• Wien-bridge oscillator :- (WBO)

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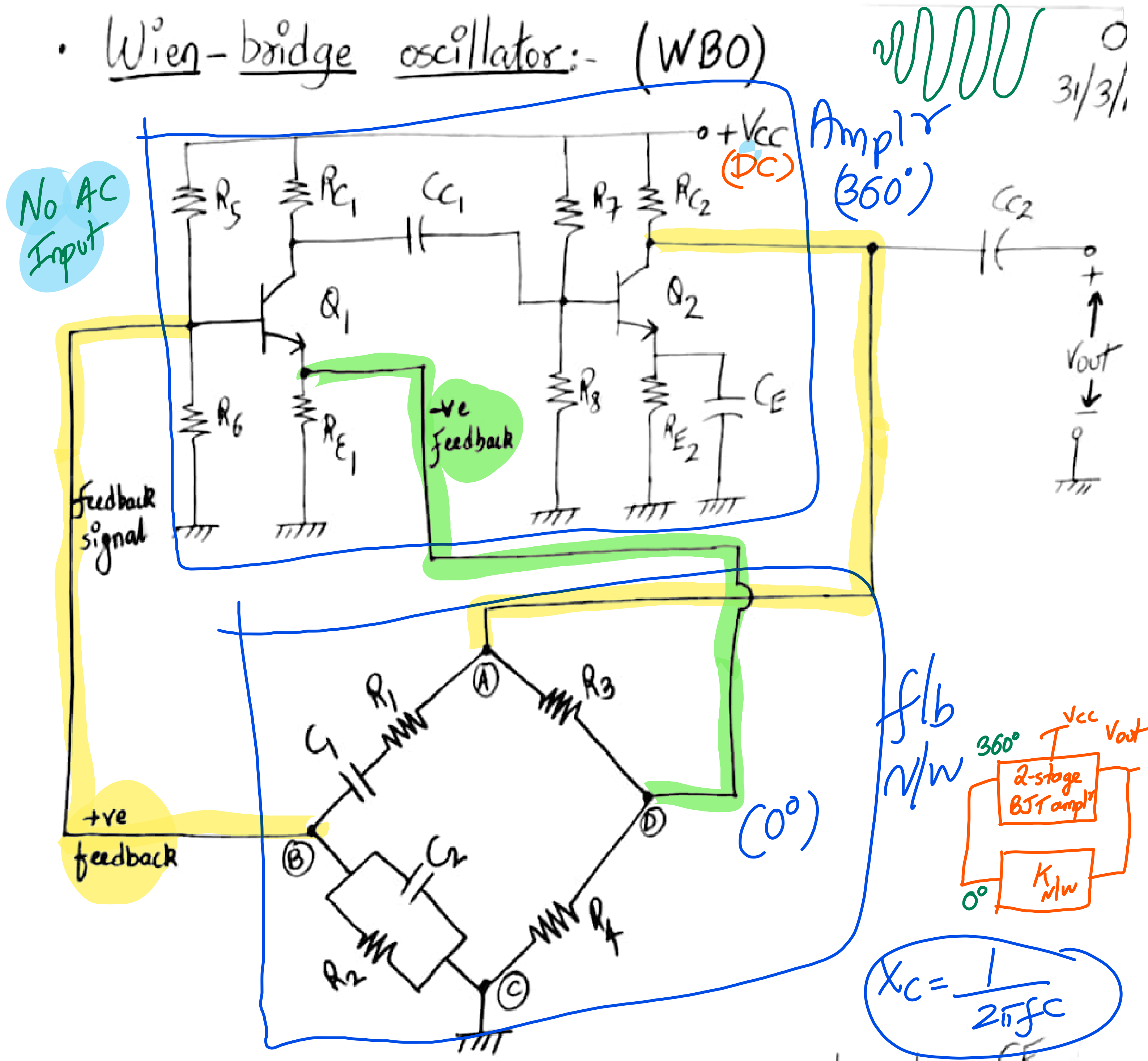

$X_C = \dfrac{1}{2\pi f C}$

ckt ① : Wien-bridge oscillator using two stage CE

- It is difficult to achieve variable frequency operation for RC phase-shift oscillator.
- An oscillator circuit, which is more useful for variable frequency operation is Wien-bridge oscillator.
- Circuit ① shows circuit of wien-bridge oscillator using BJT as an active device. We may also use FET's instead of BJT.
- Wien-bridge oscillator consists of a 2-stage RC coupled amplifiers, which provides no phase shift (0°) between its I/P and O/P terminals.

- Feedback network consists of a balanced bridge which doesn't provide any phase shift betn I/p and o/p. 11
- The Barkhausen's criterion for WBO is satisfied as follows

Transistor Q_1 and Q_2 provide 180° phase-shift each.
ie Amplifier provides 0° or 360° phase-shift
The feedback network provides a phase-shift of 0°
Thus, the total phase-shift around the loop is 0°.

- Feedback N/w consists of $C_1 - R_1$, $C_2 - R_2$ (called a lead-lag network), which is frequency-sensitive arm's of the bridge and $R_3 - R_4$ (voltage-divider).

- The two arm's ie $R_1 - C_1$ series and $R_2 - C_2$ parallel paths cancel's each other's phase shift, hence f/b N/w doesn't provide any phase-shift. at all.

- The lead-lag N/w provides a +ve feedback to the I/p of the 1st stage (Q_1) and the voltage-divider, the -ve feedback to emitter of Q_1 transistor.

- The two feedback paths are
a) +ve feedback through Z_1 and Z_2; whose components determine the frequency of oscillation.
b) -ve feedback through R_3 and R_4, whose elements affect the amplitude of the oscillations and set the gain of amplifier.

- It can be shown by simple analysis that the frequency of oscillations for WBO is given by

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}}$$

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- If components values are such that $R_1 = R_2 = R$ and $C_1 = C_2 = C$

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

then, $\boxed{f_o = \frac{1}{2\pi RC}}$ → Frequency of oscillation's of a WBO

- Also, it can be shown that ratio of R_3 to R_4 greater than 2 will provide a sufficient gain for WBO to oscillate at desired Frequency.

- F/B Factor K for a WBO should be $\left(\frac{1}{3}\right)$ $K<1$

That means, the gain of the amplifier is adjusted to 3 so that, loop gain $(A_1 K)$ is atleast unity or greater than unity (slightly). ie $|A_1 K| \geq 1$

→ Operation of a wien-bridge-oscillator:

1. When the circuit is energized by switching on the dc supply, a small random (noise) appearing at the base of Q_1 transistor are amplified, at its collector.
2. These small oscillations are further amplified at the collector of Q_2 transistor.
3. Since the oscillations at the collector of Q_2 have been inverted twice, therefore these oscillations are in phase with the I/p signal.
4. A part of the o/p signal from the collector of Q_2 is feedback to the WBO, which is Further amplified.
5. The process continues, till sustained oscillations are produced.

* How amplitude stabilization is achieved in Wien-bridge oscillator?

- For loop $|A_1 K| \geq 1$ and $K = \frac{1}{3}$, the gain of the amplifier in WBO for sustained oscillations should be $|A_1| \geq 3$.
- But, in WBO, the amplifier can easily provide a much higher gain than 3 (being a 2 stage amplifier).
- Now, the gain of the amplifier should not be too high as it will distort the o/p waveform of the oscillator.
- In order to avoid this possibility of distortion amplifier gain should be Limited.

→ This is done by introducing a -ve f/b by keeping R_{E_1} in emitter of Q_1 unbypassed.
The potential-voltage ($R_3 - R_4$) develop's a certain voltage at the emitter of Q_1). This voltage provides -ve F/B to the ckt, so that the gain is under control and stability is achieved.

- This process of gain reduction using -ve feedback is called as "Amplitude Stabilization".
- As the amplitude of oscillation's ↑ses, the value of $V_{R_{E_1}}$ will ↓se and current through R_{E_1} will ↑se. This will ↑se the amount of -ve f/b and hence will reduce the gain in WBO automatically $|A_1| \geq 3$ and avoid waveform distortions.

Note: Feedback network is responsible for frequency of oscillations in a WBO.

Since, $f_0 = \frac{1}{2\pi RC}$ for WBO

The frequency of oscillations can be varied by varying either both R or both C connected in the frequency sensitive arms of wien-bridge. Hence, WBO is also called as variable-frequency oscillator.

- Wien-bridge oscillator is generally preferred over the RC phase shift oscillator due to its ease in frequency selection (tuning), extremely low starting gain and minimum o/p waveform distortion.

Applications:- A wien-bridge oscillator is a standard oscillator ckt for generating low-frequencies in the range of 20Hz to about 100KHz. It is used in all commercial audio signal generators.

Advantages:- 1) It gives an extremely pure sine wave o/p

2) Good frequency stability and a highly stabilized amplitude are unique features of WBO.

3) Frequency variation (tuning) is easier compared to RC phase shift oscillator.

4) Extremely low starting gain ie $|A| \geq 3$ as compared to 3 stage RC phase shift oscillator ie $|A| \geq 29$

Disadvantages:- 1) It cannot be used for high frequency applications.

2) Two stage are used in amplifier's, which are complex to design, analyze and construct, but this can be overcome using operational amplifier (OPAMPS).

Analysis of Feedback network for wien-bridge oscillator:-

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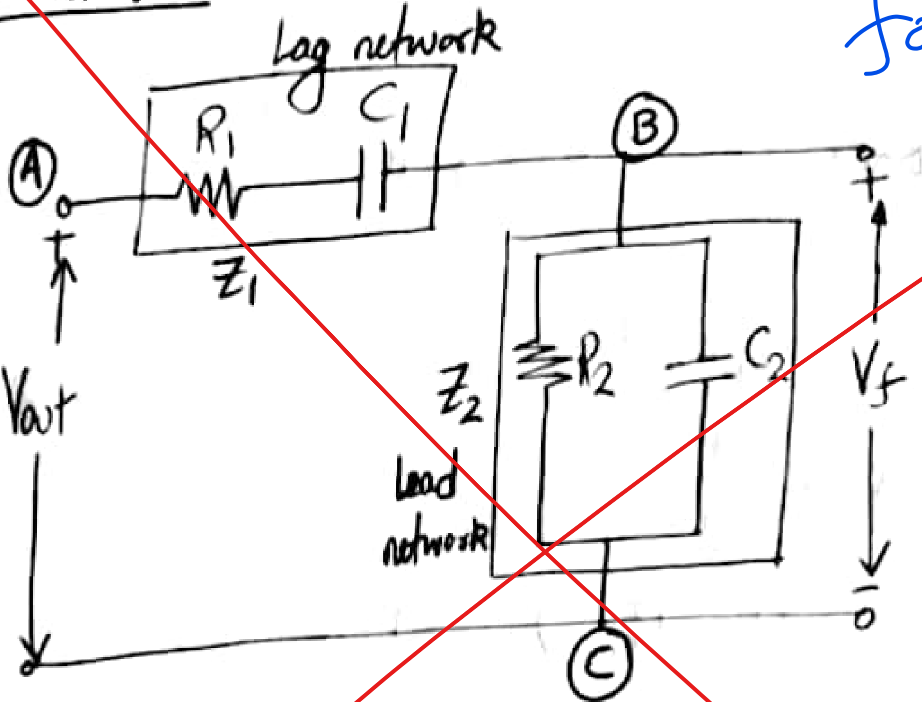
$$f_0 = \frac{1}{2\pi R C}$$

$R_1 = R_2 = R$

$C_1 = C_2 = C$



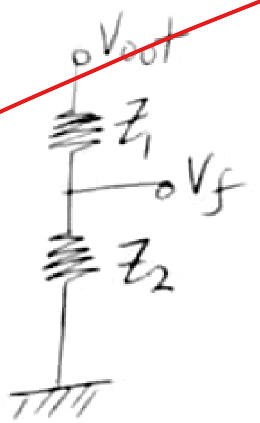
ckt C

→ Consider frequency sensitive arm AB and BC

→ Feedback factor or gain of Feedback network (K)

$$\boxed{K = \frac{V_f}{V_{out}}} \quad \text{— (1)}$$

→ By voltage-divider rule,



$$V_f = \frac{Z_2}{Z_1 + Z_2} V_{out}$$

$$K = \frac{V_f}{V_{out}} = \frac{Z_2}{Z_1 + Z_2} \quad \text{— (2)}$$

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

$$\rightarrow Z_2 = R_2 \| X_{C2} = R_2 \| \left(\frac{1}{j\omega C_2}\right)$$

$$Z_2 = \frac{R_2\left(\frac{1}{j\omega C_2}\right)}{R_2 + \frac{1}{j\omega C_2}} = \frac{R_2}{1 + j\omega C_2 R_2}$$

Substitute $R_2 = R_1 = R$; $C_1 = C_2 = C$

$$\rightarrow Z_1 = \frac{j\omega RC + 1}{j\omega C} \quad ; \quad Z_2 = \frac{R}{1 + j\omega RC}$$

ie $$K = \frac{Z_2}{Z_1 + Z_2}$$

$$= \frac{\frac{R}{1 + j\omega RC}}{\frac{R}{1 + j\omega RC} + \frac{1 + j\omega RC}{j\omega C}}$$

$$K = \frac{j\omega RC}{j\omega RC + (1 + j\omega RC)^2}$$

$$K = \frac{j\omega RC}{1 + 3j\omega RC + j^2\omega^2 R^2C^2}$$

$$K = \frac{j\omega RC}{1 + 3j\omega RC - \omega^2 R^2C^2}$$ $\boxed{j^2 = -1}$

Divide numerator and denominator by $j\omega RC$,

$$\boxed{K = \frac{1}{3 + \frac{1}{j\omega RC} - \frac{\omega^2 R^2 C^2}{j\omega RC}}} \rightarrow 2$$

→ Equating the imaginary part of eq^n 2, will generally give the frequency of oscillation.

ie $$\frac{1}{j\omega RC} - \frac{\omega^2 R^2 C^2}{j\omega RC} = 0$$

ie $$\frac{1}{\cancel{j\omega RC}} = \frac{\omega^2 R^2 C^2}{\cancel{j\omega RC}}$$

ie $$\omega^2 = \frac{1}{R^2C^2}$$

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ie $\omega = \frac{1}{RC}$

ie $2\pi f_0 = \frac{1}{RC}$

ie $\boxed{f_0 = \frac{1}{2\pi RC}}$ → Freq^n of oscillation for a wien-bridge oscillator

where, $R_1 = R_2 = R$; $C_1 = C_2 = C$

→ To obtain the value of K at frequency of oscillation (f_0).

Put $\omega = \frac{1}{RC}$ in eq^n ②,

$$K = \frac{1}{3 + \frac{1}{\cancel{j}\omega RC} - \frac{1}{\cancel{j}\omega RC}}$$

$\boxed{K = \frac{1}{3}}$ → Feedback factor

Thus, at the oscillator freq^n 'f_0' the value of feedback factor K is $\frac{1}{3}$

As per the barkhausen's criterion,

$$|A_1 \cdot K| \geq 1$$

$$\left|A_1 \cdot \frac{1}{3}\right| \geq 1$$

$$\boxed{|A_1| \geq 3}$$

A_1 is the amplifier gain

Thus, the amplifier gain (A_1) should be atleast equal to or slightly greater than 3 to ensure sustained oscillations.

→ RC network in ckt (c) is responsible for determining the frequency of oscillation.

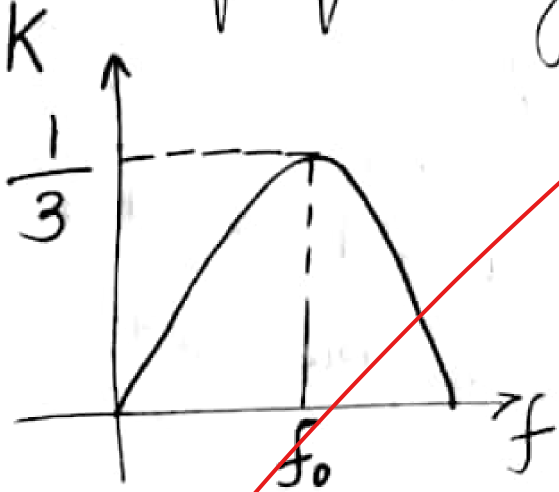
→ Referring to ckt (c),

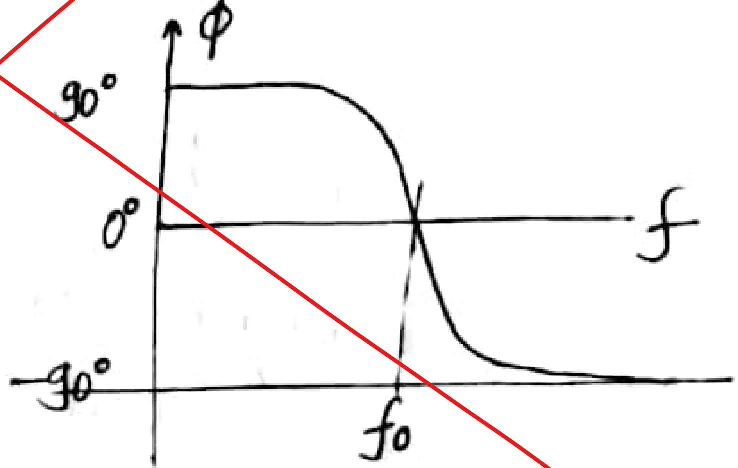
a) At low frequencies o/p of n/w ie V_f becomes zero since C_1 behaves as open-ckt $\left(X_c = \frac{1}{2\pi f C_1} \approx \infty\right)$

b) At high frequencies, o/p of n/w ie V_f becomes zero since C_2 behaves as short-ckt $\left(X_c = \frac{1}{2\pi f C_2} \approx 0\right)$

→ In between these two extreme conditions, o/p voltage reaches max values.

→ At oscillating frequency (f_0), K reaches to a max value of $\frac{1}{3}$, and the phase-shift of lead-lag network is 0°. 06





→ At f_0, feedback factor $K = \frac{1}{3}$

→ At f_0, the phase-shift of lead-lag network is zero