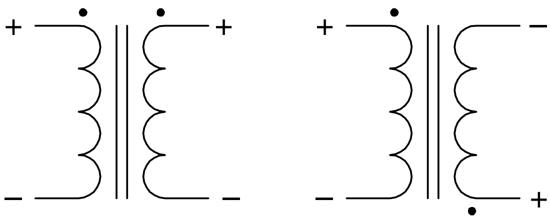

FIGURE 12.28 Transformer coil polarity graphical representation.

formers are sometimes used to attenuate *common mode noise*. A common-mode signal is one wherein current flows in the same direction on both halves of a circuit. This is in contrast to a differential-mode signal wherein current flows in opposite directions. As shown in Fig. 12.29, common-mode current can flow when a return path exists, usually ground.

To attenuate common-mode noise, the transformer is inserted into the circuit as shown in Fig. 12.30 such that each circuit half passes through the coils oriented in the same direction. Each coil's magnetic field has the same magnitude and phase as the other, because each coil has the same common-mode current passing through it. The magnetic fields do not cancel each other out, causing a voltage drop across each coil that attenuates the noise. In other words, the coils present high impedance to the common-mode portion of the signal passing through them. The differential signal, typically a desired signal carrying meaningful data, passes through the common-mode filter, because its currents are flowing in opposite directions. The magnetic fields in the coils cancel each other out, because they are of equal magnitude but opposite phase. Without a magnetic field built up, the coils do not develop a voltage drop and thereby present low impedance to the desired signal.

Impedance matching between a driver and a load is another common use of a transformer. It can be shown mathematically that maximum power is delivered to a load when the source's internal im-

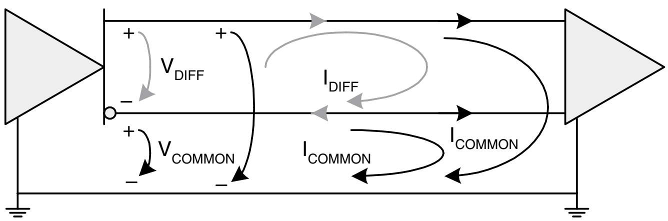

FIGURE 12.29 Common-mode current flow.

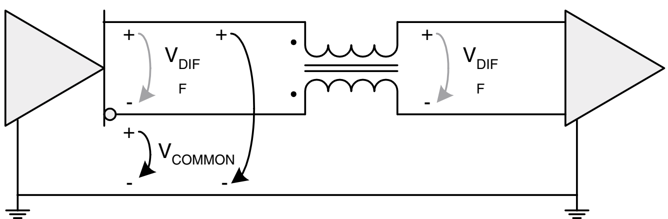

FIGURE 12.30 Common-mode filter transformer.

pedance equals that of the load. Under these conditions, only half of the total power is delivered to the load, the remaining half being dissipated by the source impedance. For unequal load and source impedances, more or less voltage and current will be delivered to the load, but always in proportions that result in less than 50 percent of the total power. It may be desirable to deliver maximum power to a load in situations where the impedance of a driver (e.g., audio amplifier) does not match that of its load (e.g., speaker). A transformer can be used to isolate the source and load from each other and present each with the necessary impedance for maximum power transfer.

If a load resistor is connected to a transformer's secondary coil as shown in Fig. 12.31, Ohm's law can be used to relate V_P and I_P by R_{LOAD}. To simplify the analysis, the secondary coil is said to have one winding and the primary N windings, for a simple N:1 ratio. Therefore,

$$\frac{V_P}{V_S} = \frac{N}{1} \text{ and } \frac{I_P}{I_S} = -\frac{1}{N}$$

More primary windings increase the voltage ratio between the primary and secondary but decrease the current because a transformer cannot amplify a signal and, hence, $V_P I_P = -V_S I_S$. The current in the secondary winding flows in the direction opposite of that in the primary, because the primary is feeding current into the transformer and the load is pulling current out.

It is known that the relationship between the voltages on either side of the transformer is given by $V_P = NV_S$ and that, maintaining proper current polarity, $V_S = -I_S R_{LOAD}$. Therefore, $V_P = -NI_S R_{LOAD}$. The secondary current term can be substituted out of the equation by using the relationship of currents to coil windings, $I_S = -NI_P$, to yield $V_P = N^2 I_P R_{LOAD}$. Finally, Ohm's law is used to remove the primary voltage and current terms: $R_{SOURCE} = N^2 R_{LOAD}$. Put in more general terms, $R_P = N^2 R_S$.

A high ratio of primary to secondary windings will present the signal source with an apparently higher impedance than is actually connected to the secondary. Similarly, the load will be presented with an apparently lower impedance than is actually present in the source. Considering the circuit in Fig. 12.32, an 8-Ω speaker can be matched to an amplifier with a 100-Ω output impedance using a transformer with a 3.5:1 winding ratio.

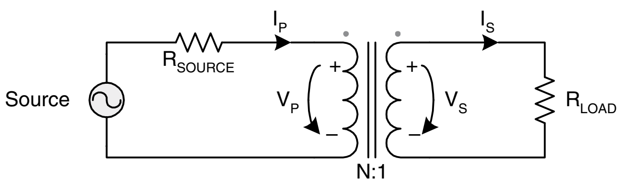

FIGURE 12.31 Impedance transformation.

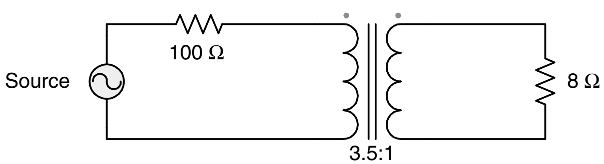

FIGURE 12.32 Amplifier/speaker impedance matching.