General Cable

Characteristic Impedance

Characteristic impedance corresponds to the input impedance of a uniform transmission line of infinite length, i.e.,

$$Z_{in} = V_i / I_I$$

It also corresponds to the input impedance of a transmission line of finite length that is terminated in its own characteristic impedance.

In general, the characteristic impedance is a complex number with a resistive and reactive component. It is a function of the frequency of the applied signal, and is unrelated to length. At very high frequencies, the characteristic impedance asymptotes to a fixed value which is resistive. For example, coaxial cables have an impedance of 50 or 75 Ohms at high frequencies. Typically, twisted-pair telephone cables have an impedance of 100 Ohms above 1 MHz.

Characteristic impedance is of prime importance for good transmission. Maximum power transfer occurs when the source has the same impedance as the load. Thus for sending signals over a line, the transmitting equipment must have the same characteristic impedance as the line to get the maximum signal into the line. At the other end of the line, the receiving equipment must also have the same impedance as the line to be able to get the maximum signal out of the line.

Where impedances do not match, some of the signal is reflected back towards the source. In many cases this reflected signal causes problems and is therefore undesirable.

The formulae for characteristic impedance are:

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$Z_0 = \sqrt{Z_{oc} \cdot Z_{sc}}$$

Characteristic impedance changes considerably with frequency, particularly from DC to about 100 kHz. Simplified formula may be derived from the one above. At DC (0kHz)

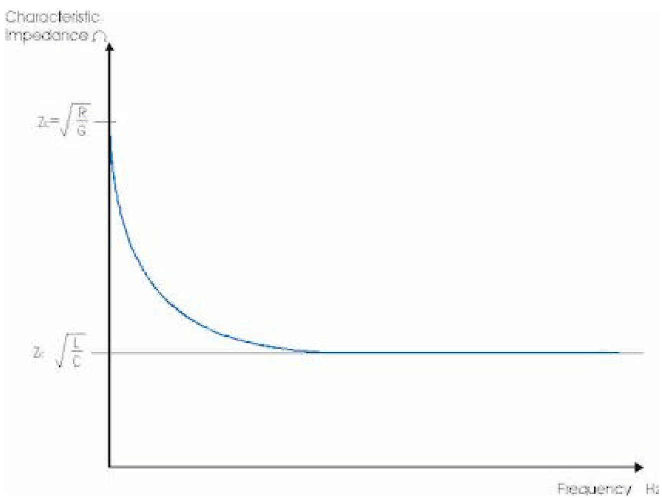
$$Z_0 = \sqrt{\frac{R}{G}}$$

At voice frequencies (eg 1kHz)

$$Z_0 = \sqrt{\frac{R}{\omega C}} \angle -45^\circ$$

At high frequencies (> 100 kHz)

$$Z_0 = \sqrt{\frac{L}{C}}$$



For twisted pair and coaxial cables, the resistance is determined by the diameter or weight of copper, the inductance is very small, and the shunt conductance is small. The major influence on characteristic impedance and other secondary coefficients is the capacitance. This is largely determined by the type of insulation (dielectric) used. Characteristic impedance, for high frequencies, can be stated in terms of the physical dimensions of the cable. These formulae apply to copper conductor cables:

For twisted pair:

$$Z_0 = \left(\frac{276}{\sqrt{\varepsilon_r}}\right)\log\frac{D}{r} = 276\log\frac{D}{r} \quad \textit{for open wire line}$$

Where D *is the spacing between the centres of the two conductors*

r *is the radius of each conductor*

ε_r *is the relative Permittivity of the dielectric*

For coaxial cable:

$$Z_0 = \left(\frac{138}{\sqrt{\varepsilon_r}}\right)\log\frac{R}{r} = 138\log\frac{R}{r} \quad \textit{in air}$$

Where R *is the inner radius of the outer conductor*

r *is the radius of the inner conductor*

ε_r *is the relative Permittivity of the dielectric*

These formulae show that the characteristic impedance of any cable is directly determined by the conductor sizes, the spacing between them and the type of insulation used. Any change in these will affect the characteristic impedance.

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Diagrams of cables are illustrative only and are not necessarily to scale.