Nalanda Open University
B.Sc. Part-III

Course-Physics
Paper-VIII

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Topic:- Filter Circuit, Classification & Elementary Filter theory**:** A filter circuit is a device to remove the A.C components of the rectified output, but allows the D.C. components to reach the load. A filter circuit is a general combination of inductor (L) and capacitor (C) called LC filter circuit. A capacitor allows A.C. only and inductor allows D.C only to pass.

Classification of Filter:-

(i) Low Pass Filter:- It transmits currents of all frequencies from zero to certain value, the cut off frequency and stops all those above this frequency.

(ii) High Pass Filter:- It transits freely currents of all frequencies from infinity down to cut off frequency and attenuates currents of all lower frequencies.

(iii) Band Pass Filter:- It transmits currents of all frequencies between two cut off frequencies and attenuates currents of all other frequencies.

Filter theory:-

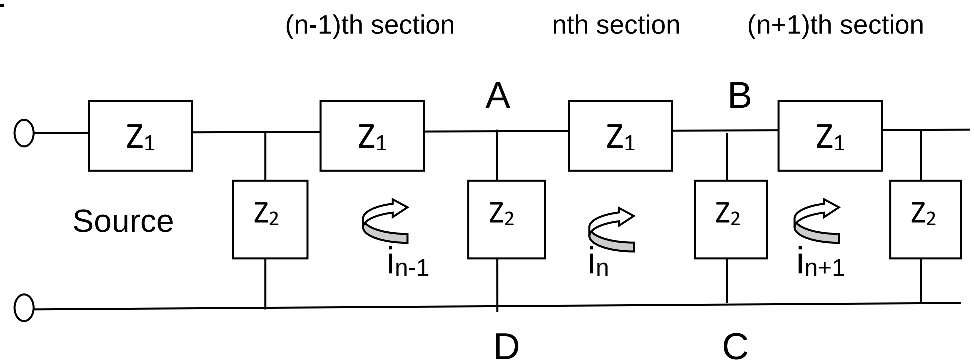

Figure. (1)

Let us assume a number of equal impedances Z_1 placed in series and separated by branches containing other equal impedances Z_2. If a generator is applied at any point in the chain, currents will flow in various sections. In order to investigate the frequency characteristic of a network, let us consider the n^{th} section ABCD of Fig. (1).

Let i_{n-1}, i_n and i_{n+1} be the current in successive section due to an e.m.f.

$V_o e^{iwt}$ to the input end of the filter.

Applying Kirchoff's Law to the mesh ABCD, we get

$$Z_1 i_n + Z_2 (i_n - i_{n-i}) + Z_2 (i_n - i_{n+1}) = 0$$

Or, $$-Z_2 i_{n-1} + (Z_1 + 2 Z_2) i_n - Z_2 i_{n+1} = 0$$

Or, $$Z_2 i_{n-1} - (Z_1 + 2 Z_2) i_n + Z_2 i_{n+1} = 0 \qquad \text{..........................(1)}$$

To solve this equation let us assume

$$i_n = A e^{n\Upsilon} + B e^{-n\Upsilon} \qquad \text{.......................... (2)}$$

where, ϒ is the propagation constant per section and A and B are constant.

Similarly, we may write

$$i_{n-i} = A e^{(n-1)\Upsilon} + B e^{-(n-1)\Upsilon} \qquad \text{......................... (3)}$$

and

$$i_{n+i} = A e^{(n+1)\Upsilon} + B e^{-(n+1)\Upsilon} \qquad \text{.......................... (4)}$$

Using equation (2), (3) and (4) in equation (1), we get

$$Z_2[Ae^{(n-1)\Upsilon} + Be^{-(n-1)\Upsilon}] - (Z_1 + 2Z_2) [Ae^{n\Upsilon} + Be^{-n\Upsilon}] + Z_2 [Ae^{(n+1)\Upsilon} + Be^{-(n+1)\Upsilon}] = 0$$

or, $$Z_2e^{-\Upsilon}[Ae^{n\Upsilon} + Be^{-n\Upsilon}] + Z_2e^{\Upsilon}[Ae^{n\Upsilon} + Be^{-n\Upsilon}] - (Z_1 + 2Z_2) [Ae^{n\Upsilon} + Be^{-n\Upsilon}] = 0$$

or, $(Ae^{n\Upsilon} + Be^{-n\Upsilon}) [Z_2e^{-\Upsilon} + Z_2e^{\Upsilon} – (Z_1 + 2Z_2)] = 0$

From which it follows that :-

$$Z_2(e^{\Upsilon} + e^{-\Upsilon}) = Z_1 + 2Z_2$$

or, $$e^{\Upsilon} + e^{-\Upsilon} = \frac{Z_1 + 2Z_2}{Z_2}$$

or, $$\frac{e^{\Upsilon} + e^{-\Upsilon}}{2} = 1 + ½ (Z_1/Z_2)$$

or, $$\cosh \Upsilon = 1 + ½ (Z_1/Z_2) \qquad ....(5)$$

We can write, $\Upsilon = \dot{\alpha} + j ß$

Where $\dot{\alpha}$ = attenuation constant per section that determines the change in amplitude of the current, and ß = those constant per section that determines the change of phase of the current passing through the filter.

From equation (2),

$$i_n = A e^{n\Upsilon} + B e^{-n\Upsilon}$$

$$i_n = A e^{n(\dot{\alpha} + jß)} + Be^{-n(\dot{\alpha}+jß)}$$

$$i_n = Ae^{n\dot{\alpha}} e^{jnß} + Be^{-n\dot{\alpha}} e^{-jnß} \qquad ....(6)$$

The above equation represents the current wave form. The first part of equation (6) represents the reflected or incoming current wave and second part gives the incident or outgoing current wave.

Constant K-Filter Circuits: The filter network for which the series and shunt impedances are (inverse reactance) such that

$$Z_1Z_2 = \text{Constant} = K^2$$

The independence of frequency is known as Constant K-filter. K is called the design independence of the network.

For low pass filter: $Z_1 = jwL$ and $Z_2 = 1/jwc$

Therefore, $Z_1Z_2 = L/C = K^2$

For high pass filter: $Z_1 = 1/jwC$ and $Z_2 = 1/jLw$

Therefore, $Z_1Z_2 = L/C = K^2$

For band pass filter: $Z_1 = \frac{j\,(w^2L_1C_1-1)}{wC_1}$

$$Z_2 = w\,L_2 / j(w^2L_2C_2 - 1)$$

Therefore, $Z_1Z_2 = \frac{L_2}{C_1} = K^2$

if, $L_1C_1 = L_2C_2$