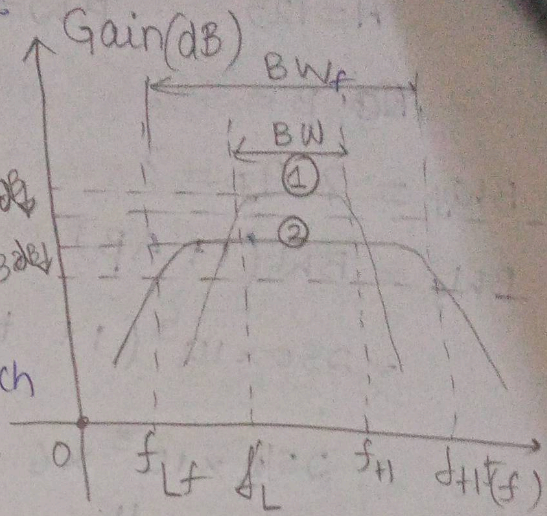
2) Increase in Bandwidth :-

Frequency – Response of an amplifier with & without –ve feedback



→ Bandwidth is range of frequencies over which gain remains is called bandwidth and it is always measured at –3dB level.

1 → without –ve

f_H = higher cutoff frequency without feedback

f_{Lf} = Lower cutoff frequency with feedback

gain in dB = $\log \frac{V_o}{V_i}$

f_L = ~~...~~ lower cut off frequency without feedback

f_{Hf} = Higher cutoff frequency with feedback

dB = log A

$$f_{Lf} = \frac{f_L}{1+A\beta}$$

B.W =

$$f_{Hf} = f_H(1+A\beta)$$

$$BW_f = BW(1+A\beta)$$

⇒ The product of gain & BW of an amplifier with fb = that of without ~~fB~~ fb.

16/02/2022:

Q: An amplifier has open loop gain of 125 and B.W of 250KHz.

(i) If 4% –ve feedback is introduced; find the new bandwidth & gain.

(ii) Band width is restricted to 1MHz; find the feedback ratio.

$\beta = 4\%$.

(i) $BW_f = ?$ $A_f = ?$

$$BW_f = BW(1 + A\beta)$$

$$= 250 \times 10^3 \left(1 + \cancel{125}^{5} \times \frac{4}{\cancel{100}_{4}}\right).$$

$$= 250 \times 10^3 \times 6.$$

$$= 150 \times 10^4.$$

$\boxed{BW_f = 15 \times 10^5}$ $\boxed{BW_f = 1.5 MHz}$

$$A_f = \frac{A}{1 + A\beta} = \frac{125}{6} = \underline{\underline{20.8}}$$

(ii) $BW_f = 1 MHz$ $BW = 250 kHz$

$$BW_f = BW(1 + A\beta)$$

$$\frac{10^{\cancel{6}\,3}}{250 \times \cancel{10^3}} = 1 + A\beta$$

$\boxed{4 = 1 + A\beta}$

$$A\beta = 3.$$

$$\beta = \frac{3}{125} = 0.024.$$

$\boxed{\beta = 2.4\%.}$

Q: An amplifier has gain of 200 and frequency response from 100Hz to 20kHz. A negative feedback with $\beta = 0.02$ is introduced into the amplifier circuit. Determine the new system performance?

$A_f = 200$ ~~$BW = 100Hz$~~ ~~$BW_f = 20kHz$~~ $\beta = 0.02$

$f_L = 100Hz$ $f_H = 20kHz$

$BW = 20000 - 100 = 100(200-1)$

$= 19900\ Hz$

$= 19.9\ kHz$

$BW_f = BW(1+A\beta)$

$= 19.9 \times 10^3 (1+4)$

$= 199 \times 10^2 \times 5$

$\boxed{BW_f = 99.5\ kHz}$

$A_f = \dfrac{200}{1+4} = \dfrac{200}{5} = 40$

$\boxed{A_f = 40}$

$f_{Lf} = \dfrac{100}{5}$

$= 20Hz$

$f_{LH} = \dfrac{20k \times 5}{}$

$= 100kHz$

3) Reduces the Noise:

$$\boxed{N_f = \frac{N}{1+A\beta}}$$

4) Reduces distortion:

$$\boxed{D_f = \frac{D}{1+A\beta}}$$

5) Input Impedance increases and output impedance decreases:

Increasing the I/P impedance of any circuit

reduces loading effect on the source.
Similarly, reducing the O/P impedance improves O/P sinking capability of circuit.

$$\boxed{\begin{aligned} Z_{if} &= Z_i(1+A\beta) \\ Z_{of} &= \frac{Z_i}{1+A\beta} \end{aligned}}$$

* An amplifier always uses negative feedback

* OSCILLATORS:

Oscillator is an electronic circuit which is designed to generate a periodic signal of required frequency (Specified frequency)

Applications:

1) They are used in audio frequency (AF) communication system.
2) Radio frequency communication (RF)
3) Ultra high frequency ; VHF
4) Timing and control circuits
5) Timers & clock signals ( )

* CLASSIFICATION:

1) Based on the type of output signal generated

→ Harmonic : Sinusoidal (Cos/Sine function)
→ Non-Harmonic : Triangle, square, ~~etc~~ Sawtooth etc

2) Based on range of frequencies that an oscillator can generate:

→ VF : Video frequency ; Audio frequency
→ High frequency.
→ Micro frequency.

3) Based on the type of feedback circuit:

→ RC oscillators : RC phase shift.
Wein bridge oscillator.

→ LC oscillators : • Hartley.
• Colpitts.

→ Crystal oscillator:

• Passive components: Resistors, Capacitors; Inductors.
• Active components: Rectifiers, diodes, BJT, FET.

→ Passive components cannot change the signal.
→ Active components can change the type of signal.

17/02/2022

* Conditions for sustained oscillations:

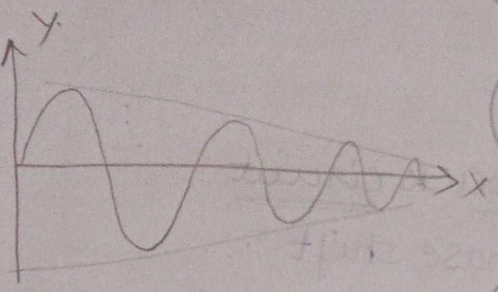
→ Barkhausen's criteria.
1) $|A\beta| = 1$ {[$A\beta$ = Loop gain] → unity}
2) Total phase shift around loop must be $0°$ (or) $360°$. (multiples of $360°$).

If the above conditions are not satisfied and 1) $|A\beta| < 1$ → damped oscillations
2) $|A\beta| > 1$ → damped oscillations
3) $|A\beta| = 1$ → Undamped oscillations

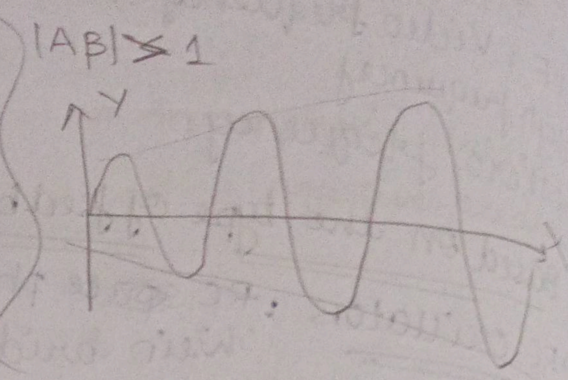
ance improves
always
ve feedback
ch is
generated
saw tooth etc

of amplitude of a wave form keeps on changing it turns out to be damped oscillation.

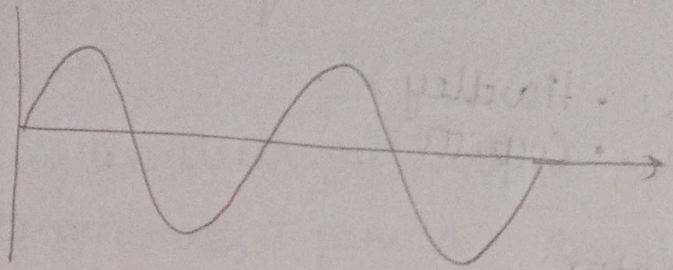
$|A\beta| < 1$



$|A\beta| > 1$



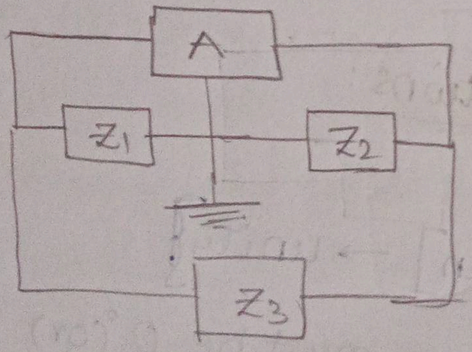
$|A\beta| = 1$



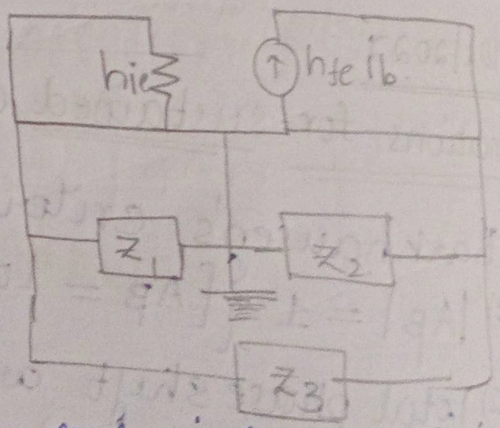
undamped $\Leftrightarrow$ Sustained oscillator

* GENERAL FORM OF OSCILLATOR :

→ Oscillators use positive feedback.



$\cong$

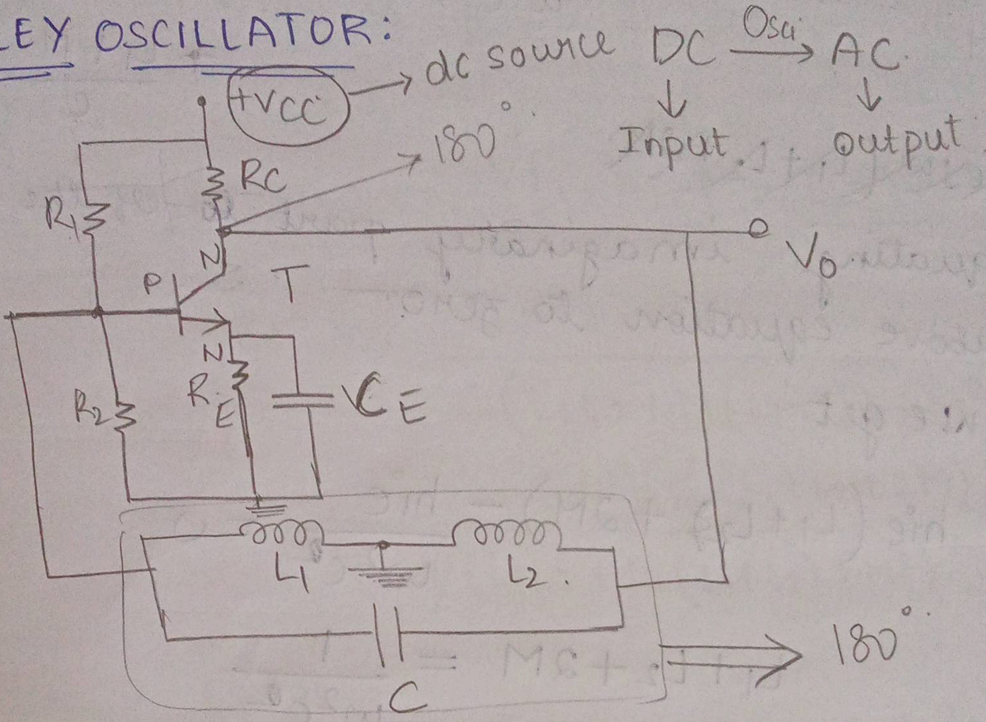


→ An amplifier can be converted into ~~a~~ oscillator, it should be supplying positive feedback.

→ From the above general form of oscillator, it can be derived that the condition for sustained oscillations $|A\beta| = 1$ and can be arrived with the following equation

$$\boxed{h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0} \quad \text{--- (1)}$$

* HARTLEY OSCILLATOR:



$$Z_1 = j\omega L_1 + j\omega M \quad \text{--- (2)}$$

$$Z_2 = j\omega L_2 + j\omega M \quad \text{--- (3)}$$

$$Z_3 = \frac{1}{j\omega C} \quad \text{--- (4)}$$

total phase Shift $= 180° + 180°$
$= 360°$

$$h_{ie}\,(j\omega)\left(L_1 + M + L_2 + M + \frac{1}{j^2\omega^2 C}\right)$$

$$+\left(j^2\omega^2 L_1 L_2 + j^2\omega^2 M L_1 + j^2\omega^2 M L_2 + j^2\omega^2 M^2\right)(1+h_{fe})$$

$$+ \frac{L_1}{C} + \frac{M}{C} = 0$$

$$h_{ie}\, j\omega\left(L_1+L_2+2M - \frac{1}{\omega^2 C}\right) + \left(-\omega^2 L_1 L_2 - \omega^2 M(L_1+L_2) - \omega^2 M^2\right)(1+h_{fe}) + \frac{L_1+M}{C} = 0$$

$$h_{ie}\, j\omega\left(L_1+L_2+2M - \frac{1}{\omega^2 C}\right) - \omega^2\left(L_1 L_2 + M(L_1+L_2) + M^2\right)(1+h_{fe}) + \frac{L_1+M}{C} = 0 \quad -(5)$$

~~$h_{ie} j\omega (L_1+L_2+2M$~~

Equating imaginary part of the above equation to zero.

we get

$$h_{ie}(L_1+L_2+2M) - \frac{h_{ie}}{\omega^2 C} = 0$$

$$L_1+L_2+2M = \frac{1}{\omega^2 C}$$

$$\omega^2 = \frac{1}{C(L_1+L_2+2M)}$$

$$\cancel{\omega = \frac{1}{C\sqrt{L_1+L_2+2M}}}$$

$$\boxed{\omega = \frac{1}{\sqrt{C(L_1+L_2+2M)}}}$$

$$2\pi f = \frac{1}{\sqrt{C(L_1+L_2+2M)}}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{C(L_1+L_2+2M)}}} \Rightarrow \text{frequency of output AC signal}$$

Equating real part of eq: (5) to zero.

We get

$$\omega^2\left(L_1L_2 + M(L_1+L_2) + M^2\right)[1+h_{fe}] = \frac{L_1+M}{C}$$

$$1+h_{fe} = \frac{L_1+M}{C\left(L_1L_2+M(L_1+L_2)+M^2\right)\omega^2}$$

$$= \frac{(L_1+M)(\cancel{C}(L_1+L_2+2M))}{\cancel{C}(L_1L_2+M(L_1+L_2)+M^2)}$$

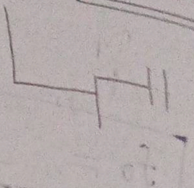
$$h_{fe} = \frac{L_1^2 + \cancel{L_1L_2} + 2ML_1 + \cancel{ML_1} + \cancel{ML_2} + 2M^2 - \cancel{L_1L_2} - \cancel{ML_1} - \cancel{ML_2} - M^2}{L_1L_2 + M(L_1+L_2) + M^2}$$

$$h_{fe} = \frac{L_1^2 + 2ML_1 + M^2}{L_1L_2 + M(L_1+L_2) + M^2}$$

$$h_{fe} = \frac{(L_1+M)^2}{(L_1+M)(L_2+M)} = \frac{L_1+M}{L_2+M}$$

$$\boxed{\dfrac{\quad}{L_2+M}}$$

COLPITTS

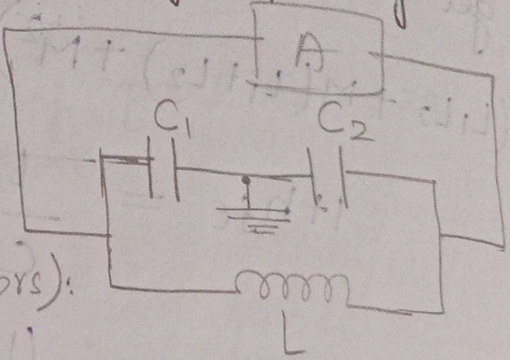


$$\Rightarrow \boxed{h_{fe} = \beta = \frac{L_1}{L_2}}$$

* ~~RC PHASE SHIFT OSCILLATOR:~~

⇒ COLPITTS:

* Hartley can be converted to Colpitts by replacing L and C.



∵ There is no mutual inductance (as there are no 2 inductors).

2) Capacitors are very small, size is less, cost also less.

→ No flux.

$$Z_1 = \frac{1}{j\omega C_1} \qquad Z_2 = \frac{1}{j\omega C_2} \qquad Z_3 = j\omega L$$

$$(Z_1+Z_2+Z_3)h_{ie} + Z_1 Z_2 (1+h_{fe}) + Z_1 Z_3 = 0$$

$$\underbrace{\frac{h_{ie}}{j^2\omega^2}\left[\frac{1}{C_1}+\frac{1}{C_2}+j^2\omega^2 L\right]}_{0} + \frac{1+h_{fe}}{j^2\omega^2 C_1 C_2} + \frac{L}{C_1} = 0$$

$$\omega^2 L = \frac{C_1+C_2}{C_1 C_2}$$

$$\boxed{f_0 = \frac{1}{2\pi}\sqrt{\frac{C_1+C_2}{L C_1 C_2}}}$$

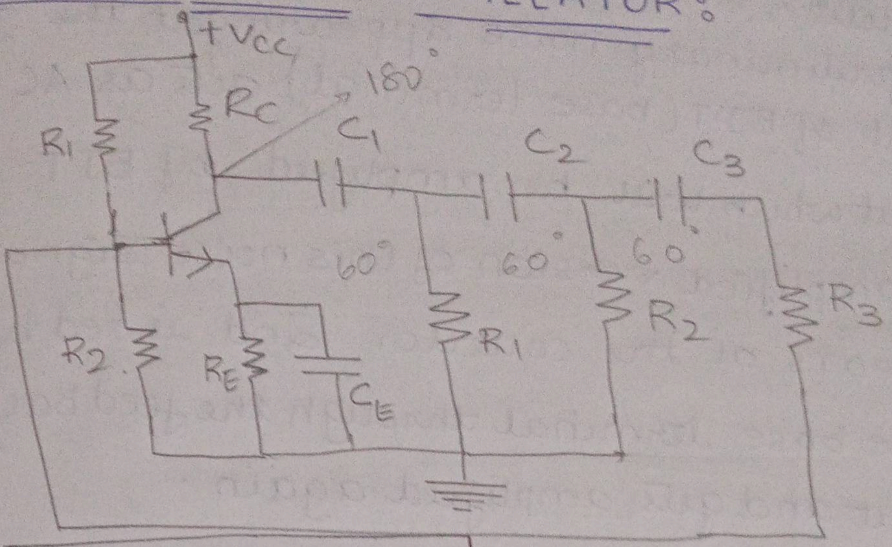
$$1+h_{fe} = \frac{L}{C_1}(\omega^2 C_1 C_2)$$

$$1+h_{fe} = L\omega^2 C_2$$

$$= \cancel{L}C_2 \frac{C_1+C_2}{C_1 \cancel{C_2}}$$

$$\boxed{h_{fe} = \frac{C_2}{C_1}}$$

RC PHASE SHIFT OSCILLATOR:



$$\boxed{\phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)}$$

total phase shift = 180 + 180 = 360°

$\sqrt{3} = \frac{1}{\omega CR}$

$$\boxed{f_0 = \frac{1}{2\pi RC\sqrt{6}}}$$

$\because$ $\boxed{\begin{array}{l} R_1 = R_2 = R_3 = R \\ C_1 = C_2 = C_3 = C \end{array}}$

19/02/2022

HARTLEY OSCILLATOR: Working

Oscillators convert DC input to AC output. (no input AC supply).

→ All Electronic components & devices depend on temperature.

i.e. As temp. varies, their values vary.

Ex: Resistance varies with temp.
α, β varies with temp in BJT

→ DC power supply V_{cc} also varies.
These variations introduce noise in the

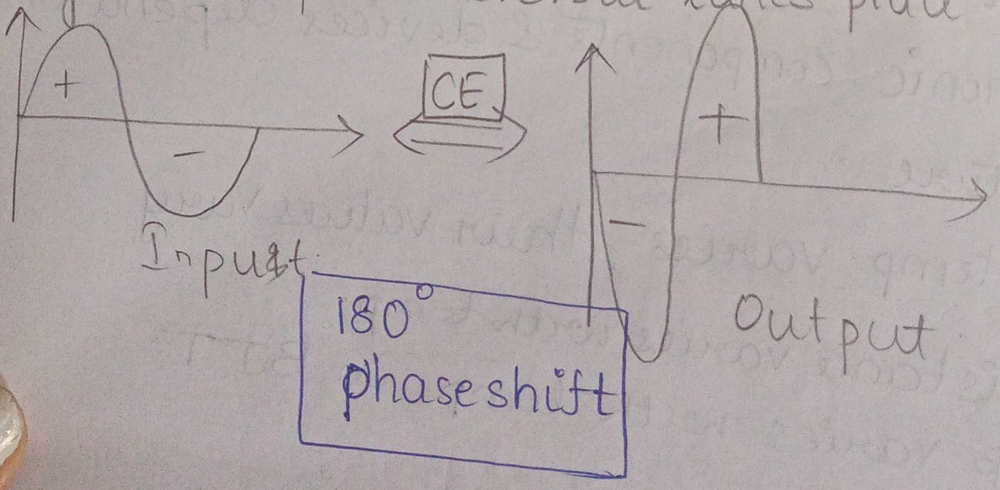
circuit.

This preliminary noise appearingat the input of BJT(base terminal) acts as AC input which will be amplified by BJT. The amplified version of this noise signal appears at the collector and is fed back to the base terminal through the feed back circuit and gets amplified again. And the procedure repeats.

⇒ Noise is produced ~~by~~ due to the variations in resistances ~~on~~ (R_1 & R_2) & V_{cc} acts as AC input.

* We know that ;
CE amplifier provides output which is 180° out of phase with input signal i.e. CE configuration output undergoes 180° phase shift (phase reversal occurs).

Only in CE phase reversal takes place



→ Another 180° phase shift is provided by LC feedback/oscillator.

23/02/2022

OPERATIONAL AMPLIFIERS: (OPAMP).

→ Operational amplifier is a multistage, very high gain, direct coupled, -ve feedback amplifier with very high stable gain.

* μA - 741 Integrated Circuits ⇒ 4 amplifiers

Multi-stage:

I/P → A1 (G_1) → A2 (G_2) → A3 (G_3) → A4 (G_4) → O/P

$\boxed{G = G_1 \times G_2 \times G_3 \times G_4}$ ⇓ Very high gain.

By default, capacitor/inductor/transistor for coupling

⇓ Min. requirement for coupling.

Direct coupling ⇒ Only capacitor is used (default).

→ Due to -ve feedback amplifier; it has high stable gain.

*→ It is called OPAMP because it is originally developed to perform: addition, multiplication, subtraction, Integration, differentiation; comparison.

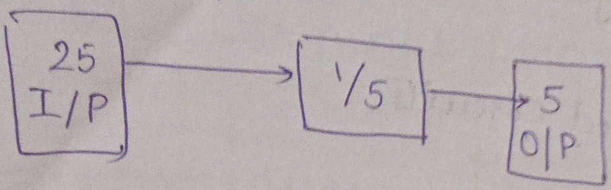
⇒ **APPLICATIONS OF OP-AMP:**

- Apart from above listed; OPAMP has many applications:

→ sign changing → phase shifting
→ scale changing → oscillator

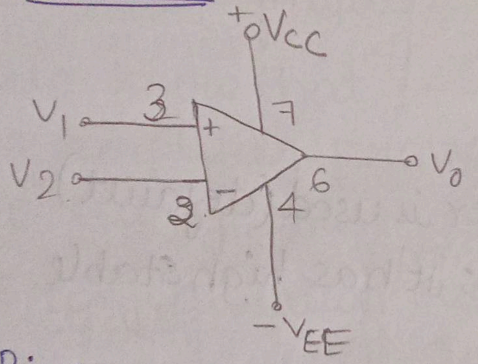
Regulator (voltage)
→ Control Systems → A to D converter
→ Communication Systems → D to A "
Analog → A ; Digital → D

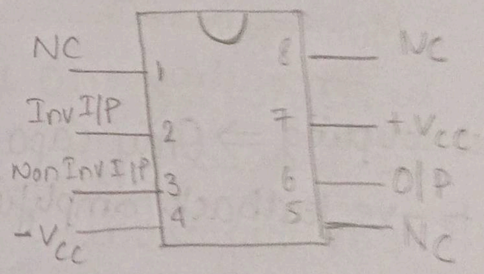
* It can generate square wave, triangular wave, ...
* Design a scale factor ; so as to get a required value of output.



* OPAMP can generate clock.
* Mobiles require A to D & D to A converters.

* SYMBOL: PIN DIAGRAM:





Pin 2 → inverting input ⇒ change in sign, wave
Pin 3 → non-inverting ~~input~~ input ⇒ no change in sign. wave

$-V_{EE}$ → internally it is using CC configuration
$+V_{cc}$ → internally it ~~uses~~ is using CE configuration

* Output of OPAMP (V_o) is given by $\boxed{V_o = A(V_1 - V_2) = A(V_{id})}$

Differential Input (V_{id})

$$\boxed{Gain = \frac{O/P}{I/P} = \frac{V_{out}}{V_{in}}}$$

Output of Amplifier = Gain times the differential input.

*IDEAL CHARACTERISTICS OF AN OPERATIONAL AMPLIFIER: 24/02/2022

- → Infinite bandwidth.
- → Infinite Gain.
- → Infinite CMRR.
- → Infinite slew rate
- → Infinite I/P Impedance
- → zero O/P Impedance
- → Zero O/P offset voltage.
- → No drift characteristics with temperature.

*OPAMP PARAMETERS:

1) Input offset voltage: / Output offset voltage:

The amount of input error voltage required to make the output voltage ~~nearly~~ zero/null (or) quiscent when both input voltages are equal.

- For μA 741; input offset voltage = 5mV.

2) Input offset current:

It is the ~~average~~ difference of 2 input currents flowing in 2 input terminals (2.83).

- For μA741; input offset current = 20nA

$$\boxed{i_1 \approx i_2}$$

3) Input Bias Current:

The average of 2 input currents I_1 & I_2.

- For $\mu A-741 \Rightarrow 80nA = \boxed{\frac{i_1+i_2}{2}}$

4) CMRR: Common Mode Rejection Ratio:

$$\boxed{CMRR = \left|\frac{A_d}{A_{CM}}\right|}$$

$A_d \rightarrow$ Gain of differential mode. $V_1 \neq V_2$

Noise is equal on both terminals $\boxed{V_1 = V_2}$ $\Leftarrow$ $A_{CM} \rightarrow$ Gain of Common mode $V_1 = V_2$

$\Rightarrow \boxed{A_{CM} = 0}$

$\boxed{\mu A\ 741 = 90dB}$

CMRR is an ability of an OPAMP to reject the common mode signals such as thermal noise.

Because CMRR is very high; it is expressed in decibel to reduce the numerical value.

Ex: $CMRR = 10^6$;

(dB)

$CMRR(dB) = 10 \log 10^6$
$= 60$

$$\boxed{CMRR(dB) = 10 \log (CMRR)}$$

- Internally; max. noise is not passed through output

$\boxed{\text{CMRR is also called figure of merit}}$

5) Slew Rate :

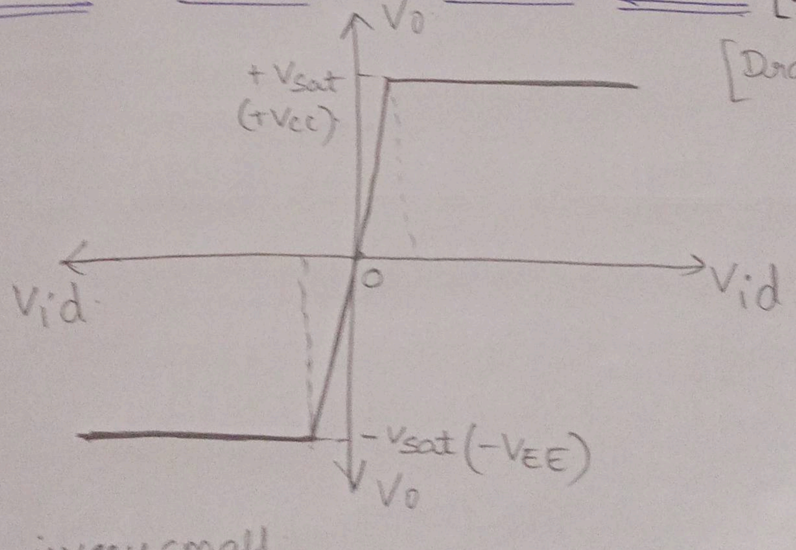
$$\boxed{SR = \left|\frac{dV_0}{dt}\right|_{max} \ \text{V}/\mu\text{sec}}$$

* It is the maximum rate of change of output voltage with respect to time (or) frequency.
* It indicates how fast OPAMP changes its output when there is a change in input.

6) Output offset voltage is zero.
→ offset voltage is not required to balance.
→ Balanced ⇒ $\boxed{V_1 = V_2}$
→ No error voltage is required at input.

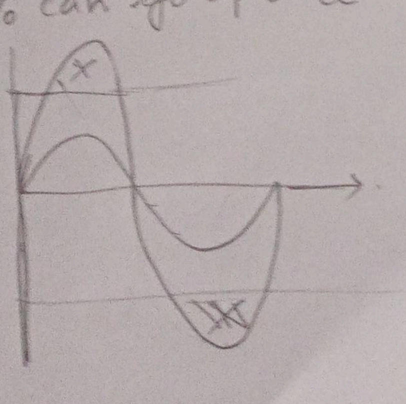
* IDEAL VOLTAGE TRANSFER CURVE: [OPEN LOOP]

[Drawback]



Vid is very small

V_0 can go upto V_{cc} and can go down upto V_{EE}



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The average of 2 input currents I_1 & I_2.

• For $\mu A-741 \Rightarrow 80 nA = \boxed{\frac{i_1+i_2}{2}}$

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$CMRR(dB) = 10 \log 10^6$

$= 60$

$$\boxed{CMRR(dB) = 10 \log (CMRR)}$$

• Internally, max. noise ~~as~~ is not passed ~~through~~ output

$\boxed{\text{CMRR is also called figure of merit}}$

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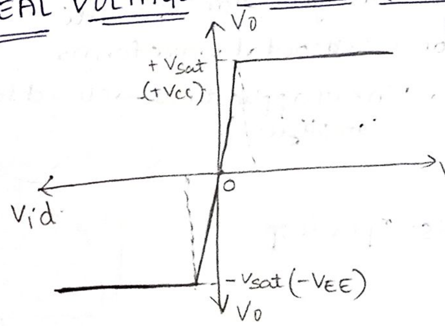
* IDEAL VOLTAGE TRANSFER CURVE: [OPEN LOOP]

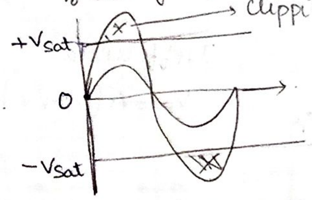
[Drawback]



Clipping of waveforms takes place when it goes above saturation values.

V_{id} is very small

V_o can go upto V_{CC} and can go down upto V_{EE}



* It can be observed from the output transfer curve that for a small input changes V_{id} output increases rapidly & saturates at $+V_{sat}$ & $-V_{sat}$ as shown. This causes clipping of waveforms.

26/02/2022 ∴ OPAMP is used as Closed loop for some applications.

* OPAMP IN OPEN-LOOP:

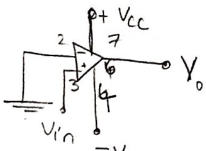
1) Inverting Amplifier.
2) Non-inverting Amplifier.
3) Differential Amplifier.

* DISADVANTAGES OF OPEN-LOOP:

→ Clipping of Waveforms.
→ Less Bandwidth.
→ Gain is not stable.
→ It is only used for non-linear applications such as square wave generators & multi vibrators ∴ Non-sinusoidal waveforms.

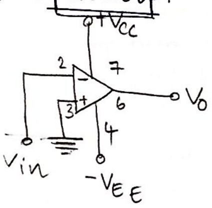
* Sinusoidal → Linear applications → Closed loop (amplifiers).

* CONFIGURATIONS: Open loop:



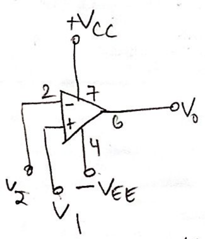
Non-inverting

$V_o = A(V_{in})$



Inverting

$V_o = -AV_{in}$



Differential

$V_o = A(V_1 - V_2)$

CLOSED LOOP OPAMP CONFIGURATIONS:

→ VIRTUAL GROUND CONCEPT:

* As we know, gain of OPAMP is very high.

Let gain $= 2\times10^5 = A$

Let output voltage $V_o = 10V$

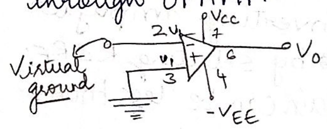
$$V_{id} = \frac{V_o}{A} = \frac{10}{2\times10^5} = 0.5\times10^{-4}$$
$$= 5\times10^{-5} = 0.05mV$$

→ As we know that input impedance of OPAMP is very high.

assume I/P impedance $= 2M\Omega$

$$I = \frac{0.05\times10^{-3}}{2\times10^6}$$
$$= 2.5\times10^{-11}$$
$$I_{in} = 2.5\times10^{-2}\,nA$$
$$\boxed{I_{in} = 0.025\,nA}$$

* Very small & negligible current is flowing through OPAMP.



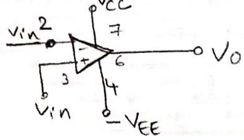
* For inverting circuit: 3 is already grounded; but due to above assumptions 2 is said to be at virtual ground.

* Input voltage $V_{id} = 0.05mV$ and $I_{in} = 0.025nA$ say that input voltages & current are negligible.

$V_{id} \simeq 0 \Rightarrow V_1 = V_2$ V_1 → already grounded

V_2 → virtual ground.

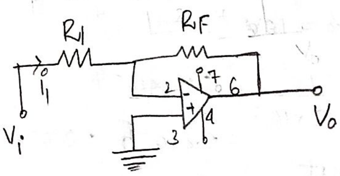
* For non-inverting:



02/03/2022

* CLOSED LOOP OPAMP CONFIGURATIONS:

1) Inverting Amplifier:



As we can from circuit; output is connected back through RF to pin2 inverting input; hence it is -ve feed back

$i_1 = i_f$ (VG concept).

$\boxed{\text{pin 2} \Rightarrow VG}$ $V_G = 0$

$I_G = 0$

$$\frac{V_i}{R} = \frac{V_G - V_o}{R_F}$$

Voltage Gain $\boxed{\frac{V_o}{V_i} = -\frac{R_F}{R_1}}$ in inverting closed loop amplifier

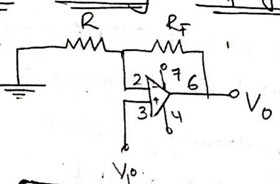
$\Rightarrow$ From the expression

→ Gain is −ve

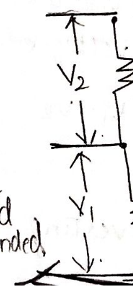
→ user can decide the gain of inverting amplifier by selecting R & RF.

→ Gain can be less than 1.

2) Non inverting Amplifier:



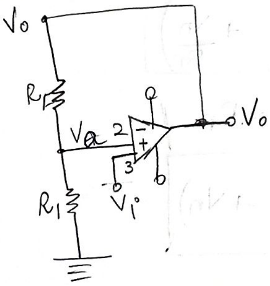
Voltage divider:



$\boxed{V_1 = \frac{R_1}{R_1+R_2} V}$

$\boxed{V_2 = \frac{R_2}{R_1+R_2} V}$

} Only when one end is grounded.



Voltage across R_1 = Voltage across pin 2.

$$\boxed{V_a = \frac{R_1}{R_1+R_F} \cdot V_o}$$

$$\boxed{V_a = \frac{R_1}{R_1+R_F} V_o}$$

Acc. to virtual ground concept

$$V_i = V_a = \frac{R_1}{R_1+R_F} V_o.$$

$$\boxed{\frac{V_o}{V_i} = \frac{R_1+R_F}{R_1}}$$

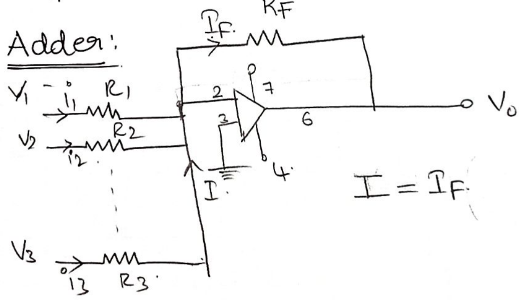
$\boxed{\frac{V_o}{V_i} = 1 + \frac{R_F}{R_1}}$ Voltage gain in non-inverting closed loop amplifier.

→ Gain is +ve

→ always greater than 1

→ User can decide the gain by changing R1 & RF.

3) Adder:



$I = I_F$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \cdots \frac{V_n}{R_n} = \frac{-V_o}{R_F}$$

$$\boxed{V_o = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n}\right)}$$

$$\boxed{V_0 = R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n}\right)}$$

if $R_1 = R_2 = \cdots = R_n$.

$$\boxed{V_0 = \frac{R_F}{R}\left(V_1 + V_2 + V_3 + \cdots + V_n\right)}$$

if $R_F = R \Rightarrow$ gain is 1.

$$\boxed{V_o = R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots\cdots + \frac{V_n}{R_n}\right)}$$

if $R_1 = R_2 = \cdots\cdots = R_n$.

$$\boxed{V_o = \frac{R_F}{R}\left(V_1 + V_2 + V_3 + \cdots\cdots + V_n\right)}$$

if $R_F = R \Rightarrow$ gain is 1.

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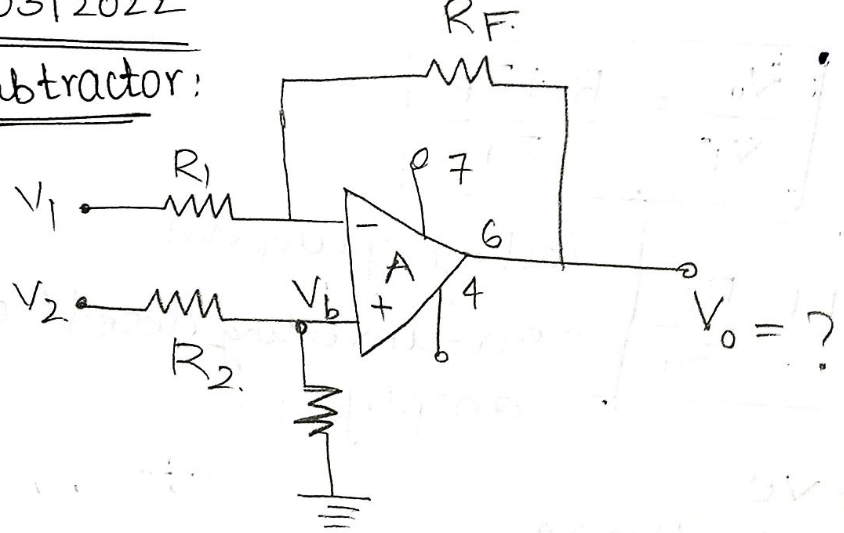
4) Subtractor:



Super-position principle:

Let V_{o1} be the o/p when $V_2 = 0$ (muted)

Let V_{o2} be the O/P when $V_1 = 0$ (muted.

Acc. to superposition principle; output V_o is the sum of individual outputs:

$$V_o = V_{o1} + V_{o2}.$$

$V_1 = 0 \rightarrow$ Non-inverting

$V_2 = 0 \rightarrow$ Inverting

$$V_{o1} = -\frac{R_F}{R_1} V_1 \qquad V_{o2} = \left(1 + \frac{R_F}{R_1}\right) V_b$$

$$\boxed{V_0 = \frac{R_3}{R_2+R_3} V_2}$$

$$V_{02} = \left(1+\frac{R_F}{R_1}\right)\left(\frac{R_3}{R_2+R_3}\right)V_2$$

Assume $R_F = R_1 = R_2 = R_3 = R$.

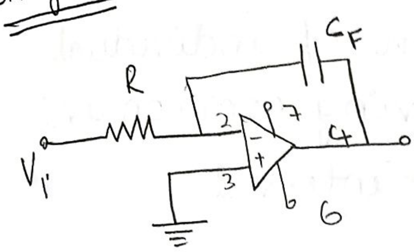
$$V_{01} = -V_1$$

$$V_{02} = 2\left(\frac{1}{2}\right)V_2 = V_2$$

$$\boxed{V_0 = V_2 - V_1}$$

$$V_0 = -\frac{V_1 R_F}{R} + \frac{(1+R_F)V_2}{2R}$$

5) ~~Differential~~ Integrator form:



$$-\frac{V_i}{R} = C_F \frac{d}{dt}(V_o)$$

$$\frac{-1}{RC_F}\int V_i\,dt = \int d V_o$$

$$\boxed{V_o = \frac{-1}{RC_F}\int V_i\,dt}$$

OPamp constructed as integrator:

Current through capacitor $= C\frac{d}{dt}(V_1 - V_2)$

$$\boxed{i = C\cdot\frac{d}{dt}(V_1 - V_2)}$$

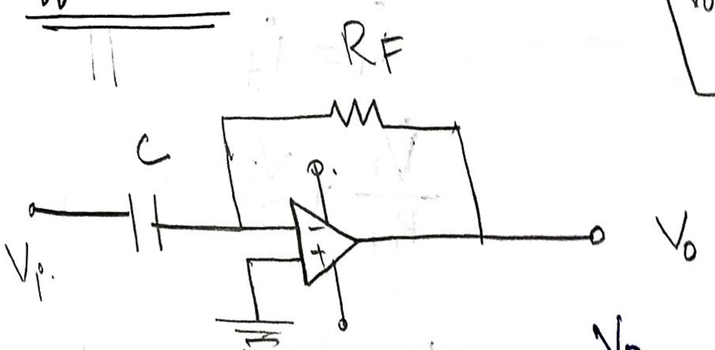
$$V_o = -\frac{V_i}{R}\cdot\frac{1}{C\omega}$$

$$V_o = -\frac{V_i R_F}{R}$$

$$= -\frac{V_i}{R}\cdot X_c \qquad \omega = \frac{2\pi}{T}$$

$$\boxed{V_o = -\frac{V_i}{R}\cdot\frac{T}{C\cdot 2\pi}}$$

6) Differential



$$\frac{V_o}{R_F} = -\frac{V_i}{X_c}$$

$$-\frac{V_o}{R_F} = C\frac{d}{dt}(V_i)$$

$$\boxed{V_o = -C\frac{d}{dt}(V_i)\cdot R_F}$$

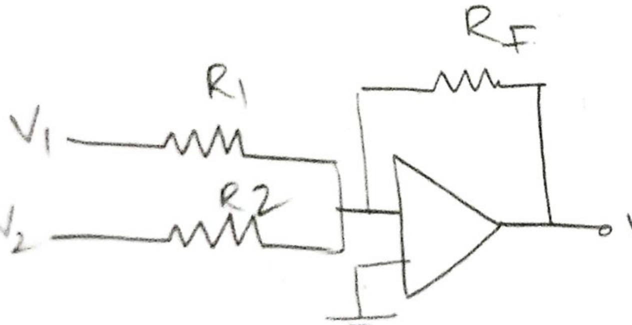
* Opamp can be constructed as differentiator by connecting resistor and capacitor as shown in above circuit.

* Differentiation is decomposing of input i.e. it is used to identify sudden change in input signal.
• Output signal is differential form of input.

* Integration is accumulation of individual points in the signal and giving common level for those ~~sig~~ in that time interval.

* Differentiator → High Pass Filter
Integrator → Low pass filter.

1)



$R_2 = R_1 = 4k\Omega$

$R_F = 8K\Omega$.

Inverting:

$i_1 = i_f$.

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = \frac{-V_o}{R_F}$$

$$\frac{V_1}{\cancel{4}} + \frac{V_2}{\cancel{4}} = \frac{-V_o}{\cancel{8}\,2}$$

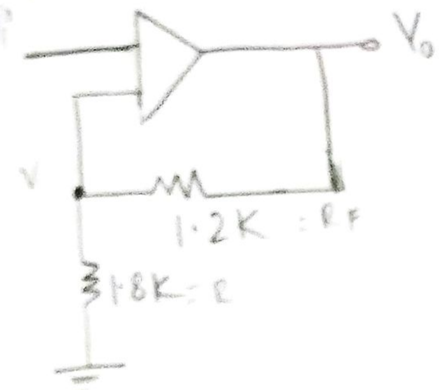
$$\boxed{V_o = -2(V_1+V_2)}$$

$V_1 = 5V$; $V_2 = 3V$ $V_o = -16V$

$$V_o = -\frac{R_F}{R}(V_1 + V_2)$$

$$-\frac{R_F}{R} = \frac{-16}{8} = -2$$

$$\boxed{\frac{R_F}{R} = \text{Gain} = 2}$$



$V_i = 0.4V$

$$V_o = 0.4\left(1 + \frac{1.2}{1.8}\right)$$

$$= 0.4\left(1 + \frac{2}{3}\right)$$

$$\boxed{\frac{2.0}{3} = 0.66\,V}$$

4) $R_F = 150k\,\Omega$ $V_i = 0.4$

Gain = 3.2

$R_2 = ?$

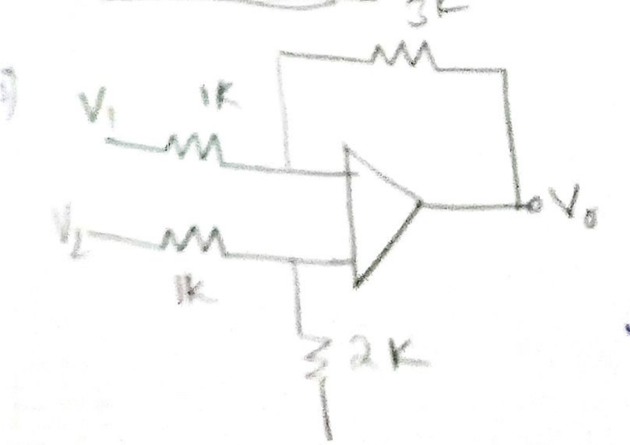
$$1 + \frac{R_F}{R} = 3.2$$

$$R = \frac{150 \times 10^3}{2.2}$$

$$\boxed{R = 68.1k\,\Omega}$$

$V_o = 3.2 \times 0.4$

$$\boxed{V_o = 1.28\,V}$$



$V_1 = 2V$

$V_2 = 3V$

$V_o = ?$

$$\cancel{V_o = -\frac{3}{1} \times 2 + \left(1 + \frac{3}{1}\right)\left(\frac{2}{3}\right)}$$

$= -6$

$$V_0 = -\frac{V_1 R_F}{R_1} + V_2\left(\frac{R_3}{R_2+R_3}\right)\left(1+\frac{R_F}{R_1}\right).$$

$$= \frac{-2\times 3}{1} + \cancel{3}\left(\frac{2}{\cancel{3}}\right)\times\left(1+\frac{3}{1}\right)$$

$$= -6 + 8 = 2V$$