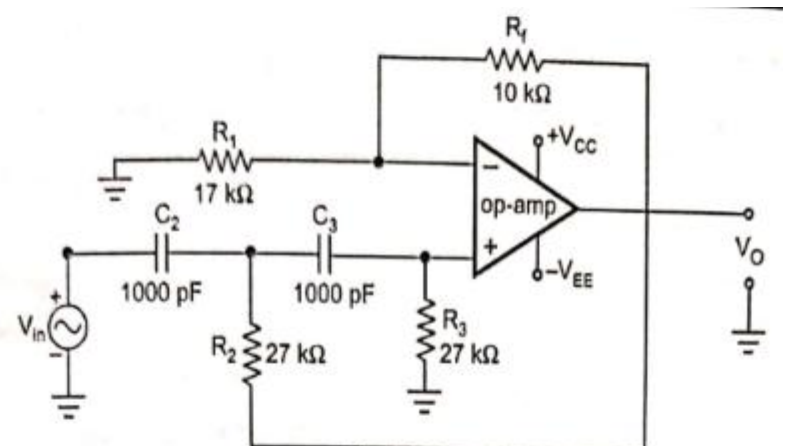


Fig. 2.8.5

6.

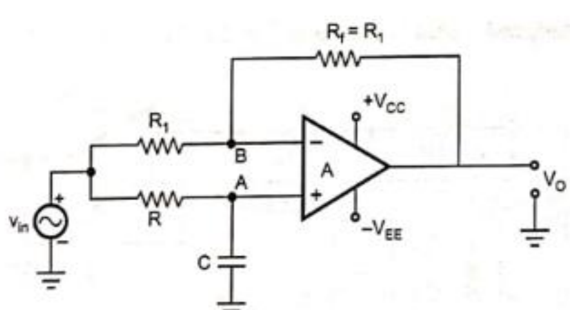


Fig. 2.12.1 All pass filter

Let us use the superposition principle to obtain the expression for the output voltage V_O.

Assume input to the non-inverting terminal zero. The circuit acts as an inverting amplifier.

$$\therefore \quad V_{O1} = -\frac{R_f}{R_1} V_{in}$$

$$\therefore \quad V_{O1} = -V_{in} \quad \text{as } R_f = R_1 \qquad \text{... (2.12.1)}$$

Now, assume input to the inverting terminal zero. The circuit acts as a non-inverting amplifier.

$$\therefore \quad V_{O2} = \left(1 + \frac{R_f}{R_1}\right) V_A$$

$$\therefore \quad V_{O2} = 2\,V_A \quad \text{as } R_f = R_1 \qquad \text{... (2.12.2)}$$

and $\quad V_A$ = Voltage at node A

By the potential divider rule, the voltage V_A can be obtained as

$$V_A = V_{in}\left[\frac{-j X_C}{R - j X_C}\right]$$

where $\quad -j X_C = -j\left(\frac{1}{2\pi f C}\right) = \left(\frac{1}{j 2\pi f C}\right) \quad \text{as } -j = \frac{1}{j}$

$$\therefore \quad V_A = V_{in}\left[\frac{\frac{1}{j 2\pi f C}}{R + \frac{1}{j 2\pi f C}}\right] = V_{in}\left[\frac{1}{1 + j 2\pi f RC}\right] \qquad \text{... (2.12.3)}$$

Substituting in (2.12.2),

$$V_{O2} = 2\,V_{in}\left[\frac{1}{1 + j 2\pi f RC}\right] \qquad \text{...(2.12.4)}$$

Hence, the total output voltage is

$$V_O = V_{O1} + V_{O2} = -V_{in} + 2\,V_{in}\left[\frac{1}{1 + j 2\pi f RC}\right]$$

$$\therefore \quad V_O = V_{in}\left[-1 + \frac{2}{1 + j 2\pi f RC}\right] \qquad \text{... (2.12.5)}$$

$$\therefore \quad \boxed{\frac{V_O}{V_{in}} = \frac{1 - j 2\pi f RC}{1 + j 2\pi f RC}} \qquad \text{... (2.12.6)}$$

The magnitude of the transfer function is

$$\boxed{\left|\frac{V_O}{V_{in}}\right| = \frac{\sqrt{1 + (2\pi f R C)^2}}{\sqrt{1 + (2\pi f R C)^2}} = 1} \qquad \text{... (2.12.7)}$$

It is mentioned earlier that the magnitude is always 1 for all pass filter and it can pass the entire range of frequency. But the phase angle is given by

$$\boxed{\phi = -2 \tan^{-1}\left(\frac{2\pi f R C}{1}\right)} \qquad \text{... (2.12.8)}$$