Electronics
Lecture 7
(For Sixth Semester General Course)

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Maximum Power Transfer Theorem:

This theorem states that the power received by one network from another connected network is maximum when the impedance of the receiving network is conjugate to the impedance of the connected network looking at its two terminal. The process of bringing about this condition is called impedance matching.

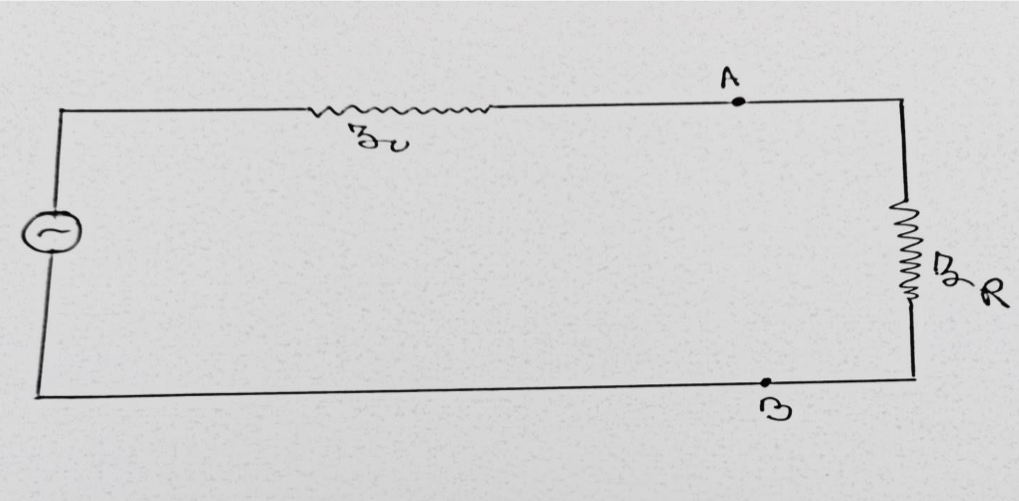

Fig 1

Let us consider a two terminal active linear network connected to a two terminal passive linear network. The former can be replaced by Thevenin's equivalent active network consisting of open circuit potential and total impedance when all the generators are replaced by their internal impedance, the latter network is replaced by equivalent impedance Z_R. Let the impedance Z_0 and Z_R are complex in nature.

$$Z_0 = R_0 + jX_0 \ , \ Z_R = R_R + jX_R$$

The current flowing in the network

$$I = \frac{E_0}{Z_0 + Z_R} = \frac{E_0}{R_0 + R_R + j(X_0 + X_R)}$$

The power delivered to passive network or the impedance Z_R is

$$P = \frac{E_0^2 R_R}{(R_0 + R_R)^2 + (X_0 + X_R)^2}$$

If the impedance of receiving network is $Z_R = R_R + jX_R$ is viewed then maximum power transfer calculated first by considering $X_R\ variable\ and\ R_R\ only$.

When X_R is varying the power will be maximum. When

$$\frac{\partial P}{\partial X_R} = \frac{-E_0^2[(R_R + R_0)^2 - 2R_R(R_R + R_0)]}{(R_R + R_0)^4} = 0$$

Since $R_R = R_0$

Therefore $P_{max} = \frac{E_0^2}{4R_0}$

Hence total impedance of passive network is

$$Z_R = R_R + jX_R = R_0 - jX_0$$

Which is conjugate to the to the impedance of active network looking at two terminals i.e. to the equivalent impedance

$$Z_0 = R_0 + jX_0$$

Therefore

$$Power\ generated\ from\ generator = \frac{E_0^2}{TotalResistance}$$

$$= \frac{E_0^2}{R_0 + jX_0 + R_0 - jX_0}$$

$$= \frac{E_0^2}{2R_0}$$

We see that maximum power transferred to the passive network when the impedance of this network is conjugate to the impedance of active network. The amount of this power is half to the total power generated. In other words we can say that the power lost in the internal generator is equal to the power delivered to the receiving network.

Superposition Theorem:

Statement: The current through or voltage across an element in a linear bilateral network is equal to the algebraic sum of currents or voltages produced independently by each source.

The superposition theorem is a way to determine the currents and voltages present in the circuit that has multiple sources (considering one source at a time). The superposition theorem states that in a linear network having a number of voltage or current sources and resistances, the current through any branch of the network is the algebraic sum of currents due to each of sources when acting independently. Superposition theorem is used only in case of linear network. This theorem is used in both AC or DC circuit.

It helps to construct Thevenin and Norton’s equivalent circuit. As shown in $Fig\ 1$ the circuit with two voltage sources is divided into two individual circuits according to the theorem’s statement.

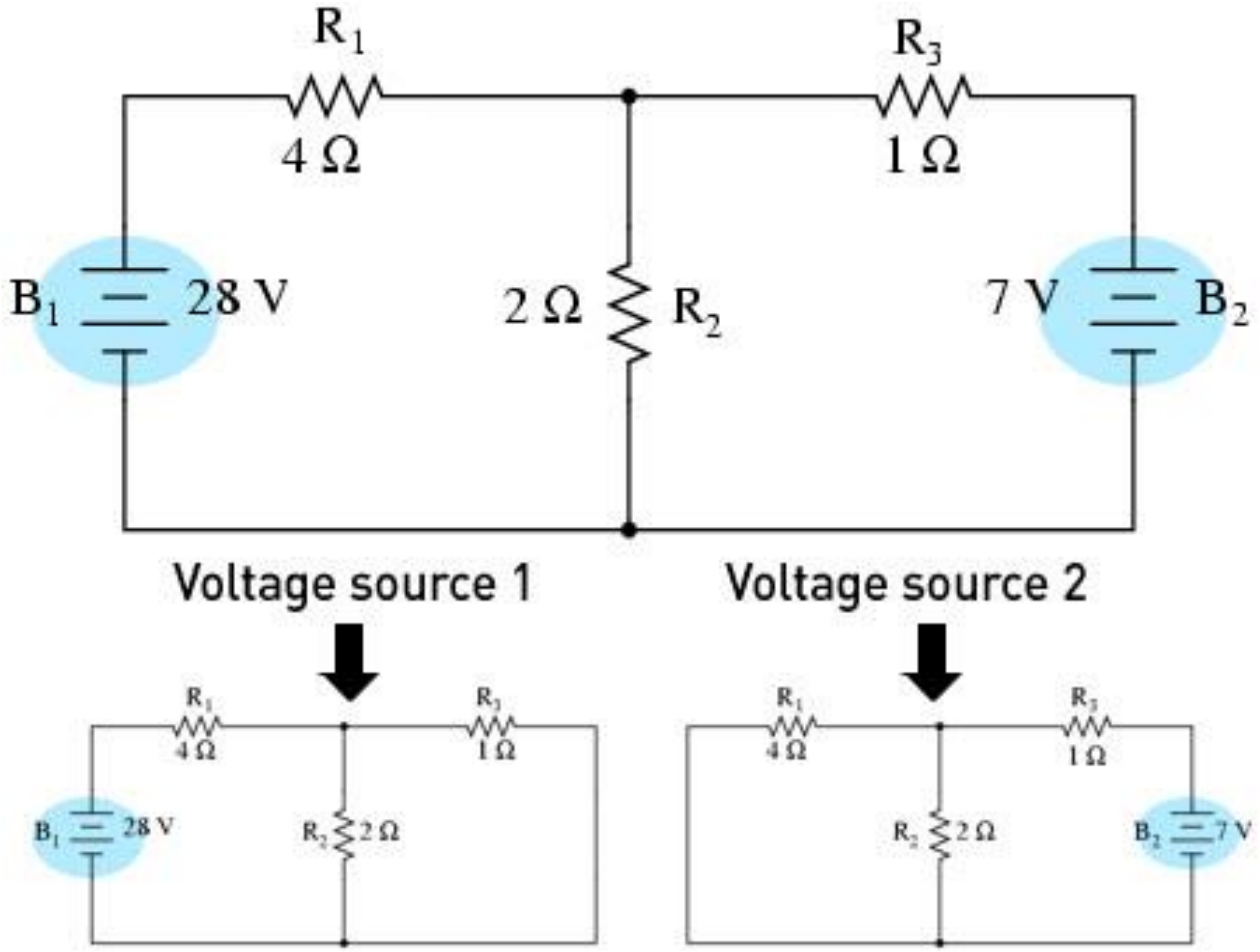

Fig 2

The individual circuits here make the whole circuit make look simpler in easier way and combining the two circuits again after individual simplification, one can easily find parameters like voltage drop at each resistance, node voltage, currents e.t.c.

When one applying this theorem, it is possible to consider the effects of two sources at the same time and reduce the number of networks that have to be analysed but in general.

$$Number\ of\ network\ to\ be\ analyze = Number\ of\ independent\ sources$$

To consider the effect of each source independently requires that sources to be removed and replaced without effecting the final result.

To remove a voltage source when applying this theorem, the difference in potential between the terminals of the voltage source must be set to zero (short circuit), removing a current source requires that its terminals to be open (open circuit).

Any internal resistance or conductance associated with the displaced sources is not eliminated but must be considered.

Definition of Oscillator:

Oscillator is an electronic circuit that produces a periodic oscillating signal, it may be sine wave, square wave, triangle wave. Oscillator convert direct current from a power supply to an alternating current.

The fundamental oscillatory circuit is LCR circuit. R_S is the series resistance and R_P is parallel resistance. If R_S becomes zero, then resonant frequency f_0 can be defined as

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

But in practice R_S is not zero and so the above equation is expressed in a modified form as

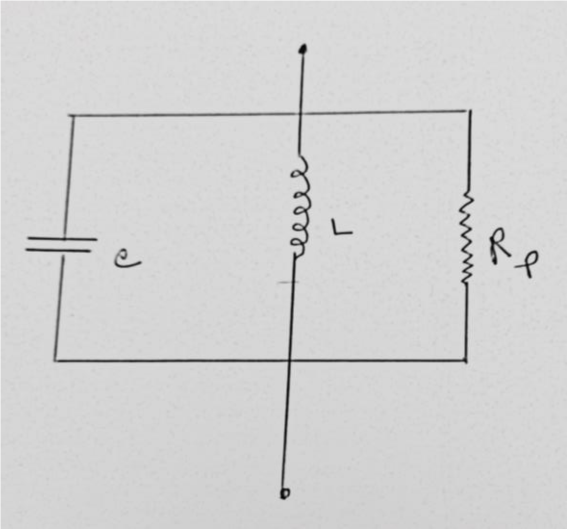

Fig 3

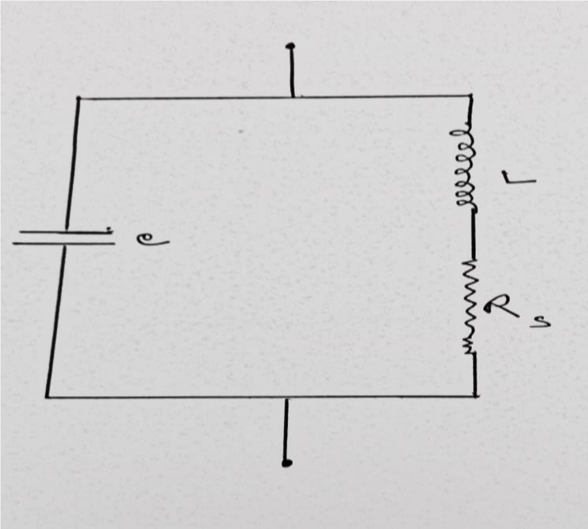

Fig 4

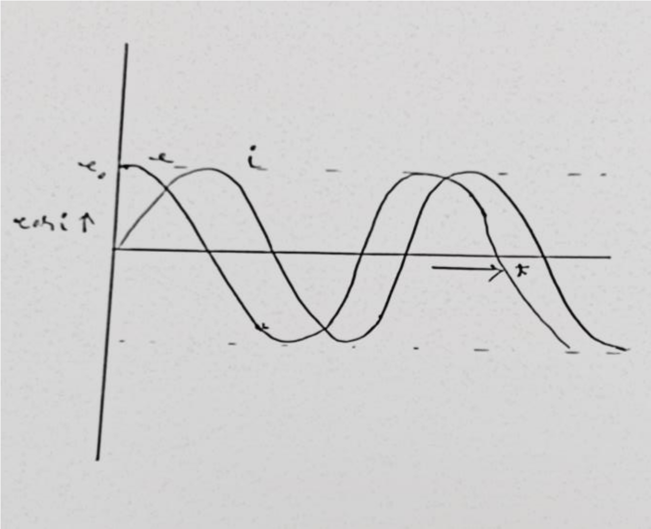

Fig 5

$$f_0 = \frac{1}{2\pi\sqrt{LC}}\left[\frac{1}{\sqrt{1+\left(\frac{\mathrm{R}C^2}{\omega_0^2 L^2}\right)}}\right]$$

The fact is that some resistance is present in circuit and some of the energy stored in the reactive elements is dissipated as heat. The quality factor (Q) is

$$Q = \frac{Energy\ stored\ in\ system}{Energy\ discipated\ per\ cycle}$$

$$Q = \frac{X_L}{R_S} = \frac{\omega_0 L}{R_S}$$

If some initial energy is given in an ideal LC circuit it will oscillate indefinitely at resonance frequency as shown in Fig 3. The oscillatory or undamped condition gives

$$\frac{L}{C} < 4R_P^2$$

The in circuit for undamped condition i.e.

$$i = i_0 e^{-\alpha t} cos\omega t$$

Where i_0 is initial current in L. The damping factor is

$$\alpha = \frac{1}{2R_P C}$$

The frequency is

$$\omega = \sqrt{\frac{1}{LC} - \frac{1}{4R_P^2C^2}}$$

When $\frac{L}{C} = 4R_P^2,$ we get the critical damping. The critically damped circuit does not oscillate but within a very short time it dissipate the circuit energy.

If $\frac{L}{C} > 4R_P^2$, the overdamped condition happens.

It is important that in an oscillator the underdamped condition is desirable. If additional energy is periodically supplied to the circuit the amplitude of oscillation remains constant.

The logarithmic decrement is an important factor in any oscillator circuit. If $i_1\ and\ i_2$ are the successive peaks of the underdamped waveform then logarithmic decrement (δ) is given by

$$\delta = ln\left(\frac{i_1}{i_2}\right)$$

In terms of Q

$$\delta = \frac{\pi}{Q_P}$$

Barkhausen Criterion for Oscillation:

Before obtaining a steady state an oscillator must build up oscillation. For oscillation to be self sustain the following condition must satisfied;

1.An Amplifying Device

2.Regenerative Feedback

3.Some Circuit Non linearity

4.Some Energy Storage System

Generally a four terminal of feedback oscillator is regenerative feedback amplifier. Positive feedback results when the feedback factor βA is positive and less than unity.

If βA is increased to unity the gain with feedback becomes infinite and the amplifier functions as an oscillator. The condition $\beta A = 1$ is known as Barkhausen Criterion and it is true at a single and precise frequency at which the feedback signal operating at the input is exactly in phase with input signal. Oscillation occur even is $\beta A > 1$ and amplitude of oscillation increased without limit. For practical purpose nonlinearity limits the theoretically infinite gain to some finite value for both $\beta A = 1 \; and \; \beta A > 1$.

Tuned Collector Oscillator:

The output of the tuned tank circuit is magnetically coupled to a secondary windings. The voltage developed acoss the output is fed back to the input base load through a series resistor R_S

The Barkhausen Criterion must be satisfied as a condition for sustained oscillation is $A\beta = 1$. This can be written in form of

$$\frac{1}{A} - \beta = 0$$

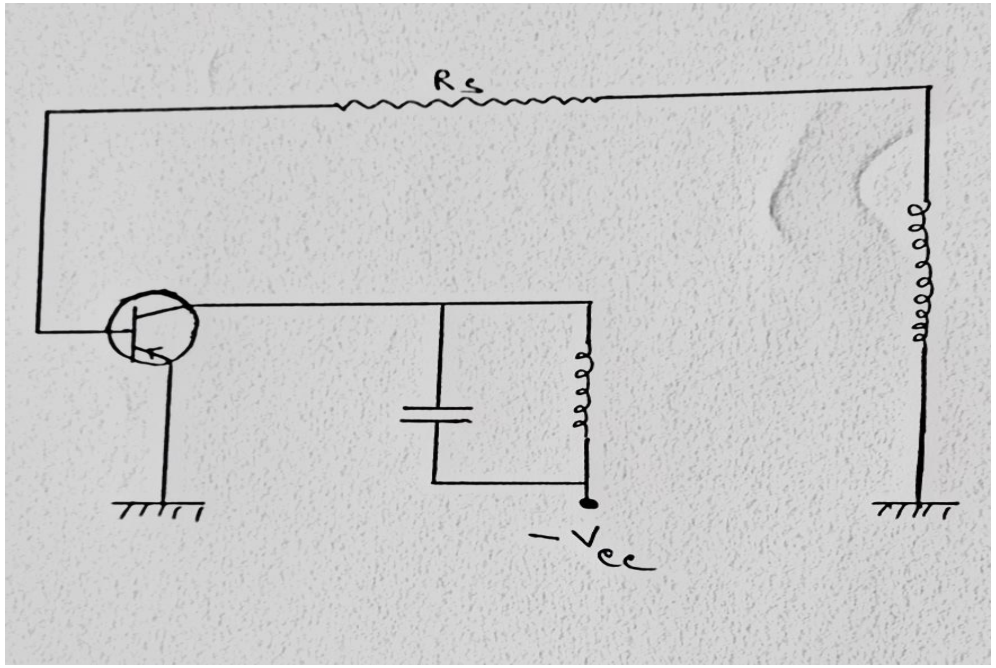

Fig 6

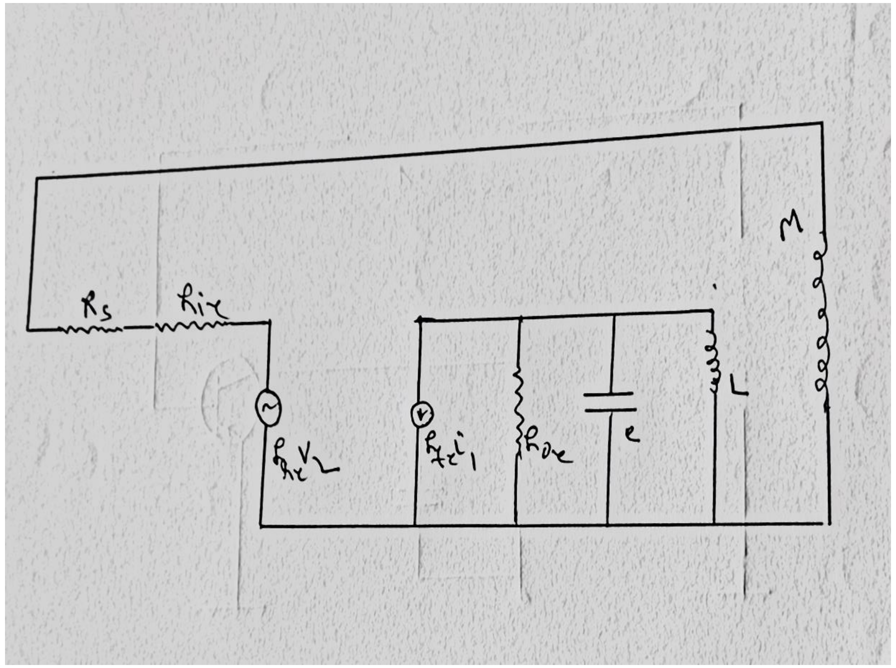

Fig 7

Now for CE transistor amplifier the equation for voltage gain with impedance load is given by

$$A_v = -\frac{h_{fe} Z_L}{h_{ie} + \Delta h_e Z_L}$$

Having satisfied the condition that R_P prevents loading the tank circuit, we can write to a good approximation.

$$\beta = \frac{-j\omega M i_1}{(R + J\omega L) i_1} = \frac{-j\omega M}{R + j\omega L}$$

Now from the above three equations we get

$$h_{ie}R\omega C + j(\omega^2 LC - 1)h_{ie} - j\Delta h_e R + \omega L\Delta h_e - \omega M h_{fe} = 0$$

Equating real and imaginary parts equal to zero we get

$$\omega^2 LC h_{ie} - h_{ie} - \Delta h_e R = 0$$

Now solving for ω we get

$$\omega = \frac{1}{\sqrt{LC}}\left[1 + \frac{\Delta h_e R}{h_{ie}}\right]^{1/2}$$

Thus we find that frequency of oscillation depends on tank circuit values and transistor parameter. Since Δh is small and also for a high $Q - value$, the coil resistance is small. So frequency of oscillation is close to the natural frequency of resonant circuit.

Again for real part

$$\omega\left(h_{ie}RC + L\Delta h_e - Mh_{fe}\right) = 0$$

Since $\omega \neq 0$, therefore

$$h_{ie}RC + L\Delta h_e - Mh_{fe} = 0$$

Therefore

$$M = \frac{h_{ie}RC}{h_{fe}} + \frac{L\Delta h_e}{h_{fe}}$$

This equation gives us a relation between the circuit and transistor values that should exist for oscillation to begin. Changes in transistor parameter and power supply voltage and in the passive circuit element cause in change from the required value. This change is called as drift.