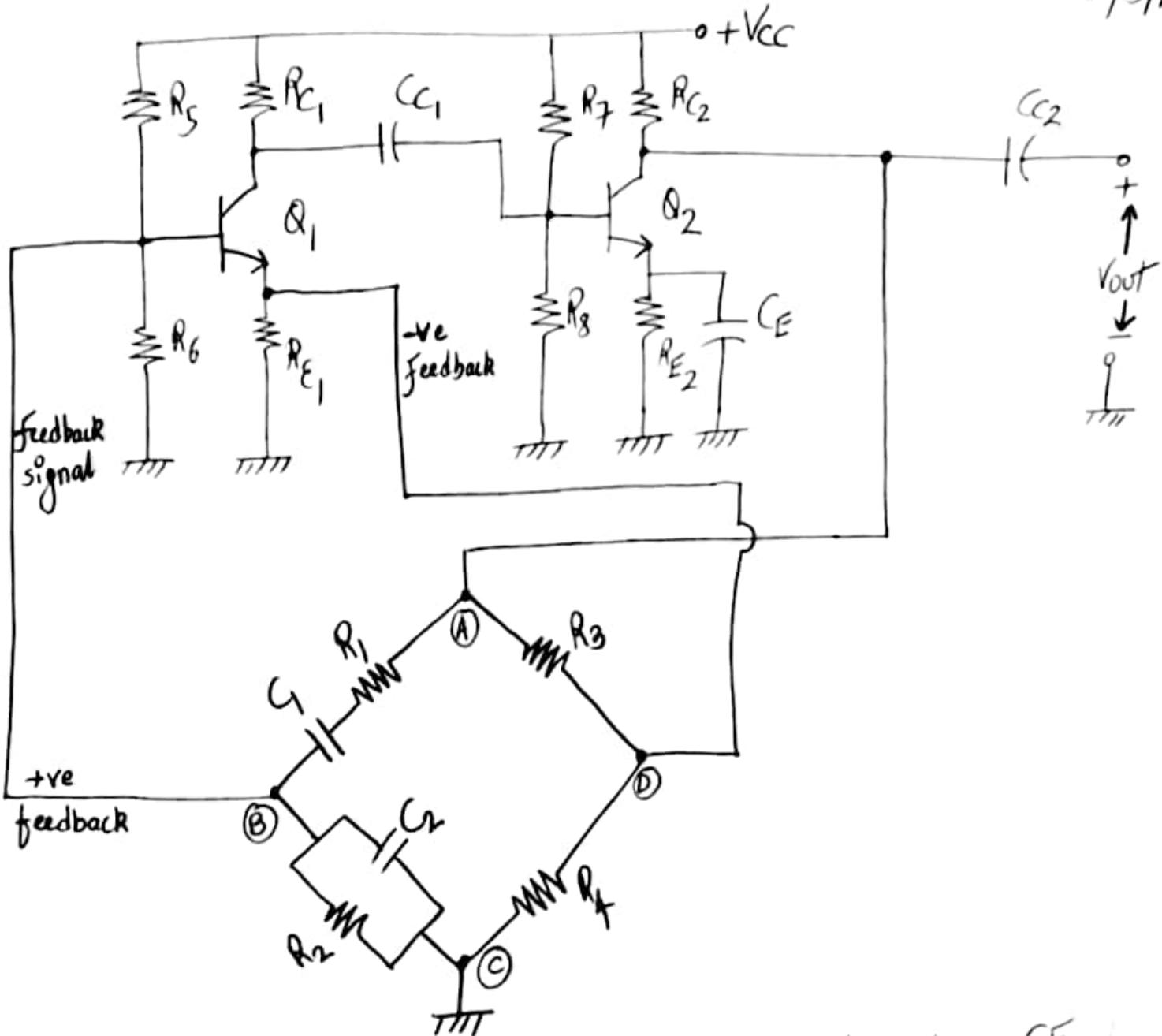


• Wien-bridge oscillator:- (WBO)

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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 IIP and OLP terminals.

- Feedback network consists of a balanced bridge which doesn't provide any phase shift betn ILP and OLP.
- 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 Nlw 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_{lb} Nlw doesn't provide any phase-shift at all.
- The lead-lag Nlw provides a +ve feedback to the ILP of the 1st stage (Q_1) and the voltage-divider, the -ve feedback to emitter of Q_1 transistor.
- The two feedback paths are
 - +ve feedback through Z_1 and Z_2 ; whose components determine the frequency of oscillation.
 - 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

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

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

then,
$$f_0 = \frac{1}{2\pi RC}$$
 → Frequency of oscillations
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 $(\frac{1}{3})$

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). i.e $|A_1 K| \geq 1$

→ Operation of a wien-bridge - oscillator:

- When the circuit is energized by switching on the dc supply, a small random(noise) appearing at the base of \textcircled{Q}_1 transistor are amplified, at its collector.
- These small oscillations are further amplified at the collector of \textcircled{Q}_2 transistor.
- Since the oscillations at the collector of \textcircled{Q}_2 have been inverted twice, therefore these oscillations are in phase with the IIP signal.
- A part of the o/p signal from the collector of \textcircled{Q}_2 is feedback to the WBO, which is further amplified.
- The process continues, till sustained oscillations are produced.

- * How amplitude stabilization is achieved in Wien-bridge oscillator?
- For Loop $|A_1 K| = 1$ and $K = \frac{1}{3}$, the gain of the amplifier in WBO for sustained oscillations should be $|A| \geq 3$.
- 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 op-amp waveform of the oscillator.
- In order to avoid this possibility of distortion amplifier gain should be limited.

→ This is done by introducing a -ve Fb by keeping R_{E_1} in emitter of Q_1 unbypassed.

The potential-voltage ($R_3 - R_4$) develops a certain voltage at the emitter of Q_1 . This voltage provides -ve Fb to the CRT, 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 increases, the value of V_{RE_1} will increase and current through R_{E_1} will increase. This will increase the amount of -ve Fb and hence will reduce the gain in WBO automatically $|A| \geq 3$ and avoid waveform distortions.

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

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

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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 circuit for generating low-frequencies in the range of 20Hz to about 100KHz. It is used in all commercial audio signal generators.

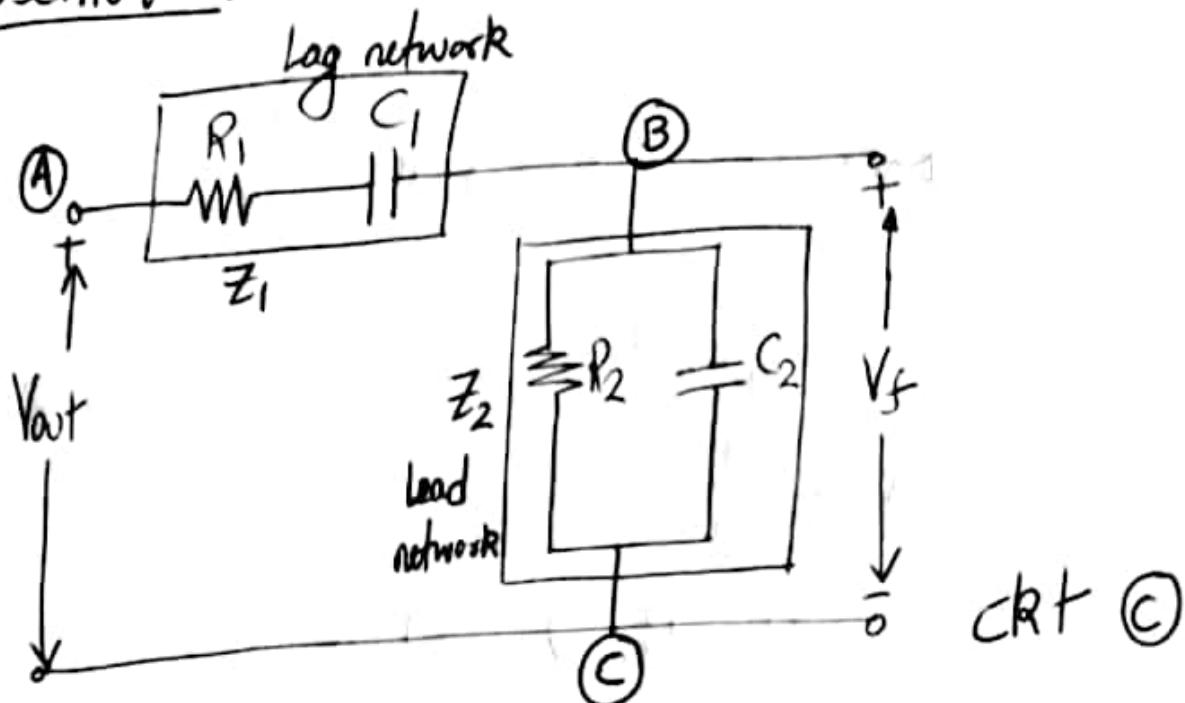
- Advantages:-
- 1) It gives an extremely pure sine wave o/p
 - 2) Good frequency stability and a highly stabilized amplitude are unique features of WBO.
 - 3) Frequency variation (tuning) is easier compared to RC phase shift oscillator.
 - 4) Extremely low starting gain ie $|A| \geq 3$ as compared to 3 stage RC phase shift oscillator ie $|A| \geq 29$

- Disadvantages:-
- 1) It cannot be used for high frequency applications.
 - 2) Two stages are used in amplifier's, which are complex to design, analyze and construct, but this can be overcome using operational amplifier (OPAMPS).

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Analysis of Feedback network for Wien-bridge oscillator:-

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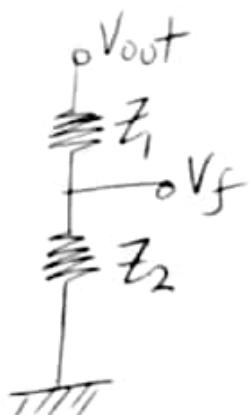


- Consider frequency sensitive arm AB and BC
- Feedback factor or gain of feedback network (K)

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

→ By voltage-divider rule,

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



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

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

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

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

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

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

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

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

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

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

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

$$j^2 = -1$$

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

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

→ Equating the imaginary part of eqⁿ ②, will generally give the frequency of oscillation.

$$\text{i.e. } \frac{1}{j\omega RC} - \frac{\omega^2 R^2 C^2}{j\omega RC} = 0$$

$$\text{i.e. } \frac{1}{j\omega RC} = \frac{\omega^2 R^2 C^2}{j\omega RC}$$

$$\text{i.e. } \omega^2 = \frac{1}{R^2 C^2}$$

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

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

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

Freqⁿ 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 eqⁿ ②,

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

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

Thus, at the oscillator freqⁿ 'f₀' the value of feedback factor K is $\frac{1}{3}$

As per the Barkhausen's criterion,

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

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

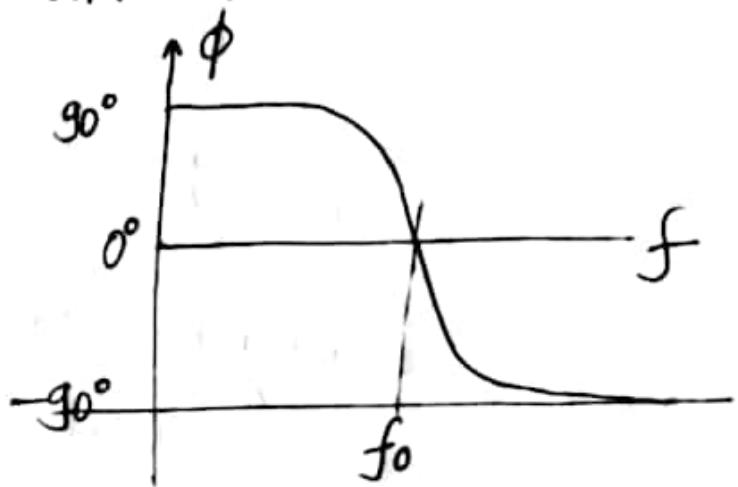
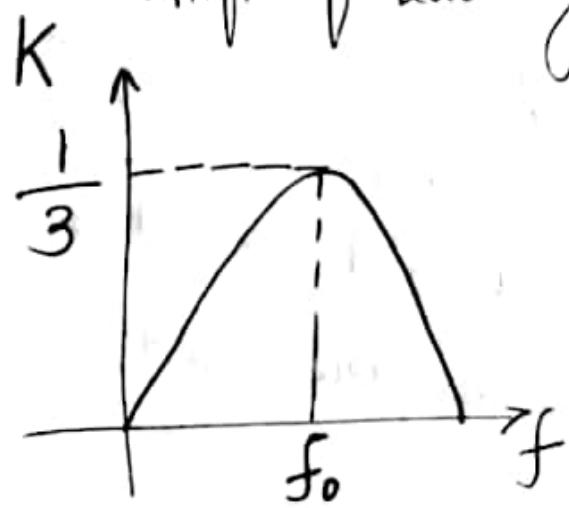
$$|A_1| \geq 3$$

A_1 is the amplifier gain

Thus, the amplifier gain (A_1) should be at least 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 becomes zero since C_1 behaves as open-ckt ($X_C = \frac{1}{2\pi f C_1} \approx \infty$)
 - b) At high frequencies, O/P becomes zero since C_2 behaves as short-ckt ($X_C = \frac{1}{2\pi f C_2} \approx 0$)
- 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° .



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

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