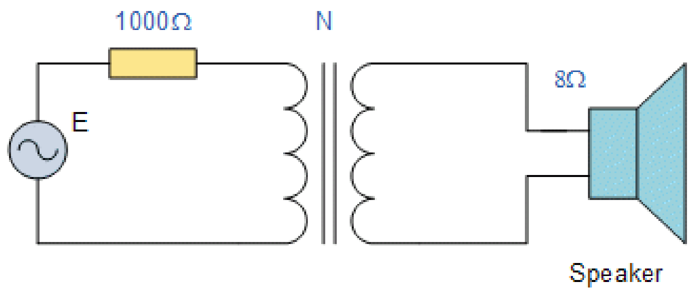


Maximum Power Transfer

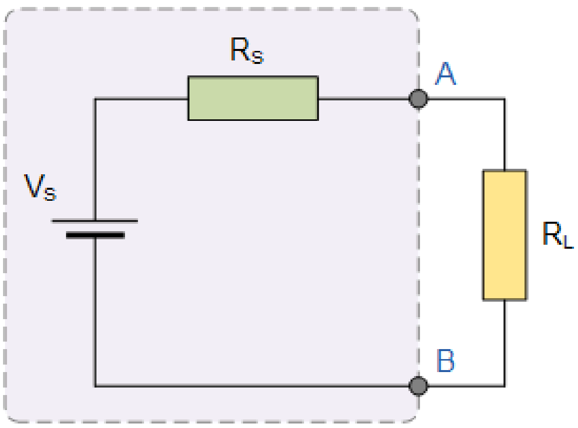
Maximum Power Transfer occurs when the resistive value of the load is equal in value to that of the voltage sources internal resistance allowing maximum power to be supplied

Generally, this source resistance or even impedance if inductors or capacitors are involved is of a fixed value in Ohm´s.

However, when we connect a load resistance, R_L across the output terminals of the power source, the impedance of the load will vary from an open-circuit state to a short-circuit state resulting in the power being absorbed by the load becoming dependent on the impedance of the actual power source. Then for the load resistance to absorb the maximum power possible it has to be “Matched” to the impedance of the power source and this forms the basis of **Maximum Power Transfer**.

The **Maximum Power Transfer Theorem** is another useful circuit analysis method to ensure that the maximum amount of power will be dissipated in the load resistance when the value of the load resistance is exactly equal to the resistance of the power source. The relationship between the load impedance and the internal impedance of the energy source will give the power in the load. Consider the circuit below.

Thevenins Equivalent Circuit

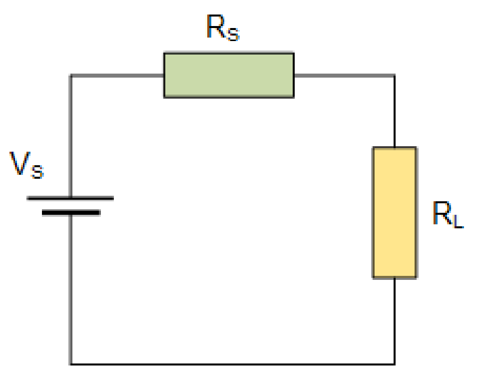


In our Thevenin equivalent circuit above, the maximum power transfer theorem states that "*the maximum amount of power will be dissipated in the load resistance if it is equal in value to the Thevenin or Norton source resistance of the network supplying the power*".

In other words, the load resistance resulting in greatest power dissipation must be equal in value to the equivalent Thevenin source resistance, then $R_L = R_S$ but if the load resistance is lower or higher in value than the Thevenin source resistance of the network, its dissipated power will be less than maximum.

For example, find the value of the load resistance, R_L that will give the maximum power transfer in the following circuit.

Maximum Power Transfer Example No1



Where:
$R_S = 25\Omega$
R_L is variable between 0 – 100Ω
V_S = 100v

Then by using the following Ohm's Law equations:

$$I = \frac{V_S}{R_S + R_L} \quad \text{and} \quad P = I^2 R_L$$

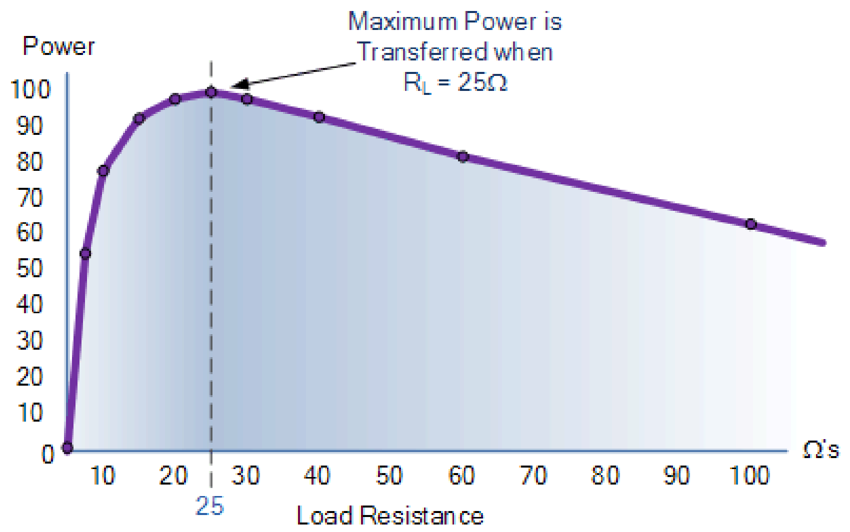
We can now complete the following table to determine the current and power in the circuit for different values of load resistance.

Table of Current against Power

R_L (Ω)	I (amps)	P (watts)	R_L (Ω)	I (amps)	P (watts)
0	4.0	0	25	2.0	**100**
5	3.3	55	30	1.8	97
10	2.8	78	40	1.5	94
15	2.5	93	60	1.2	83
20	2.2	97	100	0.8	64

Using the data from the table above, we can plot a graph of load resistance, R_L against power, $P$for different values of load resistance. Also notice that power is zero for an open-circuit (zero current condition) and also for a short-circuit (zero voltage condition).

Graph of Power against Load Resistance



From the above table and graph we can see that the **Maximum Power Transfer** occurs in the load when the load resistance, R_L is equal in value to the source resistance, R_S that is: $R_S = R_L = 25\Omega$. This is called a "matched condition" and as a general rule, maximum power is transferred from an active device such as a power supply or battery to an external device when the impedance of the external device exactly matches the impedance of the source.

One good example of impedance matching is between an audio amplifier and a loudspeaker. The output impedance, Z_{OUT} of the amplifier may be given as between 4Ω and 8Ω, while the nominal input impedance, Z_{IN} of the loudspeaker may be given as 8Ω only.

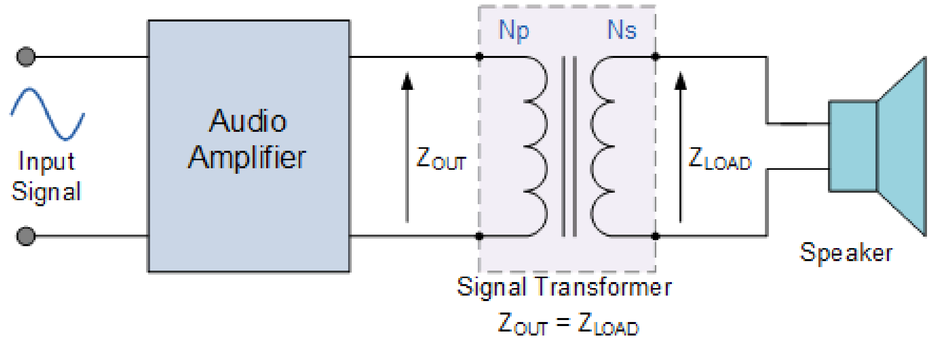
Then if the 8Ω speaker is attached to the amplifiers output, the amplifier will see the speaker as an 8Ω load. Connecting two 8Ω speakers in parallel is equivalent to the amplifier driving one 4Ωspeaker and both configurations are within the output specifications of the amplifier.

Improper impedance matching can lead to excessive power loss and heat dissipation. But how could you impedance match an amplifier and loudspeaker which have very different impedances. Well, there are loudspeaker impedance matching transformers available that can change impedances from 4Ω to 8Ω, or to 16Ω's to allow impedance matching of many loudspeakers connected together in various combinations such as in PA (public address) systems.

Transformer Impedance Matching

One very useful application of impedance matching in order to provide maximum power transfer between the source and the load is in the output stages of amplifier circuits. Signal transformers are used to match the loudspeakers higher or lower impedance value to the amplifiers output impedance to obtain maximum sound power output. These audio signal transformers are called "matching transformers" and couple the load to the amplifiers output as shown below.

Transformer Impedance Matching



The maximum power transfer can be obtained even if the output impedance is not the same as the load impedance. This can be done using a suitable "turns ratio" on the transformer with the corresponding ratio of load impedance, Z_{LOAD} to output impedance, Z_{OUT} matches that of the ratio of the transformers primary turns to secondary turns as a resistance on one side of the transformer becomes a different value on the other.

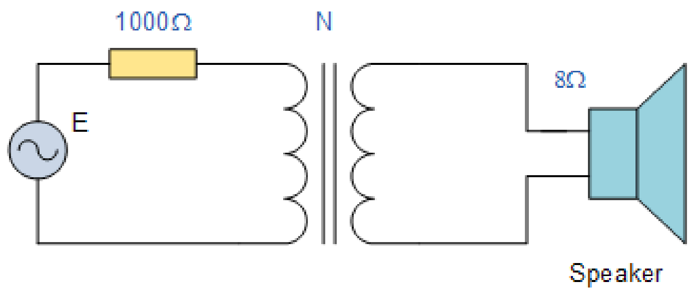
If the load impedance, Z_{LOAD} is purely resistive and the source impedance is purely resistive, Z_{OUT} then the equation for finding the maximum power transfer is given as:

$$Z_{out} = \left(\frac{N_P}{N_S}\right)^2 Z_{load}$$

Where: N_P is the number of primary turns and N_S the number of secondary turns on the transformer. Then by varying the value of the transformers turns ratio the output impedance can be "matched" to the source impedance to achieve maximum power transfer. For example,

Maximum Power Transfer Example No2

If an 8Ω loudspeaker is to be connected to an amplifier with an output impedance of 1000Ω, calculate the turns ratio of the matching transformer required to provide maximum power transfer of the audio signal. Assume the amplifier source impedance is Z_1, the load impedance is Z_2 with the turns ratio given as N.



$$Z_1 = N^2 Z_2 \quad \therefore \quad N = \sqrt{\frac{Z_1}{Z_2}}$$

therefore,

$$N = \sqrt{\frac{Z_1}{Z_2}} = \sqrt{\frac{1000}{8}} = 11.2:1$$

Generally, small high frequency audio transformers used in low power amplifier circuits are nearly always regarded as ideal for simplicity, so any losses can be ignored.

In the next tutorial about DC circuit theory, we will look at Star Delta Transformation which allows us to convert balanced star connected circuits into equivalent delta and vice versa.