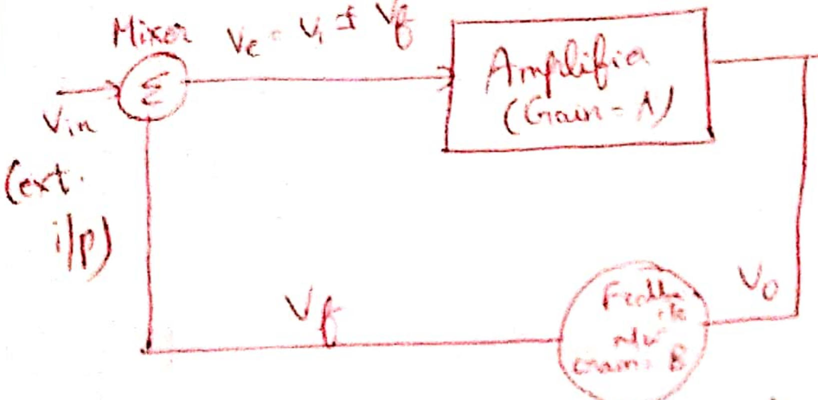
OSCILLATORS.

Oscillator : (like a generator)

- ↳ An amplifier with +ve feedback
- ↳ No external i/p signal
- ↳ generates o/p signal which oscillates with a constant desired freq and constant amplitude.

Amplifier acts as an oscillator :



(open-loop amp) gain

$A = \frac{V_o}{V_i}$

$B = \frac{V_f}{V_o}$ Gain of feedback n/w

$\Rightarrow V_o = AV_i$

$V_f = BV_o$

$\frac{V_f}{B} = AV_i$

$\boxed{V_f = (AB)V_i}$

Oscillator ⇒ No ext. i/p voltage given ⇒ V_f is given as V_i ⇒ $V_f = V_i$ ⇒ $\boxed{AB = 1}$

$\boxed{V_f \text{ \& } V_i \text{ are the same phase}}$ ⇒ $V_e = V_i + V_f$ ↓ positive feedback amplifier.

V_i given to non-inverting terminal of amplifier ⇒ phase diff b/w V_f & V_i = 0° or 360°

V_i given to inverting terminal of amplifier ⇒ phase diff b/w V_f and V_i = 180°

Barkhausen Criteria for oscillations with const freq.

Positive feedback amplifier → $V_e = V_i + V_f$

$$V_o)_{open-loop} = V_o)_{feedback}$$

$$AV_e = \frac{V_f}{B}$$

$$AB(V_i + V_f) = V_f$$

$$BAV_i = V_f - BAV_f$$

$$BAV_i = V_f(1 - BA)$$

$$V_o = \frac{V_f}{B} = \frac{\cancel{B}AV_i}{(1-AB)\cancel{B}} = \frac{AV_i}{1-AB}$$

$$A_{FB} = \frac{V_o}{V_i} = \frac{A}{1-AB}$$

$AB = 1 \Rightarrow \boxed{A_{FB} = \infty}$ → o/p cannot be ∞.

~~∴ When ex~~

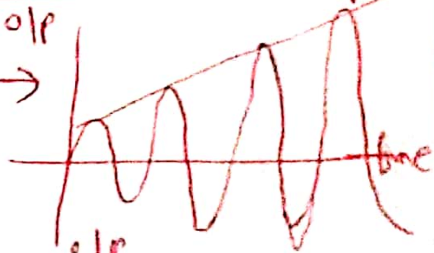
↳ $A_{FB_\infty} = \frac{V_o}{V_i} \to 0.$

⇒ When external voltage i/p is removed, the amplifier circuit oscillates with a constant freq. → based on A or B or both.

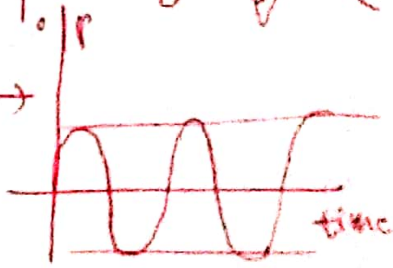
V_f & V_i are in same phase

Phase diff. = 0° or 360° (Non-inverting amplifier)

$\boxed{|AB| > 1}$ → growing type of oscillations

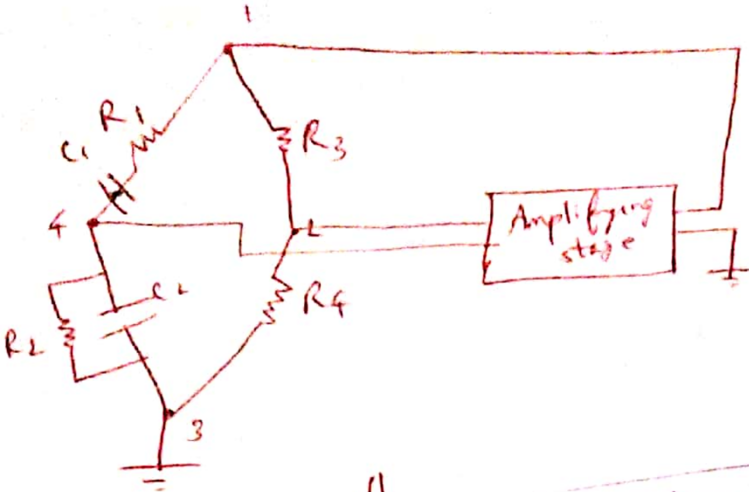


$\boxed{|AB| = 1}$ → sustained oscillations



$\boxed{|AB| < 1}$ → exponentially decaying oscillation which stop. After they stop, no oscillation amplifier circuit.

↳ Wien bridge oscillator :



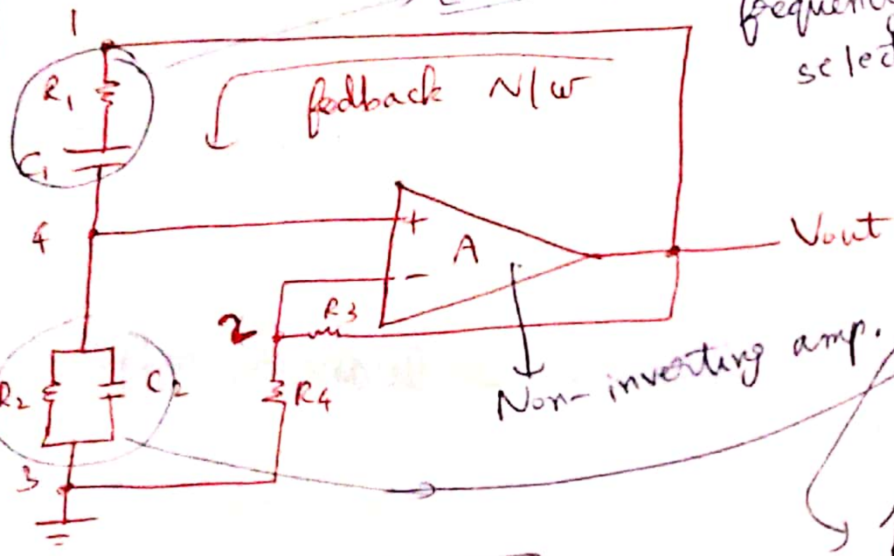
B/w 1 & 3 → feedback n/w

B/w 2 & 4 → i/p to Amplifier → o/p of feedback

o/p of amplifier → i/p to feedback

⇓

→ lead-lag networks / frequency selector → select freq. of the oscillator



Non-inverting amp.

R_3 & R_4 → to control gain of the amplifier.

↑ freq. ⇒ lag

↓ freq. → lead.

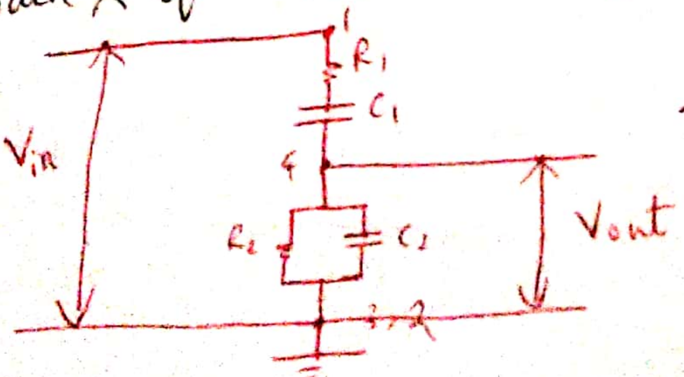
→ R_1 & C_1 in series

↳ R_2 & C_2 in ||lel

↳ B/w 1 & 3 → diagonal → feedback n/w.

↳ R_1, C_1, R_2, C_2

↳ Gain & frequency of oscillations of Wien bridge oscillator :



→ feedback N/w of a Wien bridge oscillator.

$Z_1 \rightarrow R_1$ in series with C_1

$$Z_1 = R_1 - jX_{C_1} = R_1 - \frac{j}{2\pi f C_1} = R_1 + \frac{1}{\underbrace{2\pi f}_{\omega} C_1 j}$$

$$Z_1 = R_1 + \frac{1}{\omega C_1 j}$$

$$j\omega = S \Rightarrow Z_1 = R_1 + \frac{1}{SC_1}$$

$$\boxed{Z_1 = \frac{SC_1R_1 + 1}{SC_1}}$$

$Z_2 \rightarrow R_2 \parallel C_2$

$$Z_2 = \frac{(R_2)(-jX_{C_2})}{R_2 - jX_{C_2}}$$

$$-jX_{C_2} = \frac{X_{C_2}}{j}$$

$$X_{C_2} = \frac{1}{2\pi f C_2}$$

$$-jX_{C_2} = \frac{1}{\underbrace{2\pi f}_{\omega} C_2 j} \quad \omega, S$$

$$= \frac{1}{SC_2}$$

$$= \frac{(R_2)\left(\frac{1}{SC_2}\right)}{R_2 + \frac{1}{SC_2}}$$

$$\boxed{Z_2 = \frac{R_2}{SC_2R_2 + 1}}$$

$\boxed{Z = Z_1 + Z_2} \rightarrow$ impedence of feedback n/w.

$$I = \frac{V_{in}}{Z} = \frac{V_{in}}{Z_1 + Z_2}$$

$$V_{out} = (I)(Z_2) = \frac{V_{in} Z_2}{Z_1 + Z_2}$$

$\rightarrow$ in feedback n/w

$$\Rightarrow \beta = \frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

$$\beta = \frac{\frac{R_2}{SC_2R_2 + 1}}{\frac{R_2}{SC_2R_2 + 1} + \frac{SC_1R_1 + 1}{SC_1}} = \left(\frac{R_2}{\cancel{SC_2R_2+1}}\right)\left(\frac{SC_1(\cancel{SC_2R_2 + 1})}{SC_1R_2 + S^2C_1C_2R_1R_2 + SC_2R_2 + 1 + SC_1R_1}\right)$$

$$\beta = \frac{SC_1R_2}{1 + S^2C_1C_2R_1R_2 + S(C_1R_1 + C_1R_2 + C_2R_2)}$$

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~~$R_1 = R_2 = R$, $C_1 = C_2 = C$~~ $s = j\omega$, $s^2 = -\omega^2$

$$B = \frac{j\omega C_1 R_2}{1 - \omega^2 C_1 C_2 R_1 R_2 + j\omega (C_1 R_1 + C_1 R_2 + C_2 R_2)}$$

Rationalising,

$$B = \frac{(j\omega C_1 R_2)(1 - \omega^2 C_1 C_2 R_1 R_2 - j\omega (C_1 R_1 + C_2 R_2 + C_1 R_2))}{(1 - \omega^2 C_1 C_2 R_1 R_2)^2 + \cancel{j}\omega^2 (C_1 R_1 + C_1 R_2 + C_2 R_2)^2}$$

$$B = \frac{\omega^2 C_1 R_2 (C_1 R_1 + C_2 R_2 + C_1 R_2) + j\omega C_1 R_2 (1 - \omega^2 C_1 C_2 R_1 R_2)}{(1 - \omega^2 C_1 C_2 R_1 R_2)^2 + \omega^2 (C_1 R_1 + C_2 R_2 + C_1 R_2)^2}$$

Phase shift $= 0 \Rightarrow$ img. part $= 0$

$$\omega^2 C_1 R_2 (1 - \omega^2 C_1 C_2 R_1 R_2) = 0$$

ignore $\omega = 0 \Rightarrow$ $\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$

$$\text{freq.} = f = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}$$

$R_1 = R_2 = R$, $C_1 = C_2 = C$ in B, $\omega = \frac{1}{RC}$.

$$B = \frac{\left(\frac{1}{R_1 R_2 C_1 C_2}\right)(C_1 R_2)(3RC) + \frac{j}{R_1 R_2 C_1 C_2} C_1 R_2 \left(1 - \cancel{\frac{C_1 C_2 R_1 R_2}{C_1 C_2 R_1 R_2}}\right)}{\left(1 - \frac{R^2 C^2}{C^2 R^2}\right) + \left(\frac{1}{\cancel{R^2 C^2}}\right)(9 R^2 C^2)}$$

$$= \frac{3}{9}$$

$\boxed{B = \frac{1}{3}} > 0 \Rightarrow$ +ve gain $\Rightarrow V_f$ & V_{in}

phase shift $= 0°$.

$|AB| \geq 1$ (criteria for osc.)

$$|A| \geq \frac{1}{\left(\frac{1}{3}\right)} \geq 3$$

$$\boxed{|A| \geq 3}$$

⑤

If $R_1 \neq R_2$, $C_1 \neq C_2$ then:

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}, \quad \boxed{f = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}}$$

$R_1 = R_2 = R$, $C_1 = C_2 = C$: $\boxed{f = \frac{1}{2\pi\sqrt{RC}}}$ #

$$B = \frac{C_1 R_2}{C_1 R_1 + C_2 R_2 + C_1 R_2}$$

$$A \geq \frac{C_1 R_1 + C_2 R_2 + C_1 R_2}{C_1 R_2} \quad (\text{as } |AB| \geq 1)$$

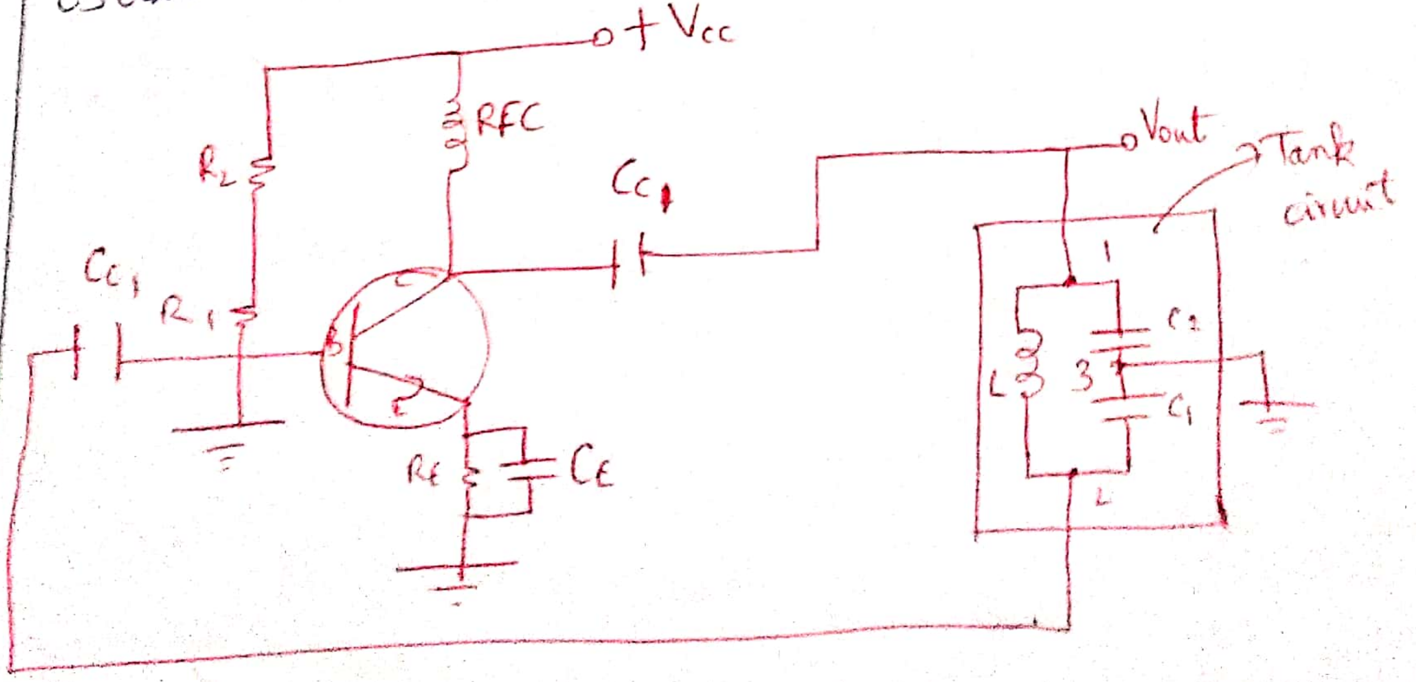
COLPITTS OSCILLATOR:

→ LC oscillator (2 capacitors & 1 inductor).

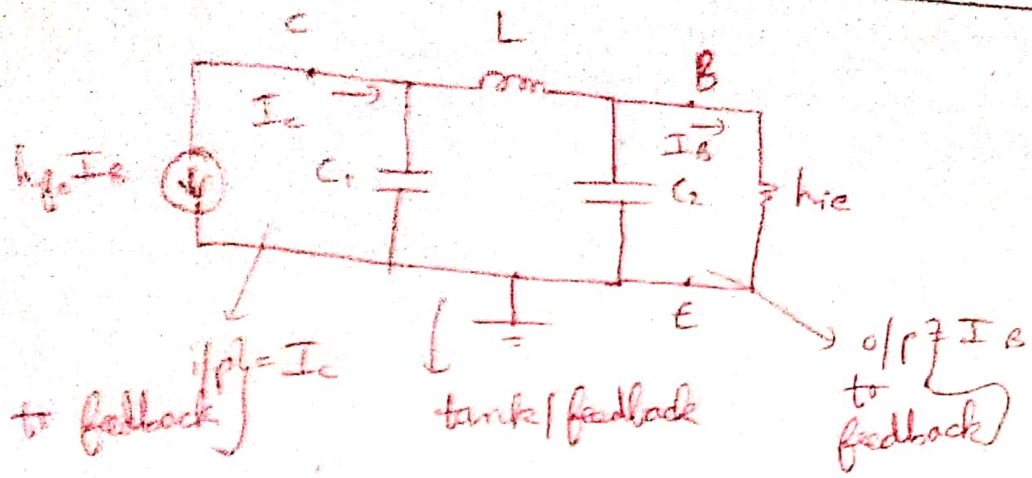
→ CE transistor → amplifier.

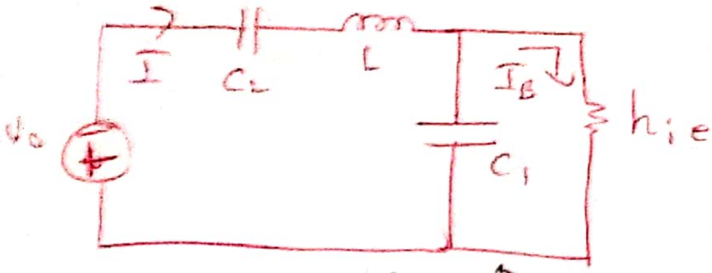
→ Tank circuit → feedback network.

→ CE transistor ⇒ phase shift by 180°. So, tank circuit further adds $180° = 360°$ ⇒ oscillations criteria ✓.



Hybrid model :





$$V_0 = h_{fe} I_B \left(\frac{X_c}{j} \right)$$

$$\boxed{V_0 = h_{fe} I_B \left(\frac{1}{j\omega C_2} \right)}$$

Simplified Hybrid model ↑

Frequency of oscillations of Colpitts oscillator – derivation:

Applying KVL to simplified hybrid model,

$$-V_0 - I(X_{C_2} + X_L) - I(X_{C_1} \| h_{ie}) = 0.$$

$$I = \frac{-V_0}{(X_{C_2} + X_L) + (X_{C_1} \| h_{ie})}$$

$$X_{C_2} + X_L = \frac{1}{j\omega C_2} + j\omega L$$

$$X_{C_1} \| h_{ie} = \frac{(X_{C_1})(h_{ie})}{X_{C_1} + h_{ie}} = \frac{\left(\frac{1}{j\omega C_1} \right) h_{ie}}{\frac{1}{j\omega C_1} + h_{ie}}$$

$$X_{C_1} \| h_{ie} = \frac{h_{ie}}{1 + j\omega h_{ie} C_1}$$

$$I = \frac{-V_o}{\left(\frac{1}{j\omega C_2} + j\omega L\right) + \frac{h_{ie}}{1 + j\omega h_{ie} C_1}}$$

$$V_o = h_{fe} I_B \left(\frac{1}{j\omega C_2}\right)$$

$$I = \frac{\frac{-h_{fe} I_B}{j\omega C_2}}{\frac{1}{j\omega C_1} + j\omega L + \frac{h_{ie}}{1 + j\omega h_{ie} C_1}}$$ $j\omega = s$

$$= \frac{\frac{-h_{fe} I_B}{s C_2}}{\frac{1}{s C_2} + sL + \frac{h_{ie}}{1 + s C_1 h_{ie}}}$$

$$= \left(\frac{-h_{fe} I_B}{\cancel{s C_2}}\right)\left(\frac{\cancel{s C_2}(1 + s C_1 h_{ie})}{s^2 L C_2 (1 + s C_1 h_{ie}) + s h_{ie} C_2 + 1 + s C_1 h_{ie}}\right)$$

$$\boxed{I = \frac{-h_{fe} I_B (1 + s C_1 h_{ie})}{s^3 L C_2 C_1 h_{ie} + s^2 L C_2 + s h_{ie}(C_1 + C_2) + 1}}$$

$$I_B = I \left(\frac{X_{C_1}}{X_{C_1} + h_{ie}}\right)$$ (as $C_1 \parallel h_{ie}$)

$$= I \left(\frac{\frac{1}{j\omega C_1}}{\frac{1}{s C_1} + h_{ie}}\right)$$

$$= I \left(\frac{\frac{1}{s C_1}}{\frac{1}{s C_1} + h_{ie}}\right)$$

$$\boxed{I_B = I \left(\frac{1}{1 + h_{ie} s C_1}\right)}$$

$$I_B = \left(\frac{1}{1+h_{ie}sC_1}\right)\left(\frac{-h_{fe} I_B (1+sC_1 h_{ie})}{s^3 L C_2 C_1 h_{ie} + s^2 L C_2 + s h_{ie}(C_1+C_2)+1}\right)$$

$$1 = \frac{-h_{fe}}{s^3 L C_2 C_1 h_{ie} + s^2 L C_2 + s h_{ie}(C_1+C_2) + 1}$$

$s = j\omega$, $s^2 = -\omega^2$, $s^3 = -j\omega^3$

$$1 = \frac{-h_{fe}}{-j\omega^3 L C_2 C_1 h_{ie} - \omega^2 L C_2 + j\omega h_{ie}(C_1+C_2) + 1}$$

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

img part $= 0$.

$\Rightarrow$ $\omega h_{ie}(C_1+C_2-\omega^2 L C_1 C_2) = 0$.

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

$$\omega^2 = \frac{1}{L}\left(\frac{1}{\frac{C_1C_2}{C_1+C_2}}\right)$$

$$C_{eq} = \frac{C_1 C_2}{C_1+C_2}$$ (C_1 & C_2 in series)

$$\Rightarrow \omega^2 = \frac{1}{L C_{eq}}$$

$$\omega = \frac{1}{\sqrt{L C_{eq}}}$$

frequency of oscillation in colpitts oscillator $\leftarrow$ $\boxed{f = \frac{1}{2\pi\sqrt{L C_{eq}}}}$

$\rightarrow$ Gain $= A_v = h_{fe} = \frac{C_2}{C_1} = \frac{V_{o/p}}{\text{feedback voltage } (V_f)}$

→ Gain of feedback network (tank circuit) = B.

$$A_v B = 1 \text{ (oscillator)}$$

$$\rightarrow B = \frac{1}{A_v} = \frac{C_2}{C_1} = \frac{V_{o/p}}{V_f}$$

Note:

→ freq. of Wien's bridge oscillator $= \frac{1}{2\pi\sqrt{RC}}$

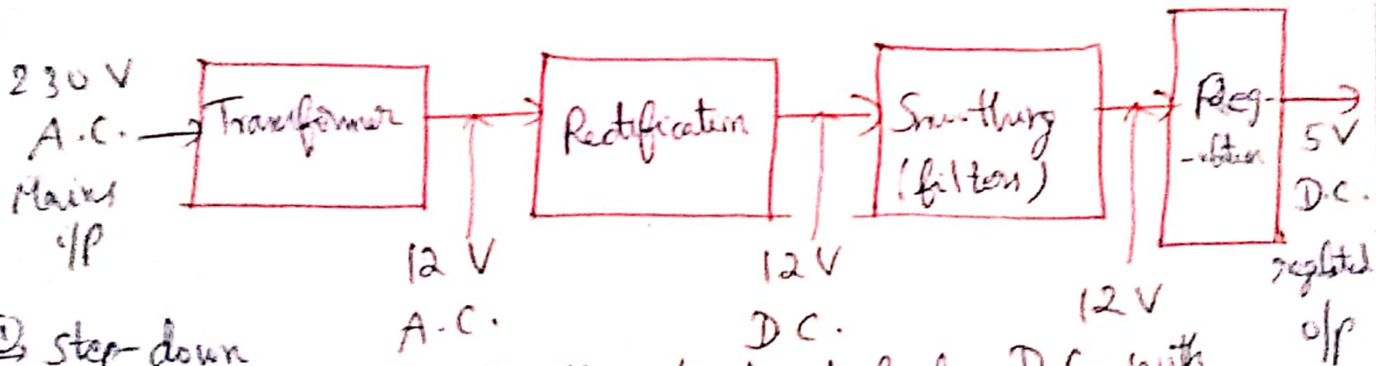
→ " " Collpit's oscillator $= \frac{1}{2\pi\sqrt{LC_{eq}}}$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

POWER SUPPLY SYSTEM.

↳ To supply a constant power (DC voltage) to electronic devices.

↳ Block diagram:



① Step-down transformer to ↓ voltage to desired levels.

② → rectifier → converts A.C. into D.C. D.C. with ripple

③ Filter → to reduce ripples & smoothen voltage

④ Regulator → o/p voltage → almost ripple free & constant even under variable load cond^ns.

∴ Power supply system → i/p → unregulated voltage
o/p → regulated DC voltage

VOLTAGE REGULATORS.

→ Series
↓ Shunt

↳ Basic components:
- → Voltage reference (V_{ref})
- → Error amplifier
- → Feedback network
- → Active series/shunt control elements.

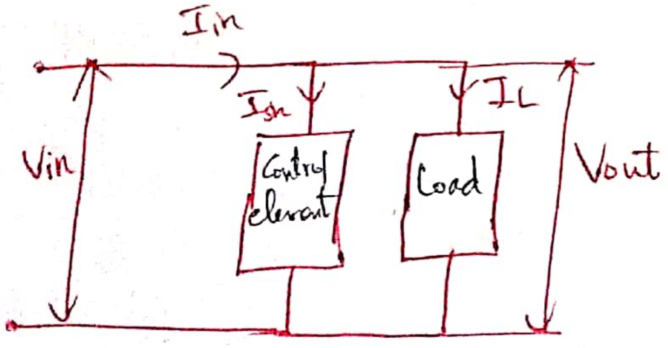
① V_{ref} provides a ~~const~~ voltage level → i/p to $\boxed{\text{error amplifier}}$ → comparator circuit.

② V_f from feedback network → other i/p to error amplifier ⇒ o/p voltage

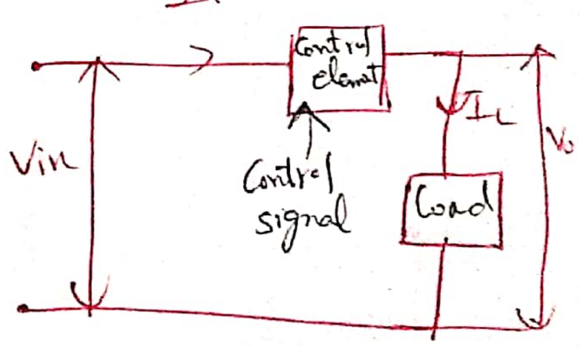
③ Samples of V_{out} → compared with V_{ref} & error amplifier amplifies the error signal.
controls the active element to compensate the change in V_{out}.

(i) Block diagram:

Shunt



Series

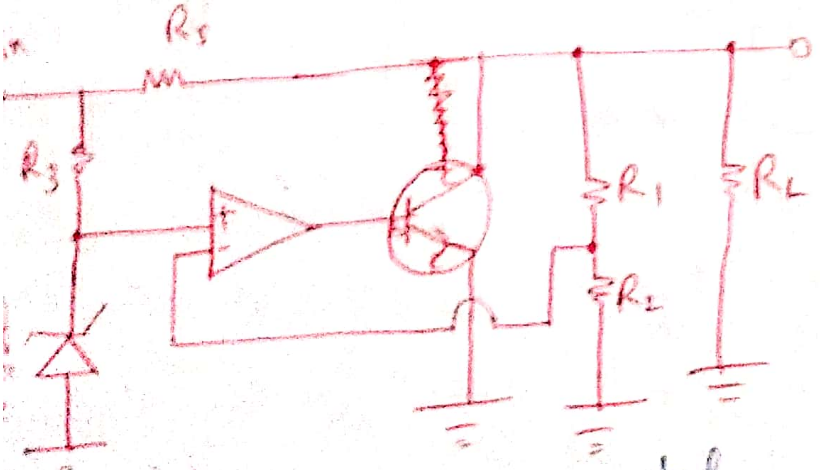


→ control element ‖ load
→ A part of load current passes through control ele.

→ control element series with load
→ All I_L through control ele.

Shunt	Series
→ Compensate V_o → control I_{in}	→ Compensate change in V_o ⇒ by adjusting voltage across the control ele.
→ Efficiency depends on I_L	→ Efficiency depends on V_o.
→ High voltage rating as controlled by ↓ curr.	→ ↓ voltage rating as controlled by ↑ curr.
→ Poor regulation	→ Gud regulation
→ Fixed voltage app^ns	→ Fixed & variable voltage app^ns.
→ Eg: Zener shunt regulator	→ Eg: Series feedback type regulators.
→ Simple to design	→ Complicated to design.

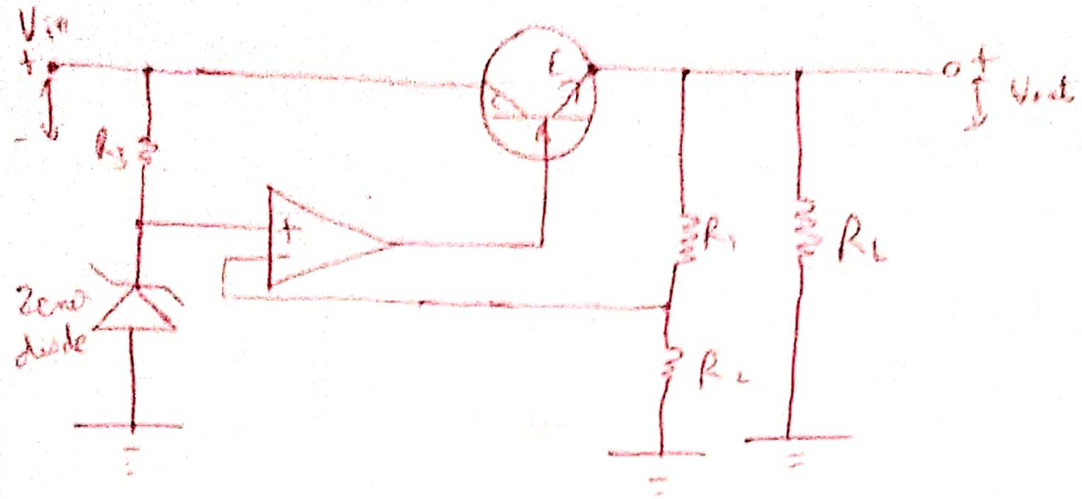
Shunt Voltage regulator using op-amp:



→ op-amp as comparator
→ R_1 & R_2 → potential divider ⇒ part of Vout as V_f
→ Zener diode generates reference voltage.

V_o changes → op-amp → control signal to control ele (transistor)

Series voltage regulator using op-amp:



→ Same as shunt regulator

→ R_s in shunt regulator ⇒ to maintain const. Vo/p.

THREE TERMINAL IC REGULATORS (IC VOLTAGE REGULATORS).

Advantages:

① Easy to use

② Low ~~power supply~~
 ↳ cost

③ ↓ internal short circuits ⇒ safe.

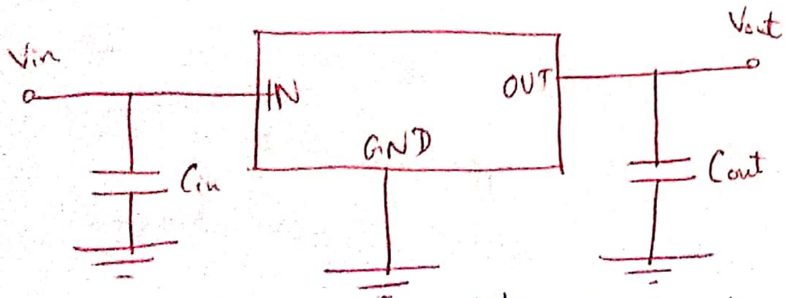
④ Simplifies power supply.

Types → Linear regulators (Continuously dissipates power) → Linear power supply used ↑ size due to big transformers.

↓ Switching regulators → uses SMPS (↓ wt. & ↓ size) → switches b/w on & off states.

expensive ← complex circuit design ↑ & ↓ dissipations

Three-terminal IC Voltage regulator:

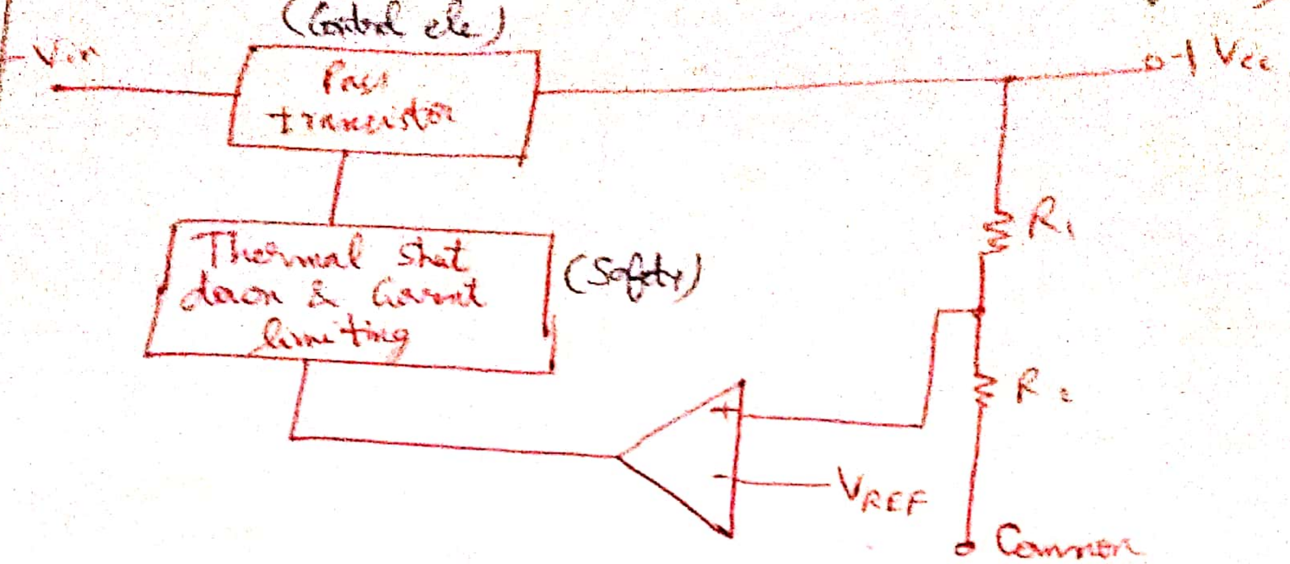


→ 3 terminals: IN, OUT, GND

→ Cout → ↓ noise in o/p, improve response of voltage regulator

→ Cin → ensure that filter regulator is at min. 5cm from power supply.

Block diagram : (Series three - terminal voltage regulator)



→ > 175°C → temp. of circuity → due to safety ⇒ automatically off → thermal shutdown of circuit.

→ R_1 & R_2 → potential divider circuit ⇒ part of it to i/p of comparator → compares V_f with V_{ref} & control signal to control ele (pass transistor) ⇓ compensates the change in V_o & keeps V_o const.

V_{ref} generated internally by zener diode.

Performance of power Supply:

→ Factors which help judge the overall performance of the power supply.

↳ Pass transistor → supplies extra I_L to ensure a regulated dc o/p. → also called as outboard bypass / power supply transistor.

① Line regulation : (ideal = 0, practical ↓)
→ Change in V_o due to change in i/p V.

② Load regulation : (ideal = 0, practical ↓)
→ No load to full load → I_L changes ⇒ change in V_{out} ?

③ RR (Ripple Rejection) : Filter & Rectifier o/p → ripples. By how much the regulator ↓ these ripples.

④ Rated o/p current → Max. curr. → which → curr. limit ?

⑤ Max. operating junction temp. → which → thermal shutdown

⑥ Dropout voltage → Max voltage b/w I/p & o/p terminals

⑦ Max. i/p voltage

⑧ Max. power dissipation

⑨ Quiescent current → supply current taken by regulator when no load.

⑩ o/p noise voltage → tendency of V_o to fluctuate > 5V.

⑪ Output resistance → $\dfrac{\Delta V_o}{\Delta I_o}$

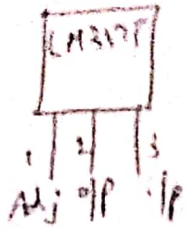
↳ Voltage regulator → ~~78xx~~ series → <u>78XX.</u>

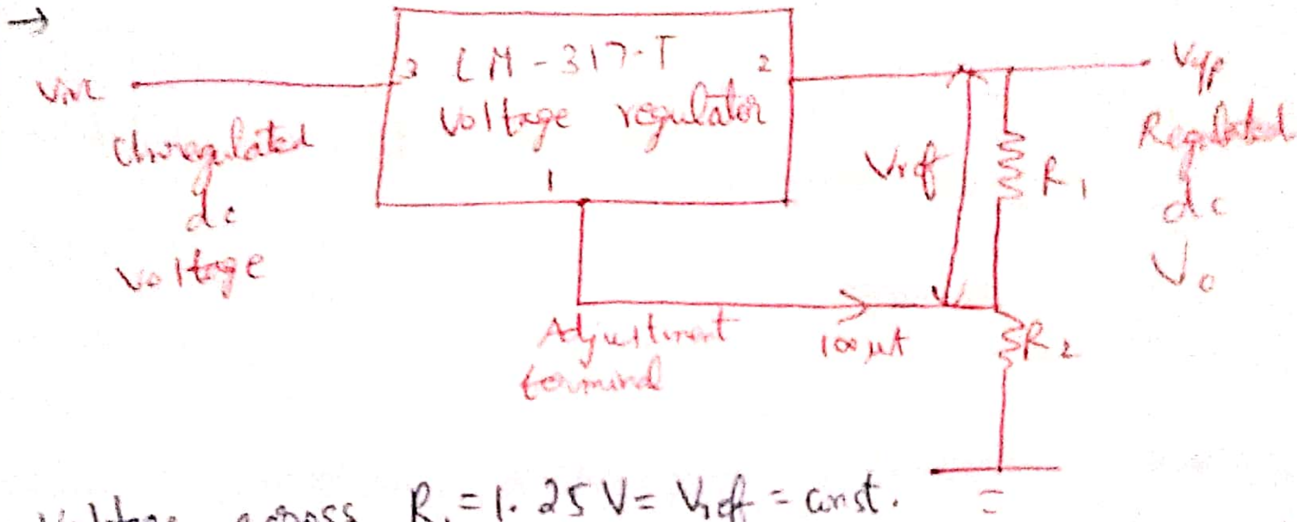
$$\boxed{I_c = (1+\beta) I_o - \frac{\beta V_{BE}}{R_1}}$$, $\beta = \frac{I_c}{I_B}$

load current.

Variable Voltage regulator :

→ LM 317T → 3-pin →





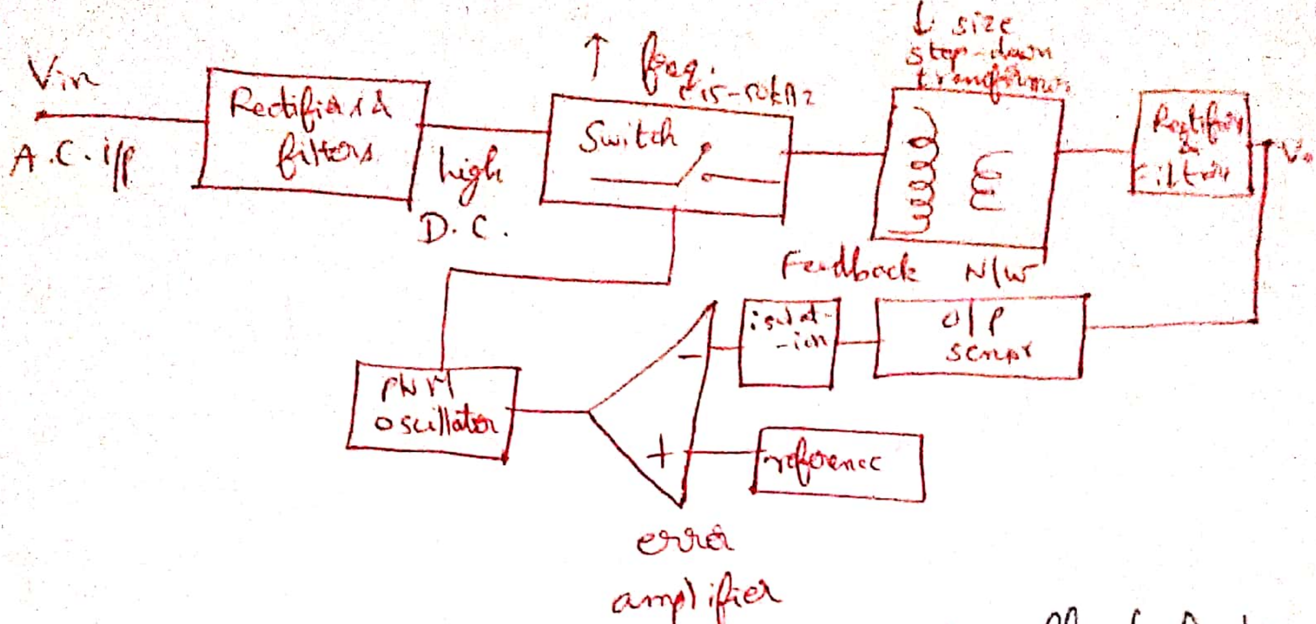
- Voltage across $R_1 = 1.25V = V_{ref}$ = const.
- Current through adjustment terminal = 100 μA = const.
- $V_{R_1} + V_{R_2} = V_o$

$$\boxed{V_o = 1.25\left(1 + \frac{R_2}{R_1}\right)}$$

- $\boxed{V_{in} \geq V_o + 2.5}$ (as $R_2 = R_1 = 1$ $V_o = 1.25(1+1)$
  $= 1.25(2)$
  $\underline{V_o = 2.5}$ → min. o/p voltage).

↳ Any power supply transfers power from DC/AC src. to DC loads. → Same in SMPS (Switched Mode Power Supply)

SMPS BLOCK DIAGRAM:



→ SMPS → high power density & flexible technology

→ MOSFET Switch
→ feedback n/w
→ step-down transformer
→ Rectifiers & filters

→ Components of SMPS.

→ D.C. voltage from battery / rectifier → given to switch → to → transformer → finally $V_o = 5V$ (regulated)

→ Part of V_o to error amplifier → compares with V_{ref} & control signal to control circuit ⇒ maintain V_o @ a desired level.