CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - I

Sub:	**OPERATIONAL AMPLIFIERS AND LINEAR ICs**							Code:	15EE46
Date:	30 / 03/ 2017	Duration:	90 mins	Max Marks:	50	Sem:	IV	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	CO	RBT
1 (a)	With a block diagram explain the different stages of a typical Op-amp.	[5]	CO1	L2
1 (b)	Define slew rate and CMRR for an Op-amp with necessary expressions.	[5]	CO1	L2
2	Derive the expression for closed loop gain of a voltage series and voltage shunt feedback amplifier with circuit diagrams.	[10]	CO1	L2
3	Using an uA741 Op-amp design a capacitor coupled non inverting amplifier. The specifications of the circuit are :-Closed loop voltage gain =3,Input voltage =2V, load resistance =2.2kΩ and lower cut off frequency =120 Hz.	[10]	CO1	L3
4	Explain how an Op-amp can be used as a summing amplifier and subtractor.	[10]	CO1	L2
5	Demonstrate an Instrumentation amplifier with bridge input. Derive the expression of output voltage for the same.	[10]	CO1	L2
6	Design a two stage wide- band band- pass Butterworth filter with a lower cut off frequency of 400 Hz and upper cut off frequency of 2 kHz. Calculate the value of Q and draw the frequency response curve.	[10]	CO6	L3
7	Define the performance parameters of voltage regulators with necessary equations.	[10]	CO6	L2
8	Explain the internal circuit of an adjustable voltage regulator and design a voltage regulator using LM317 IC to produce an output voltage of 9V.	[10]	CO6	L3

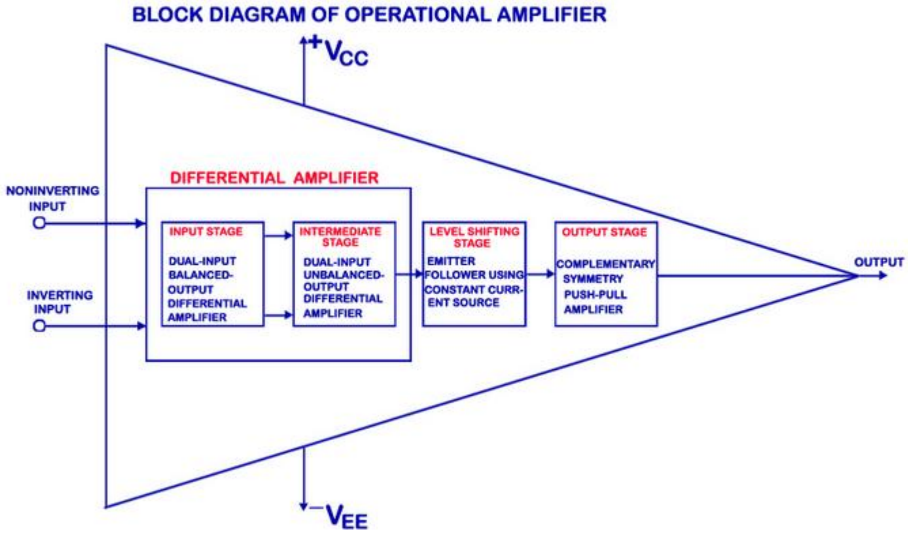
Standard resistance values

10% Tolerance							
Ω	Ω	Ω	kΩ	kΩ	kΩ	MΩ	MΩ
—	10	100	1	10	100	1	10
—	12	120	1.2	12	120	1.2	12
—	15	150	1.5	15	150	1.5	15
—	18	180	1.8	18	180	1.8	18
—	22	220	2.2	22	220	2.2	22
2.7	27	270	2.7	27	270	2.7	—
3.3	33	330	3.3	33	330	3.3	—
3.9	39	390	3.9	39	390	3.9	—
4.7	47	470	4.7	47	470	4.7	—
5.6	56	560	5.6	56	560	5.6	—
6.8	68	680	6.8	68	680	6.8	—
8.2	82	820	8.2	82	820	8.2	—

Standard capacitor values

pF	pF	pF	pF	µF	µF	µF	µF	µF	µF	µF
5	50	500	5000	—	0.05	0.5	5	50	500	5000
—	51	510	5100	—	—	—	—	—	—	—
—	56	560	5600	—	0.056	0.56	5.6	56	—	5600
—	—	—	6000	—	0.06	—	6	—	—	6000
—	62	620	6200	—	—	—	—	—	—	—
—	68	680	6800	—	0.068	0.68	6.8	68	680	6800
—	75	750	7500	—	—	—	—	75	—	—
—	—	—	8000	—	—	—	8	80	—	—
—	82	820	8200	—	0.082	0.82	8.2	82	—	—
—	91	910	9100	—	—	—	—	—	—	—
10	100	1000	—	0.01	0.1	1	10	100	1000	10000
—	110	1100	—	—	—	—	—	—	—	—
12	120	1200	—	0.012	0.12	1.2	—	—	—	—
—	130	1300	—	—	—	—	—	—	—	—
15	150	1500	—	0.015	0.15	1.5	15	150	1500	15000
—	160	1600	—	—	—	—	—	—	—	—
18	180	1800	—	0.018	0.18	1.8	18	180	—	—
20	200	2000	—	0.02	0.2	2	20	200	2000	—
22	220	2200	—	—	0.22	2.2	22	220	2200	22000
24	240	2400	—	—	—	—	—	240	—	—
—	250	2500	—	—	0.25	—	25	250	2500	—
27	270	2700	—	0.027	0.27	2.7	27	270	—	—
30	300	3000	—	0.03	0.3	3	30	300	3000	—
33	330	3300	—	0.033	0.33	3.3	33	330	3300	—
36	360	3600	—	—	—	—	—	—	—	—
39	390	3900	—	0.039	0.39	3.9	39	—	—	—
—	—	4000	—	0.04	—	4	—	400	—	—
43	430	4300	—	—	—	—	—	—	—	—
47	470	4700	—	0.047	0.47	4.7	47	470	4700	—

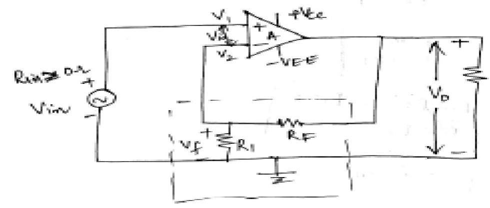
1.(a)



1(b)**Slew Rate** : The slew rate is the maximum rate of change of output voltage caused by a step input voltage and is usually specified in V/µS. For example 1V/µS slew rate means that the output rises or falls by 1V in one microseconds. Ideally slew rate is infinite which means that op-amp's output should be changed instantaneously in response to input step voltage. Practical op-amps are available with slew rates from 0.1V/µS to well above 1000V/µS.

CMRR : It can be defined as the ratio of the differential gain A_D to the common mode gain A_{CM} that is,$CMRR = A_D / A_{CM}$.

2.



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(1) Voltage - series feedback amplifier

→ Used as Non-inverting amplifier.

open loop voltage gain ($A = \frac{V_o}{V_{id}}$)

closed loop voltage gain $A_F = \frac{V_o}{V_{in}}$

Gain of feedback circuit $B = \frac{V_f}{V_o}$

Negative feedback

$V_{id} = V_{in} - V_f$

V_{in} → input voltage V_f - feedback voltage V_{id} = diff i/p V.

feedback always the input voltage (180°).

closed loop voltage gain

$A_F = \frac{V_o}{V_{in}}$

$V_o = A(V_1 - V_2)$.

From fig $v_1 = V_{in}$

$$v_2 = V_f = V_o \times \frac{R_1}{R_1 + R_F}$$

$$V_o = A\left[V_{in} - \frac{R_1 V_o}{R_1 + R_F}\right]$$

$$V_o = A\left[\frac{V_{in}(R_1+R_F) - R_1 V_o}{R_1 + R_F}\right]$$

$$V_o\left[1 + \frac{R_1}{R_1+R_F}\right] = A V_{in}$$

$$V_o = \frac{A(R_1+R_F)V_{in}}{R_1 + R_F + AR_1}$$

$$A_F = \frac{V_o}{V_{in}} = \frac{A(R_1+R_F)}{R_1+R_F+AR_1}$$

A is very large (10^5)

$AR_1 >> (R_1+R_F)$ so $R_1+R_F+AR_1 \simeq AR_1$

$$A_F = \frac{V_o}{V_{in}} = \frac{A(R_1+R_F)}{AR_1} = 1 + \frac{R_F}{R_1} \text{ (ideal)}$$

$$B = \frac{V_f}{V_o} = \frac{R_1}{R_1+R_F}$$ **8**

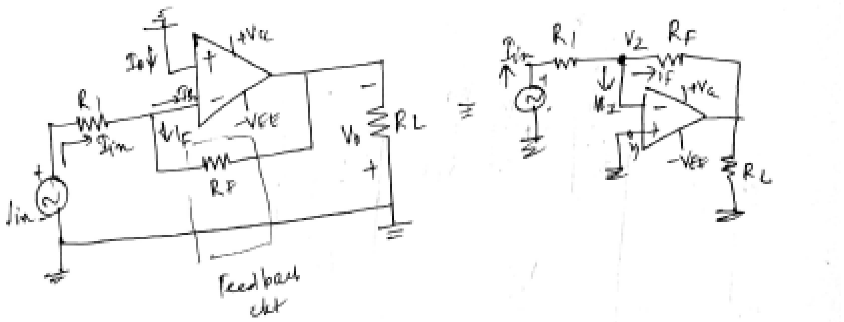
Comparing A & B

$$\boxed{A_F = 1/B}$$

$$A_F = \frac{A(R_1+R_F)}{R_1+R_F+AR_1} = \frac{A\left(\frac{R_1+R_F}{R_1+R_F}\right)}{\frac{R_1+R_F}{R_1+R_F} + \frac{AR_1}{R_1+R_F}}$$

$$\boxed{A_F = \frac{A}{1+AB}}$$

Voltage shunt feedback amplifier



closed loop voltage gain

$$i_{in} = i_F + i_B$$

$i_B <<$ $\quad i_{in} \approx i_F$

$$\frac{v_{in} - v_2}{R_1} = \frac{v_2 - v_o}{R_F}$$

$$v_1 - v_2 = v_o / A$$

$v_1 = 0 \quad v_2 = \frac{-v_o}{A}$

$$\frac{v_{in} + v_o/A}{R_1} = \frac{-(v_o/A) - v_o}{R_F}$$

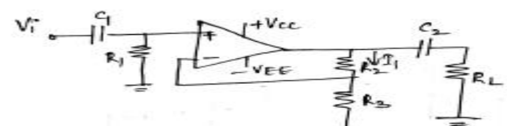
$$A_F = \frac{v_o}{v_{in}} = \frac{-A R_F}{R_1 + R_F + A R_1}$$

$A R_1 >> R_1 + R_F$

$$A_F = \frac{v_o}{v_{in}} = \frac{-R_F}{R_1}$$

3.

Non-inverting amplifier



Given $V_i = 2V$ $\quad A_v = 2$ $\quad R_L = 2.2k\Omega$ $\quad I_1 = 100 I_{Bmax} = 50\mu A$

$f_1 = 120Hz$

$$R_1 = \frac{0.1 V_{BE}}{I_{Bmax}} = \frac{0.1 \times 0.7}{500nA} = 140k\Omega \ (120k\Omega)$$

$$R_3 = \frac{V_i}{I_1} = \frac{2}{50\mu A} = 40k\Omega \ (39k\Omega)$$

$A_v = 2 \qquad 1 + \frac{R_2}{R_1} = 2 \qquad R_2 = R_1 = 39k\Omega$

$X_{C1} = \frac{R_1}{10} \qquad \frac{1}{2\pi f_1 C_1} = \frac{R_1}{10} \qquad C_1 = \frac{10}{2\pi f_1 R_1} = 0.1\mu F$

$C_1 = 0.1\mu F$

$X_{C2} = R_L$

$$\frac{1}{2\pi f_1 C_2} = 2.2k\Omega$$

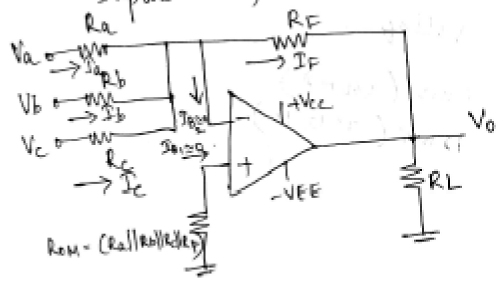
$C_2 = 0.6\mu F \ (0.47\mu F)$

4.

(i) Adder

Inverting configuration

Inputs – Va, Vb & Vc



$$I_a + I_b + I_c = I_B + I_F$$

$$\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = \frac{-V_o}{R_F}$$

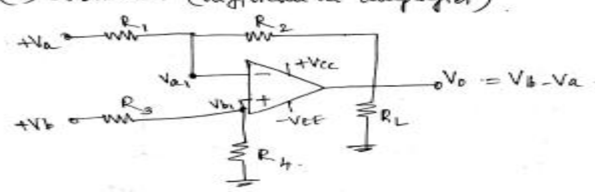
$$V_o = -\left(\frac{R_F}{R_a} V_a + \frac{R_F}{R_b} V_b + \ldots\right)$$

If $R_a = R_b = R_c = R$

$$V_o = -\frac{R_F}{R}(V_a + V_b + V_c)$$

If $R_F = R$ $\quad V_o = -(V_a + V_b + V_c)$

(b) Subtractor (differential amplifier)



Applying superposition theorem,

considering Va, Vb = 0

$$V_{o1} = -\frac{R_2}{R_1} V_a$$

Considering Vb, Va = 0

$$V_{b1} = \frac{V_b \times R_4}{R_3 + R_4}$$

$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right) V_{b1} = \left(\frac{1 + R_2}{R_1}\right) \times \left(\frac{R_4}{R_3 + R_4}\right) V_b$$

$$= \left(\frac{R_1 + R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right) V_b$$

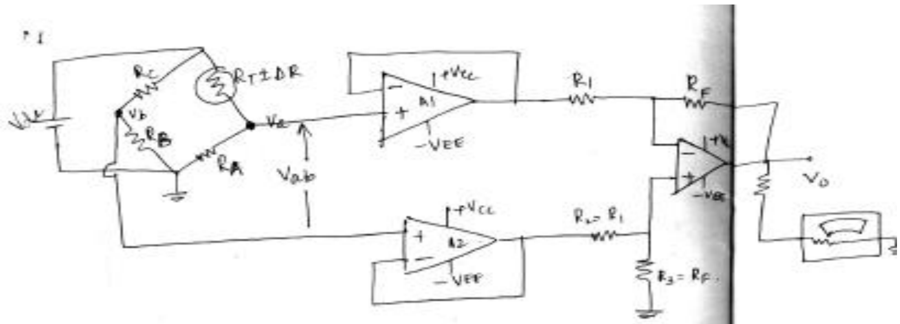
If $R_1 = R_2$ & $R_3 = R_4$.

$V_{o1} = -V_a$ $\quad V_{o2} = +V_b$.

$$V_o = V_{o1} + V_{o2} = V_b - V_a$$

$$V_o = V_b - V_a$$

5.



Resistance changes as physical energy

$R_T \pm \Delta R$

$V_a = V_b$

$$\frac{R_B \cdot V_{dc}}{R_B + R_C} = \frac{R_A \cdot V_{dc}}{R_A + R_T}$$

$$R_B(R_A + R_T) = R_A(R_B + R_C)$$

$$R_A R_B + R_B \cdot R_T = R_A R_B + R_A \cdot R_C$$

$$R_B \cdot R_T = R_A \cdot R_C$$

$$\boxed{\frac{R_C}{R_B} = \frac{R_T}{R_A}}$$

when resistance changes

V_a

$$V_a = \frac{R_A \cdot V_{dc}}{R_A + (R_T + \Delta R)}$$

$$V_b = \frac{R_B \cdot V_{dc}}{R_B + R_C}$$

$V_a =$ $V_{ab} = V_a - V_b$

$$V_{ab} = \frac{R_A \cdot V_{dc}}{R_A + R_T + \Delta R} - \frac{R_B \cdot V_{dc}}{R_B + R_C}$$

$$R_A = R_B = R_C = R_T = R$$

$$V_{ab} = \frac{R \cdot V_{dc}}{\underset{2R + \Delta R}{R + R + \Delta R}} - \frac{R \cdot V_{dc}}{\underset{2R}{R + R}}$$

$$\frac{R \cdot V_{dc}}{2R + \Delta R} - \frac{R \cdot V_{dc}}{2R}$$

$$= R \cdot V_{dc} \left[\frac{2R - 2R - \Delta R}{2R(2R + \Delta R)} \right]$$

$$= R \cdot V_{dc} \left[\frac{-\Delta R}{2R(2R + \Delta R)} \right] = -\left[\frac{\Delta R \cdot V_{dc}}{2(2R + \Delta R)} \right]$$

$$V_0 = V_{ab}\left(\frac{-R_F}{R_1}\right) = \left(-\frac{R_F}{R_1}\right)\left(\frac{-\Delta R \cdot V_{dc}}{2(2R + \Delta R)}\right)$$

$2R + \Delta R \simeq 2R$ $\quad V_0 = \frac{R_F}{R_1} \frac{\Delta R}{4R} V_{dc}$

$$\boxed{V_0 \propto \Delta R}$$

6.

Solution : Design the low pass filter,

$f_H = 2$ kHz

Let $C' = 0.01\ \mu F$ and $f_H = \frac{1}{2 \pi R' C'}$

$\therefore$ $R' = \frac{1}{2 \pi \times 2 \times 10^3 \times 0.01 \times 10^{-6}} = 7.957\ k\Omega$

Design the high pass filter,

$f_L = 400$ Hz

Let $C = 0.05\ \mu F$ and $f_L = \frac{1}{2 \pi R C}$

$\therefore$ $R = \frac{1}{2 \pi \times 400 \times 0.05 \times 10^{-6}} = 7.95\ k\Omega$

Now $A_{FT} = A_1 A_2$

where A_1 = Gain of high pass section, A_2 = Gain of low pass section is given, $A_{PT} = 4$

Let $A_1 = A_2 = 2$

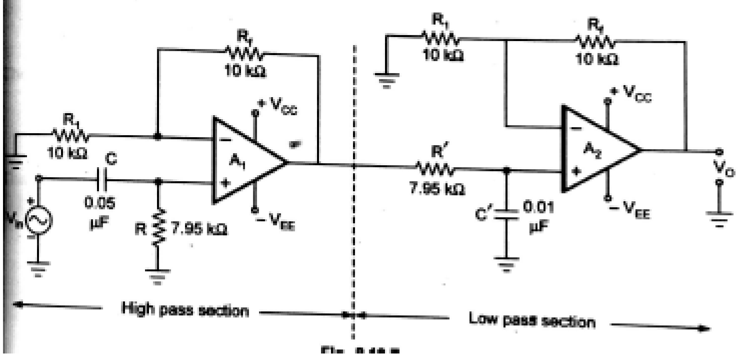
Now, for the non inverting op-amp,

$$A_1 = A_2 = 1 + \frac{R_f}{R_1} = 2$$

$$R_f = R_1 \text{ for both the sections}$$

Let $R_f = R_1 = 10\ k\Omega$

Hence, the designed circuit is shown in Fig. 2.10.7.



7.

Performance defined by
(1) Line regulation
(2) Load regulation
(3) Ripple rejection

Line regulation :-
~~change in~~ Variation in o/p voltage that occurs when supply voltage increase or decreases by specified amount, usually 10%.

Line regulation = $\frac{\Delta V_o \text{ for } \pm 10\% \ V_s \text{ change}}{V_o} \times 100$

Load regulation :-
Regulator performance in ~~pe~~ relation to load current changes.
Load current changes from zero to full load ~~load~~ the output changes by the amount ΔV_o

Load regulation = $\frac{\Delta V_o \text{ for } \Delta I_L = I_{max}}{V_o} \times 100$

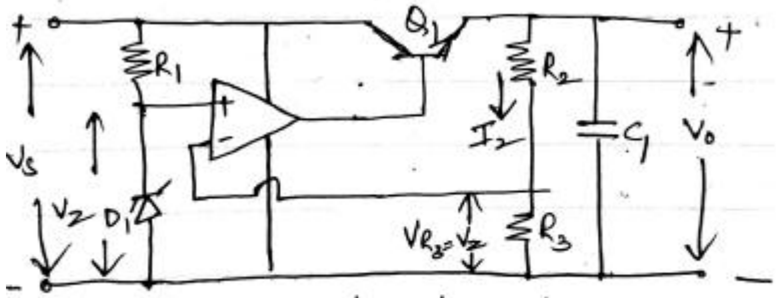
The ripple rejection =
How much voltage regulator attenuates the supply voltage ripple.

$$\text{ripple rejection} = 20 \log \left[\frac{V_{rs}}{V_{ro}}\right] dB$$

8.

Adjustable voltage regulator

→ o/p V greater than zener diode voltage.



$V_{R_3} = V_Z$ $\quad$ $V_{R_3} > V_Z$ o/p will fall.

$V_o \downarrow$ until $V_{R_3} = V_Z$.

Op-amp is error amplifier because it amplifies error i.e. to keep output to desired level.

$$V_{R_3} = V_Z$$

$$V_Z = \frac{V_o \times R_3}{R_2 + R_3}$$

$$V_o = \frac{V_Z (R_2 + R_3)}{R_3}$$

$$\Delta V_o = \frac{\Delta V_s Z_Z}{R_1} \left(\frac{R_2 + R_3}{R_3}\right)$$

Solution : I_{R1} must be much higher than I_{ADJ}.

Let $I_{R1} = 5$ mA where $I_{ADJ} = 100\ \mu A$

$$R_1 = \frac{V_{ref}}{I_{R1}} = \frac{1.25}{5 \times 10^{-3}} = 250\ \Omega$$

(Use **270** Ω standard)

$$\therefore \quad I_{R1} = \frac{1.25}{270} = 4.63 \text{ mA}$$

$$R_2 = \frac{V_o - V_{R1}}{I_{R1}} = \frac{9 - 1.25}{4.63 \times 10^{-3}}$$

$$= 1.67\ k\Omega$$

(Use **1.5 kΩ** and **220** Ω in series)

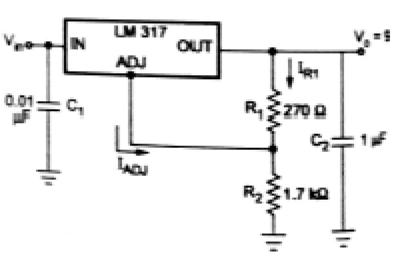


Fig. 3.13.4