Audio Transformer

Audio Transformers are designed for use in the amplifier and high frequency audio and voice circuits for coupling and impedance matching applications.

As well as stepping up (increase) or stepping down (decrease) a signal voltage, transformers also have one very other useful property, **isolation**. Since there is no direct electrical connection between their primary and secondary windings, transformers provide complete electrical isolation between their input and output circuits and this isolation property can also be used between amplifiers and speakers.

We have seen in this section about transformers, that a transformer is an electrical device which allows an sinusoidal input signal (such as an audio signal or voltage) to produce an output signal or voltage without the input side and output side being physically connected to each other. This coupling is achieved by having two (or more) wire coils (called windings) of insulated copper wire wound around a soft magnetic iron core.

When an AC signal is applied to the primary input winding, a corresponding AC signal appears on the output secondary winding due to the inductive coupling of the soft iron core. The turns ratio between the input and output wire coils provides either an increase or a decrease of the applied signal as it passes through the transformer.

Then audio transformers can be considered as either a step-up or step-down type, but rather than being wound to produce a specific voltage output, audio transformers are mainly designed for impedance matching. Also, a transformer with a turns ratio of 1:1, does not change the voltage or current levels but instead isolates the primary circuit from the secondary side. This type of transformer is known commonly as an Isolation Transformer.

Transformers are not intelligent devices, but can be used as bidirectional devices so that the normal primary input winding can become an output winding and the normal secondary output winding can become an input and due to this bidirectional nature, transformers can provide a signal gain when used in one direction or a signal loss when used in reverse to help match signal or voltage levels between different devices.

Note also that a single transformer can have multiple primary or secondary windings and these windings may also have multiple electrical connections or “taps” along their length. The advantage of multi-tap audio transformers is that they offer different electrical impedances as well as different gain or loss ratios making them useful for impedance matching of amplifiers and speaker loads.

As their name suggests, **audio transformers** are designed to operate within the audio band of frequencies and as such can have applications in the input stage (microphones), output stage (loudspeakers), inter-stage coupling as well as impedance matching of amplifiers. In all cases, the frequency response, primary and secondary impedances and power capabilities all need to be considered.

Audio and impedance matching transformers are similar in design to low frequency voltage and power transformer, but they operate over a much wider frequency range of frequencies. For example, 20Hz to 20kHz voice range. Audio transformers can also conduct DC in one or more of their windings for use in digital audio applications as well as transforming voltage and current levels at high frequency.

Audio Transformer Impedance Matching

One of the main applications for *audio frequency transformers* is in impedance matching. Audio transformers are ideal for balancing amplifiers and loads together that have different input/output impedances in order to achieve maximum power transfer.

For example, a typical loudspeaker impedance ranges from 4 to 16 ohms whereas the impedance of a transistor amplifiers output stage can be several hundred ohms. A classic example of this is the LT700 Audio Transformer which can be used in the output stage of an amplifier to drive a loudspeaker.

We know that for a transformer, the ratio between the number of coil turns on the primary winding (N_P) to the number of coil turns on the secondary winding (N_S) is called the “turns ratio”. Since the same amount of voltage is induced within each single coil turn of both windings, the primary to secondary voltage ratio (V_P/V_S) will therefore be the same value as the turns ratio.

Impedance matching audio transformers always give their impedance ratio value from one winding to another by the square of the their turns ratio. That is, their impedance ratio is equal to its turns ratio squared and also its primary to secondary voltage ratio squared as shown.

Audio Transformer Impedance Ratio

$$\frac{Z_P}{Z_S} = \left(\frac{N_P}{N_S}\right)^2 = \left(\frac{V_P}{V_S}\right)^2$$

Where Z_P is the primary winding impedance, Z_S is the secondary winding impedance, (N_P/N_S) is the transformers turns ratio, and (V_P/V_S) is the transformers voltage ratio.

So for instance, an impedance matching audio transformer that has a turns ratio (or voltage ratio) of say 2:1, will have an impedance ratio of 4:1.

Audio Transformer Example No1

An audio transformer with a turns ratio of 15:1 is to be used to match the output of a power amplifier to a loudspeaker. If the output impedance of the amplifier is 120Ω's, calculate the nominal impedance of the loudspeaker required for maximum power transfer.

$$\frac{Z_P}{Z_S} = \left(\frac{N_P}{N_S}\right)^2 = 15:1$$

$$\frac{120\Omega}{Z_S} = \frac{15}{1} = \left(\frac{3.873}{1}\right)^2$$

$$\therefore\ Z_S = \frac{120 \times 1}{3.873^2} = 8\Omega$$

Then the power amplifier can efficiently drive an 8-ohm speaker.

Audio 100V Line Transformer

Another very common impedance matching application is for 100 volt line transformers for the transmission of music and voice over public address tannoy systems. These types of ceiling based speaker systems use multiple loudspeakers located some distance from the power amplifier.

By using line isolating transformers, any number of low-impedance loudspeakers can be connected together in such a way that they properly load the amplifier providing impedance matching between the amplifier (source) and speakers (load) for maximum power transfer.

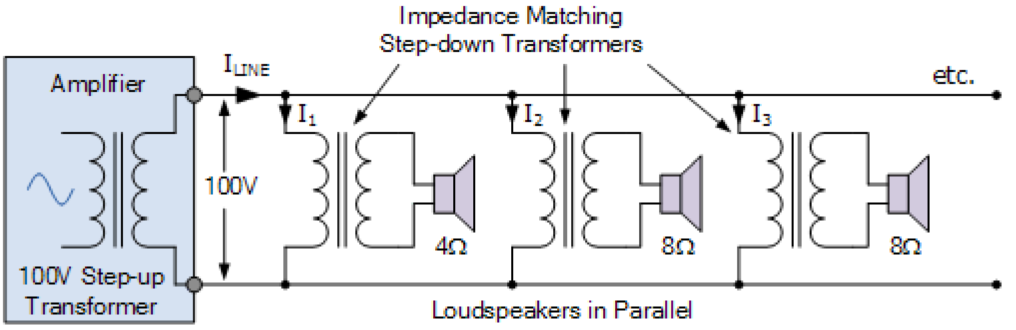
As power loss of signals through speaker cables is proportional to the square of current ($P = I^2R$) for a given cable resistance, the output voltage of an amplifier used for public address (PA) or tannoy systems uses a standard and constant voltage output level of 100 volts peak, (70.7 volts rms).

So for example, a 200 watt amplifier driving an 8-ohm speaker delivers a current of 5 amps, whereas a 200 watt amplifier using a 100 volt line at full power delivers only 2 amps allowing smaller gauge cables to be used. Note however that this 100 volts only exists on the line when the power amplifier driving the line is operating at full rated power otherwise there is reduced power (sound volume) and line voltage.

So for a 100V (70.7V rms) line speaker system, the line transformer steps up the audio output signal voltage to 100 volts so that the transmission line current for a given power output is comparatively low, reducing signal losses allowing smaller diameter or gauge cables to be used.

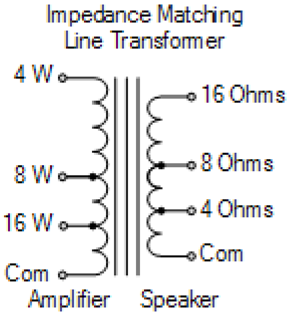
Since the impedance of a typical loudspeaker is generally low, an impedance matching step-down transformer (usually called a line to voice-coil transformer) is used for each loudspeaker connected to the 100V line as shown.

100V Transmission Line Transformers



Here the amplifier uses a step-up transformer to provide a constant 100 volts transmission line voltage at reduced current, for a given power output. The loudspeakers are connected together in parallel with each speaker having its own impedance matching step down transformer to reduce the secondary voltage and increase the current, thereby matching the 100V line to the low impedances of the loudspeakers.

The advantage of using this type of audio transmission line is that many individual speakers, tannoy’s or other such sound actuators can be connected to a single line even if they have different impedances and power handling capabilities. For example, 4 ohms at 5 watts, or 8 ohms at 20 watts.



Generally transmission line matching transformers have multiple connections called tapping points on the primary winding allowing for suitable power levels (and therefore sound volume) to be selected for each individual loudspeaker. Also, the secondary winding has similar tapping points offering different impedances to match that of the connected loudspeakers.

In this simple example, the 100V line-to-speaker transformer can drive 4, 8, or 16 Ohm speaker loads on its secondary side with amplifier power ratings of 4, 8 and 16 watts on its primary side depending on the tapping points selected. In reality, PA system line transformers can be selected for any combination of series and parallel connected speaker loads with power handling capabilities up to several kilo-watts.

But as well as constant voltage impedance matching line transformers, audio transformers can be used to connect low impedance or low signal input devices such as microphones, turntable moving coil pick-ups, line inputs, etc to an amplifier or pre-amplifier. As input audio transformers must operate over a wide range of frequencies, they are usually designed so that the internal capacitance of their windings resonates with its inductance to improve its operating frequency range allowing for a smaller transformer core size.

We have seen in this tutorial about **audio transformers**, that audio transformers are used to match impedances between different audio devices, for example, between an amplifier and speaker as a line driver, or between a microphone and amplifier for impedance matching. Unlike power transformers which operate at low frequencies such as 50 or 60Hz, audio transformers are designed to operate over the audio frequency range, that is from about 20Hz to 20kHz or much higher for radio-frequency transformers.

Due to this wide frequency band, the core of audio transformers are made from special grades of steel, such as silicon steel or from special alloys of iron which have a very low hysteresis loss. One of the main disadvantages of audio transformers is that they can be somewhat bulky and expensive, but by using special core materials allows for a smaller design because generally a transformers core size increases as the supply frequency decreases.