

What is Impedance?

Electrical impedance is a measure of the opposition to the flow of current within a circuit or electrical component. It is made up of two parts, **Resistance** and **Reactance**.

- **Resistance** is the opposition to the flow of current caused by the physical properties of the electrical components. The value is proportional to the voltage and current.
- **Reactance** is the opposition of an electrical component or circuit to a change in current or voltage caused by the capacitance or inductance of a circuit. The value is proportional to the frequency of the excitation voltage.

Impedance is a *complex* mathematical number, meaning it has both *real* and *imaginary* components — this is important when calculating impedance values.

$$Z = R + jX$$

$$Z = \text{Impedance}$$

$$R = \text{Resistance (Real component)}$$

$$X = \text{Reactance (Imaginary component, designated by } j)$$

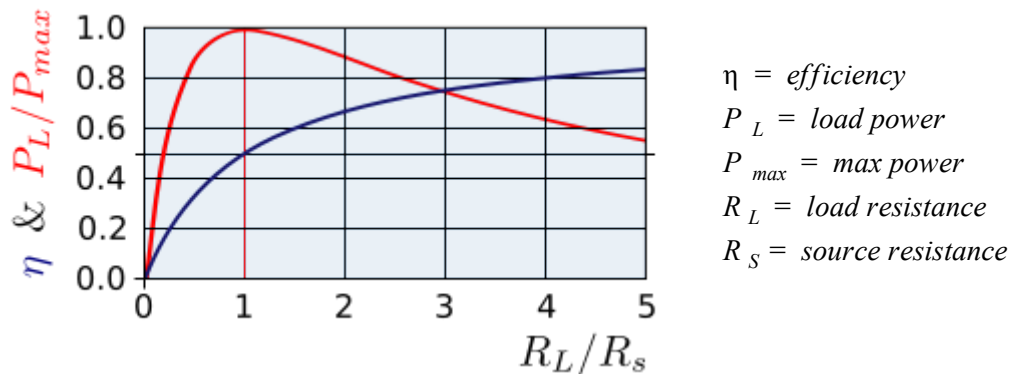
DC circuits are a special case where frequency is 0 and thus reactance is 0, making $Z = R$; impedance equal to resistance. In any AC circuit, impedance will be a factor.

AC circuits include all electrical devices that are plugged into a wall socket at home or in a factory, as well as radio transmission systems, sonic delivery systems (including hi-fi and ultrasonic detection equipment) and the transmission of electrical power over long distances — most of the circuits that you come into contact with on a day to day basis.

This paper will go straight to how impedance affects your circuit, however, to know more about how these values are calculated, skip to the **Calculations and Proofs** section for a full explanation.

Maximum Power Transfer Theorem: How Impedance Affects Power Transfer in a Circuit

The ratio of impedance in the source and the load affect how much power can be transferred from the source to the load. For maximum power transfer (assuming a fixed source impedance), the source impedance and load impedance must be equal in magnitude.



If the impedance of the source is lower than the impedance of the load, the magnitude of power transfer is reduced, but the efficiency of the transfer is increased. If the source impedance is higher than the load impedance, the total power transfer is increased with most of the power being dissipated in the source.

For DC circuits, maximum power transfer is quite simple — the source resistance and load resistance need to be equal for maximum power transfer.

$$R_{source} = R_{load}$$

For maximum power transfer in AC circuits, the source impedance and load impedance must be complex conjugates — this means that the source resistance and load resistance must be the same, while the source reactance and load reactance must be equal in magnitude but opposite in phase.

$$Z_{source} = R + jX$$
$$Z_{load} = R - jX$$

The power curve above shows that a maximum power transfer system has efficiency losses of 50%! For most applications, maximum power transfer is chosen over maximum efficiency. The power that is not transferred is dissipated as heat. The audio world has some great examples of this; guitar amplifiers, or any amplifier that has tubes (valves) get very hot due to the high output impedance.

