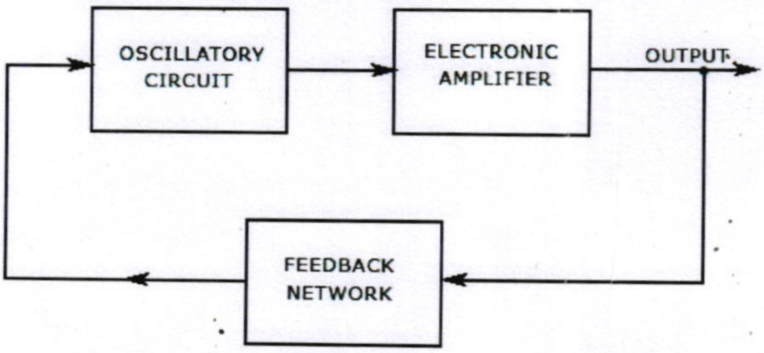
Hands out on Oscillators

A- Barkhausen criterion for oscillations:

⇨ An oscillator can be defined as a static electronic device that produces sinusoidal oscillations of desired frequency.

⇨ An oscillator circuit contains three basic units as shown in the block diagram :



1- A Frequency determining network usually known as tank or oscillatory circuit

2- An electronic amplifier to boost oscillations

3- A network to provide positive feedback

⇨ As we know that gain of an amplifier in positive feedback is given as:

$$A_v' = A_v / (1 - \beta A_v)$$

⇨ If by suitable means, value of βA_v is selected as 1 means when βA_v=1, then denominator in above equation becomes zero.

⇨ Which means in the condition when βA_v =1, Output of such an amplifier is infinite & the feedback used is positive feedback.

⇨ In such situation, output fed through feedback network will be the input to this amplifier & in such condition when there is output without external input, oscillations will be there.

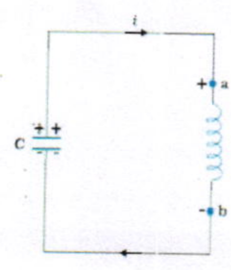
⇨ This Condition of Oscillation when βA_v =1, is known as **Barkhausen criterion** for oscillations.

⇨ Fulfilment of Barkhausen criterion demands that the input signal & the feedback signal should be in phase. The amplifier used provides 180^0 phase shift for input signal & additional 180^0 phase shift is obtained by using any simple phase shifting network.

B- Tank Circuits

⇨ For producing sinusoidal oscillations, an oscillator uses a circuit that is commonly known as tank circuit. A tank circuit is in fact a suitable combination of capacitance & inductance as shown in the diagram .

⇨ Here energy taken from a source and given to capacitor keeps oscillating between L & C. The oscillations between L and C are referred as LC oscillations.



⇨ When AC voltage is applied to the capacitor, it will first charge and then will discharge ,again will charge and discharge and this process will keep on continuing.

⇨When the capacitor is fully charged it will start discharging and the charge is transferred to the inductor which is connected to the capacitor.

⇨Because of change in the current there will be change in the magnetic flux of the inductor in the circuit.

⇨As a result there will be an emf induced in the inductor.

⇨The EMF is given by e = - L (dI/dt). The self-induced emf will try to oppose the growth of the current.

⇨ As a result when the capacitor gets completely discharged all the energy stored in the capacitor will now be stored in the inductor.

⇨The capacitor will become fully discharged whereas inductor will be storing all the energy.

⇨As a result now the inductor will start charging the capacitor. The energy stored in the capacitor will start again increasing .

⇨As a result of this cycle, sustained oscillations will be generated.

C- Use of positive feedback :

⇨As per Barkhausen criterion ,the feedback in the amplifier section of an oscillator must be positive feedback .

⇨ This is the condition where a fraction of the amplifier's output signal is fed back to the input in such a way that both are in the same phase. As a result the feedback output and input signals are added & this increases amplitude of input signal. Here, it is to make sure that the positive feedback loop used must provide180° phase change in such a way that it is added with 180° phase shift of amplifier to make it completely in phase with input signal.

⇨The kind of arrangement leads to higher gain with increased noise and distortion of amplifier. However, if the amount of positive feedback is large enough, the result is oscillation.

⇨ When an amplifier is operated without feedback it is operating in "open loop" mode while With feedback, either positive or negative, it is in "closed loop" mode.

⇨ In ordinary amplifiers negative feedback is used to provide advantages in bandwidth, distortion and noise generation, and in these circuits the closed loop gain of the amplifier is much less than the open loop gain.
⇨ However with positive feedback , such amplifier have closed loop gain greater than the open loop gain.

⇨Additional effects of positive feedback are reduced bandwidth and increased distortion. But reduction in bandwidth does not matter in an oscillator which is generally used to produce single frequency sine wave at a time. Increased distortion may not be a major issue in **some** sine wave oscillator designs, where it does not affect the shape of the output wave.

⇨In oscillators, it is significant to keep amplitude of the oscillator stable. To achieve this, the closed loop gain must be 1 (unity).

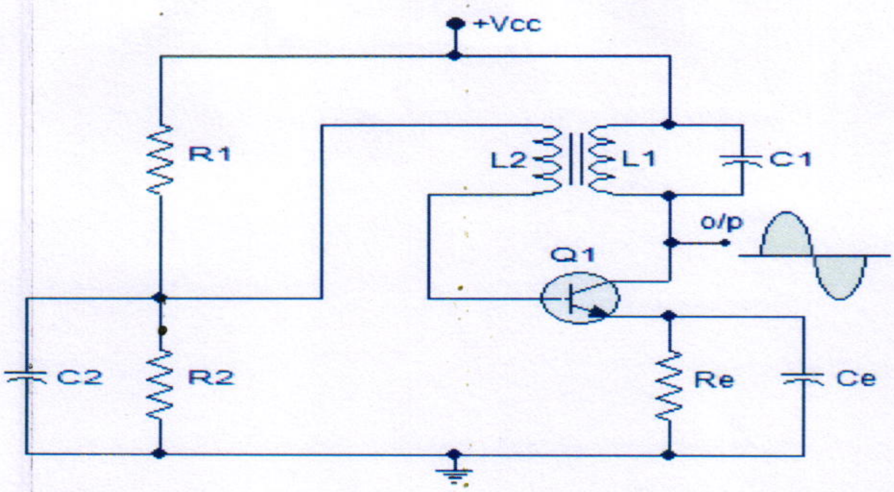
D- Classification of oscillators:

⇨Basically all oscillators work on the same principle, however on the basis of feedback to supply losses to the oscillatory circuit ,the following is the type of oscillators:

1- Tuned collector Oscillator,
2-Hartley Oscillator,
3- Colpits Oscillator,
4- Phase shift Oscillator,
5- Wien's bridge Oscillator,
6- Crystal oscillator.

1- Tuned collector Oscillator :

⇨ Called as because the circuit of this oscillator contains a tuned circuit in the collector of the transistor as shown in the diagram.



⇨ This oscillator circuit has an oscillatory circuit L_1-C_1 in the collector as shown above. The frequency of oscillations depends on the value of L_1 & C_1 and is given by the expression:

$$f= \frac{1}{2\pi\sqrt{L_1C_1}}$$

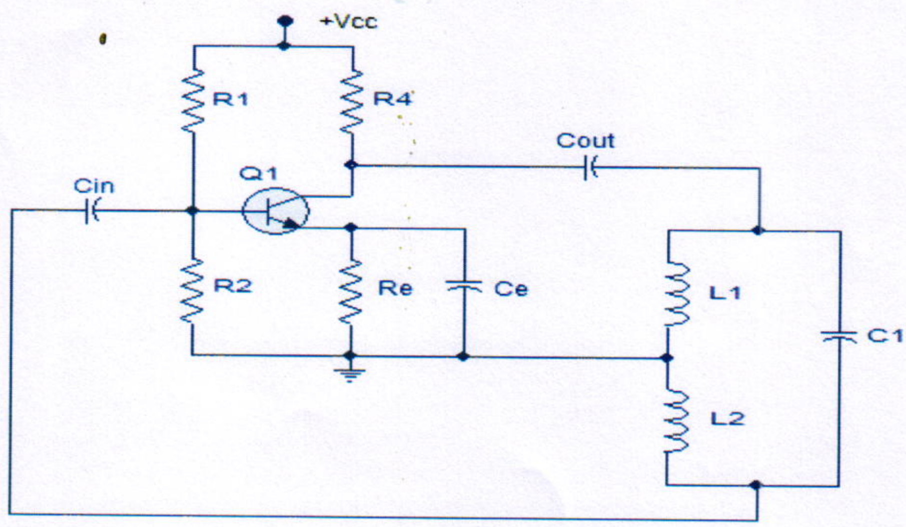
⇨ Thus suitably selecting values of L_1 & C_1, oscillations of any desired frequency can be obtained.

⇨ The coil L_2 in the base circuit is magnetically coupled to L_1 & in fact L_1 & L_2 form the primary & secondary of a transformer.

⇨ R_1, R_2, R_E & C_E are the components that provide biasing & necessary stabilisation to the circuit. Capacitor C_2 provides a low reactance path to oscillations.

2-Hartley Oscillator:

⇨ Due to easy adaptability to wide range of frequencies, this is the most popular oscillator circuit. The oscillator is commonly used in radio receivers.



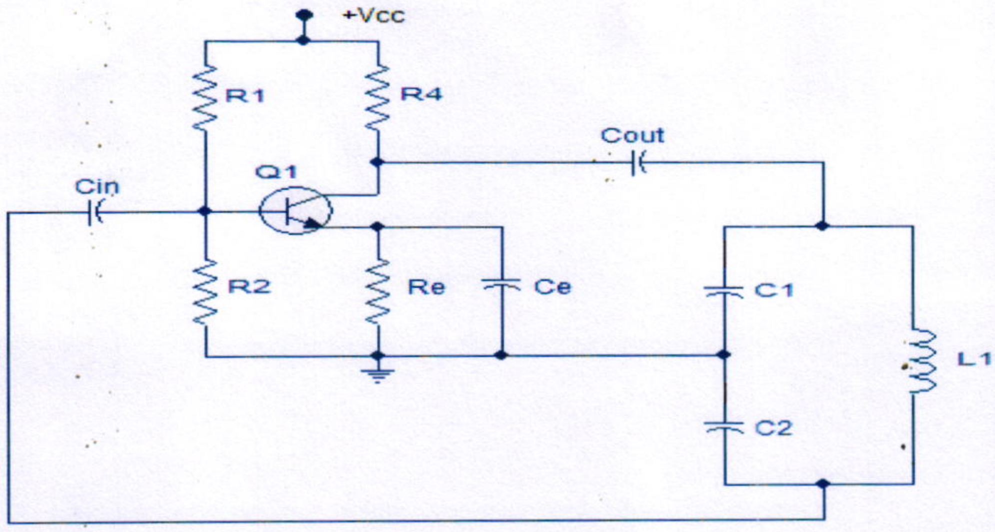
⇨ Working principle of Hartley Oscillator is similar to tuned collector Oscillator except the difference in circuit configuration as shown above.

⇨The circuit of Hartley oscillator has two coils L_1 & L_2 wound on the same core to provide effect of mutual induction. A capacitor C_1 is connected across the combination of L_1 & L_2 to form L-C circuit. Resistor R_1 , R_4 connected between collector & base of transistor provide necessary biasing.

⇨ Capacitor C_i blocks the dc Component in input fed from output. The frequency of oscillations is determined by L_1 , L_2 & C_1.

3- COLPITT'S OSCILLATOR :

⇨ Very similar to Hartley oscillator. The only difference is that in case of Colpitt's Oscillator coupling is capacitive instead of inductive as in case of Hartley Oscillator.



⇨ Here the tank circuit consists of an inductive coil L_1 in parallel with two capacitors C_1 & C_2 Connected in series as shown in above diagram.

⇨Combination of resistor R_1 & R_4 along with R_2, R_E & C_E between collector & base provide the necessary biasing.

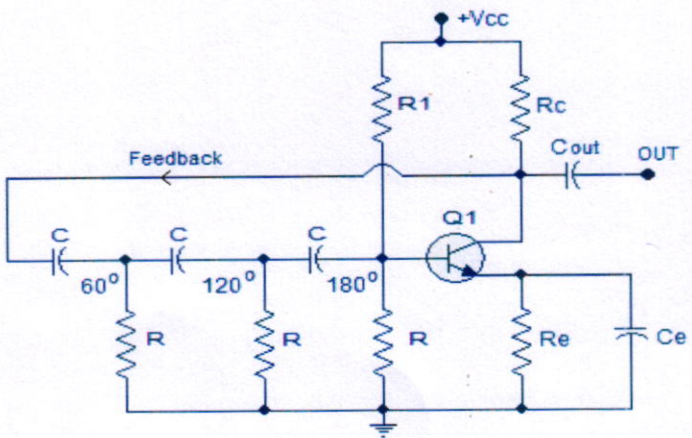
⇨ Capacitor C_i blocks dc component that may creep into input from feedback circuit. The frequency of Oscillations is given as :

$$f=\frac{1}{2\pi\sqrt{LC_T}}$$

$$\text{Where } C_T = \frac{C_1C_2}{C_1+C_2}$$

4- RC PHASE SHIFT OSCILLATOR :

⇨ Also known as phase shift oscillator & uses an RC network to obtain additional 180⁰ phase shift as required for fulfilling Barkhausen Criterion for sustained oscillations. This oscillator is different from Hartley or Colpitt's oscillator as it does not use transformer action with an LC network as shown in the diagram:



⇨ The collector is connected to base of transistor through phase shift network that consists of three identical sections of R & C with each section providing phase shift of 60^0.

⇨ The frequency of oscillations is given as :

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

⇨ **Advantages** of Phase shift Oscillator:

1- Less Bulky & Low Cost as it involves Combination of R & C instead of transformer.

2- Output obtained is pure & sinusoidal as core saturation effect is missing as no transformer is used.

⇨ **Disadvantages :**

1- Low feedback makes the circuit difficult to start oscillations. This is because of R & C which has high reactance in comparison to inductance.

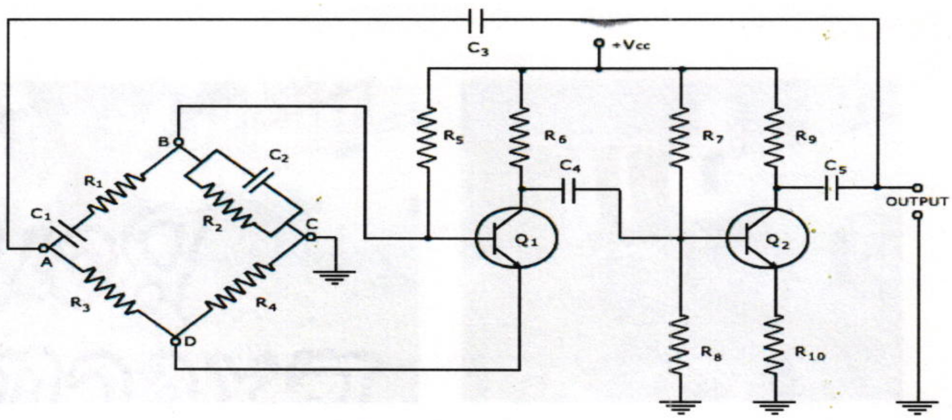
2- The Output is low as amount of feedback is low.

3- Requires high voltage battery for V in comparison to Hartley or Colpitt's Oscillator circuit.

5- WEIN BRIDGE OSCILLATOR

⇨ Standard oscillator circuit to be used over frequency range of 10Hz to 1MHz. Used extensively as audio oscillator as output of this oscillator circuit is free from circuit fluctuations & ambient temperature.

⇨In this type of oscillator circuit, phase shift is produced using two transistors as shown in the diagram. Each of the transistor produces a phase shift of 180^0 & thus a phase shift of 360^0 is achieved by two transistors.



⇨The circuit used is essentially a two stage amplifier with R-C bridge circuit. The bridge circuit has four arms each containing components - R_1 & C_1 in series, R_2 & C_2 in parallel, R_3 & R_4.

⇨ Transistor Q_1 with its biasing network serves as an oscillator and amplifier where as transistor Q_2 with its biasing network is used for phase reversal.

⇨ The frequency of oscillations is determined by series components R_1 C_1 & parallel component R_2 C_2 of the bridge network & is given by the following expression:

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

⇨**Advantages** of Wien bridge Oscillator:

1-Working is easy & simple.

2- Output is constant .

3- Excellent Stability

4- High Overall gain due to use of two transistors

5- Easy Adjustment of frequency as it needs variation of capacitors C_1 & C_2.

⇨**Disadvantages :**

1-Since no. of components involved is high, it is costlier.

2- Not suitable for generation of high frequency.

⇨Limitations of RC & LC Oscillators:

⇨Oscillators using either RC or LC network cannot be used for generating a highly stable frequency because in these oscillators frequency of oscillations depends on values of these components. Since value of such components is subject to change with variation in temperature, it may be difficult to get a perfectly constant output at certain temperature.

⇨ Therefore where perfectly constant frequency is required another type of oscillator is used which uses crystals.

6- CRYSTAL OSCILLATOR :

⇨ The limitations of RL or RC oscillators can be overcome by replacing these oscillators with crystal oscillator.

⇨ In a crystal oscillator RL or RC tank Circuit is substituted by a suitable crystal to provide a comparative constant frequency irrespective of change in temperature etc.

⇨ One of such crystal is piezoelectric crystal which functions on the principle of piezoelectric effect.

⇨ When an ac voltage is applied across a crystal, it starts vibrating at frequency of supply voltage, this effect is known as "**piezoelectric effect** " & the crystals that exhibits this effect are known as PIEZOELECTRIC CRYSTALS.

⇨Though Rochelle Salt, Quartz & Tourmaline are the piezoelectric materials which can be used as crystals , yet Quartz is the most suitable one due to its low cost, high mechanical strength & great piezoelectric effect.

⇨ The natural shape of Quartz crystal is hexagonal but it can be cut in different ways(like perpendicular to x axis or perpendicular to y axis) . The piezoelectric properties of a crystal mainly depends upon its cut.

$$f = K/t$$

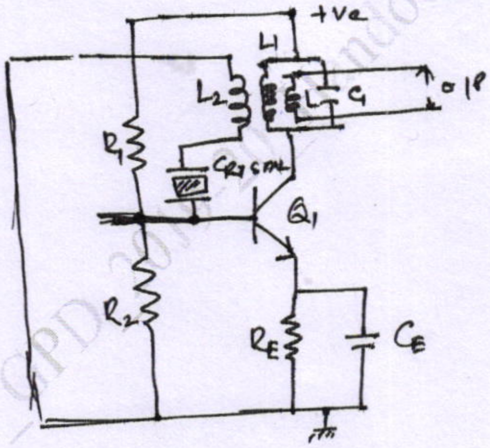
where K= is a constant that depends on dimension, cut & mounting of crystal & t is thickness of crystal

⇨Since value of K is almost constant for a particular crystal, therefore frequency of crystal mainly depends upon the thickness.

⇨TRANSISTOR CRYSTAL OSCILLATOR :

⇨Used when constant high frequency is required.

⇨Basic circuit arrangement for a crystal transistor oscillator is shown in the diagram .



⇨ A tank circuit L_1-C_1 is connected in the collector of transistor & the crystal is placed in the base circuit through a feedback coil L_2 where The coil L_2 is inductively coupled to coil L_1.

⇨ The natural frequency of L_1-C_1 circuit is made approximately equal to natural frequency of crystal.

⇨ Another coil L is inductively coupled to L_1 to obtain output.

⇨Advantages of Transistor Crystal Oscillator:

1- High order of frequency stability is obtained
2- Due to high Quality factor(Q) of crystal, energy loss is low.

⇨Disadvantages of Transistor Crystal Oscillator:

1- There is no option for variation in oscillation frequency.