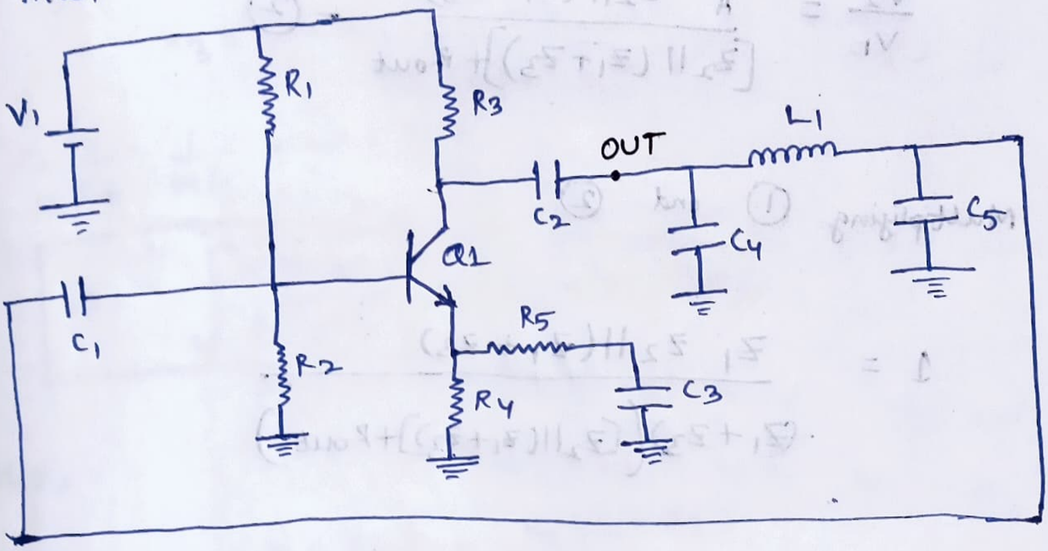
Colpitts Oscillator

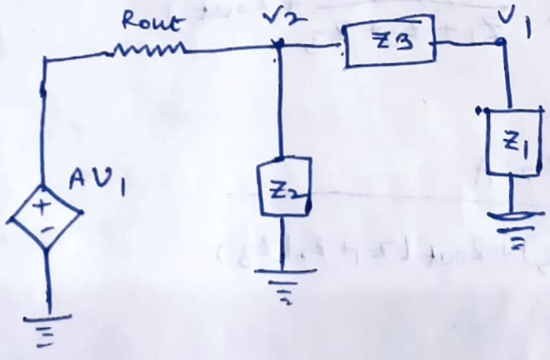
Frequency Calculation:-

If we were to design an RC circuit as the tank circuit to achieve radio frequencies, we find out that the resistor and capacitor values have to be very small. Therefore we use inductor and capacitors in the feedback network for the filter.



Colpitts Circuit

We can redraw the circuit in the following way



Here, A is the amplification factor

Since the ratio of voltages is equal to the ratio of the effective resistance the voltage supplies current to,

we have

$$\frac{V_1}{V_2} = \frac{Z_1}{Z_1 + Z_3} \quad -①$$

$$\frac{V_2}{AV_1} = \frac{Z_2 \| (Z_1 + Z_3)}{[Z_2 \| (Z_1 + Z_3)] + R_{out}}$$

$$\frac{V_2}{V_1} = A \frac{Z_2 \| (Z_1 + Z_3)}{[Z_2 \| (Z_1 + Z_3)] + R_{out}} \quad -②$$

$$\boxed{\text{Multiplying ① and ②} \qquad 1 = \frac{Z_1 \cdot Z_2 \| (Z_1 + Z_3)}{(Z_1 + Z_3)\left([Z_2 \| (Z_1 + Z_3)] + R_{out}\right)}}$$

$$1 = \frac{Z_1 \dfrac{Z_2 \cancel{(Z_1 + Z_3)}}{Z_1 + Z_2 + Z_3} A}{\cancel{(Z_1 + Z_3)}\left(\dfrac{Z_2 (Z_1 + Z_3)}{Z_1 + Z_2 + Z_3} + R_{out}\right)}$$

$$1 = \frac{Z_1 Z_2 A}{Z_2 (Z_1 + Z_3) + R_{out} (Z_1 + Z_2 + Z_3)}$$

$$1 = \frac{jX_1 \, jX_2 \, A}{jX_2(jX_1 + jX_3) + (jX_1 + jX_2 + jX_3)R_{out}}$$

Since $(jX_1 + jX_2 + jX_3)R_{out}$ is the only imaginary part it must be 0.

$$\Rightarrow j(X_1 + X_2 + X_3) = 0$$

$\Rightarrow$ Here, $X_1 = -\frac{1}{wC_4}$

$$X_2 = -\frac{1}{wC_5}$$

$$X_3 = wL_1$$

$$\Rightarrow -\frac{1}{wC_4} - \frac{1}{wC_5} + wL_1 = 0$$

$$\Rightarrow \boxed{w = \sqrt{\frac{C_4 + C_5}{L_1 C_4 C_5}}}$$

Also,

$$\Rightarrow A = \frac{Z_2(Z_1 + Z_3)}{Z_1 Z_2} = \frac{X_2(X_1 + X_3)}{X_1 X_2}$$

$$\Rightarrow A = \frac{X_2(-X_2)}{X_1 X_2}$$

$$\Rightarrow \boxed{A = \frac{-X_2}{X_1}}$$

$$\Rightarrow A = -\left(\frac{-\frac{1}{wC_5}}{-\frac{1}{wC_4}}\right) \Rightarrow \boxed{A = -\frac{C_4}{C_5}}$$

The desired frequency is 100KHz. We are not using capacitors with very low capacitance such as capacitance of pF order; Since the picofarads between rows and adjacent connections in the breadboard can interfere with the capacitance of the component making it ineffective. So we chose capacitors of nF range.

Taking $C_4 = 47nF$, $C_5 = 47nF$

Substituting these values along with frequency value in the formula,

$$\Rightarrow L_1 = \frac{C_4 + C_5}{\omega^2 C_4 C_5}$$

$$\Rightarrow L_1 = \frac{C_4 + C_5}{(2\pi f)^2 C_4 C_5} = \frac{2(47 \times 10^{-9})}{(2 \times 3.14 \times 10^5)^2 \times 47 \times 10^{-9} \times 47 \times 10^{-9}}$$

We get $L_1 = 100.79\mu H$

So we chose $L_1 = 100\mu H$

DC Blocking

In order to make sure that the transistor is in active mode [base-emitter in forward-bias and base-collector in rev-bias] we need to make sure that DC current is not flowing into the base. So we use C_1 to block DC current from feedback

$$\frac{1}{\omega C_1} \lesssim R_1 + R_2$$

$$C_1 \geqslant \frac{1}{2\pi f(R_1+R_2)}$$

After biasing the BJT $R_1 = 12K\Omega$, $R_2 = 8.2K\Omega$

$$C_1 \geqslant \frac{1}{2\times 3.14\times 20.2\times 10^3 \times 10^5}$$

$$C_1 \geqslant 0.08\,nF$$

Since we want to avoid values closer to pF, we took C_1 to be 100nF

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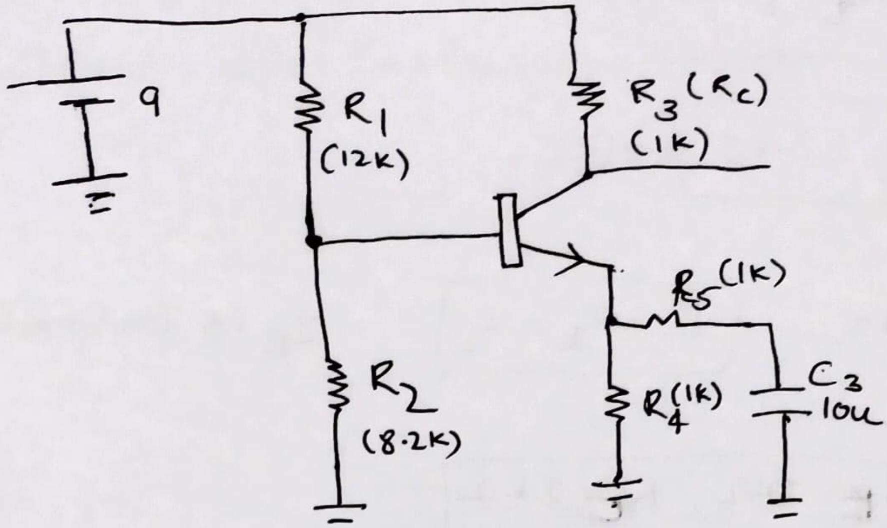

⇒ BJT to Work as an Amplifier it must be in Active Region

→ (B−E) Junction ⇒ Forward Bais

(B−C) Junction ⇒ Reverse Bais

⇒ For Transtistor to be in Active Region, $\boxed{V_{BE} \geq 0.7\,V}$

So, Let's fix $R_1 = 12K$, $R_2 = 8.2K$ and check that $V_{BE} \geq 0.7V$ or Not

$$V_B = \frac{9 \times 8.2}{12 + 8.2} = \frac{9 \times 8.2}{20.2} \Rightarrow \frac{73.8}{20.2} = 3.65 > 0.7$$

So, we can fix R_1 and R_2.

⇒ For (B−E) Junction To Be in forward Bias,

$$V_E \geq 3.65 - 0.7$$

$$V_E \geq 2.95$$

⇒ For (B−C) Junction To Be in Reverse Bias,

$$V_B < V_C$$

⇒

$$\boxed{2.95 = R_E I_E} \rightarrow ①$$

$$\boxed{9 - R_C I_C > 3.65} \rightarrow ②$$

$\Rightarrow$ $\boxed{I_C \approx I_E}$ Because $\boxed{I_C + I_B = I_E}$ I_B is Too Small..

So Let's Fix, $\boxed{R_E = 1K\Omega,\ R_C = 1K\Omega}$

$$I_E = I_C = 2.95.$$

$9 - 1 \times 2.95 \Rightarrow \boxed{6.05 > 3.65} \rightarrow$ So Condition ② is Sat

So, We can fix $\boxed{R_E = 1K\Omega,\ R_C = 1K\Omega}$

$\Rightarrow$ As our Amplicfication, $\boxed{A_1 = -\frac{C_2}{C_1} = -1}$

Amplicafication factor $\approx \frac{R_E}{R_E} = 1$

$\Rightarrow$ So, we are Using Emmiter By passing, to Increase our gain and ensure that DC Baising doesn't get effected

$\Rightarrow$ At initial State, (Capisitor is a wire)

So, Initial Gain = $1/0.5 = 2$

$\Rightarrow$ After Capasitor ~~reaches~~ stedy State, (Capistor is open Circuit)

So, Final Gain = $1/1 = 1$

⇒ So, Intially there will be a Amplification of a factor 2 and the oscillations are Sustained through Amplification factor of 1