



The Institute of Sound and
Communications Engineers

Engineering Note 12.3

'Power' tapplings on 100 V line transformers

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How does it work?

The maximum power delivered to the loudspeaker drive unit is set by transforming the (usually) 8 Ω impedance of the voice-coil to the appropriate impedance that absorbs the required power at 100 V. For example, a power of 8 W at 100 V corresponds to a resistance of:

$$R = V^2/W = (100 \times 100)/8 = 1250 \Omega$$

To transform 8 Ω to 1250 Ω, we need a turns ratio of :

$$n = \sqrt{(Z_{\text{primary}}/Z_{\text{secondary}})} = \sqrt{(1250/8)} = 12.5$$

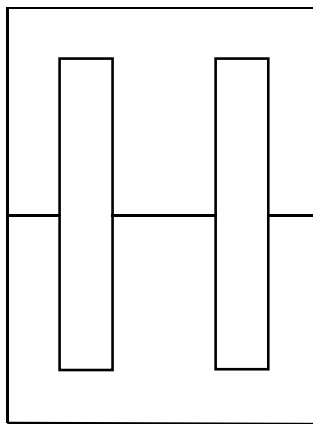
To set the power to a quarter of 8 W, i.e. 2 W, we need a turns ratio twice as large. To set it to a quarter of that, 0.5 W, we need a turns ratio twice as large again. We could achieve this by winding more turns on the primary winding, or by making tapplings at fewer turns on the secondary winding. Which is better?

Transformer losses

Losses in transformers are of two kinds:

- copper loss, due to the resistances of the windings;
- iron loss, due to hysteresis in the iron core.

It can be shown that minimum total losses occur if the copper and iron losses are equal, but that isn't possible for a transformer that works over a wide frequency range, because the iron losses are frequency-dependent, but the copper losses are almost independent of frequency. It isn't practicable even to make the losses equal at some fixed low frequency, because the geometry of the 'scrapless' core laminations doesn't leave much room for the windings, and to make the iron loss equal to the copper loss, the iron would have to be worked at a very high magnetic induction, causing distortion and a great sensitivity of loss to the applied voltage. So, the copper loss is always considerably greater than the iron loss.



Geometry of scrapless laminations: two 'E' and two 'I' stampings form a rectangular 'tile'

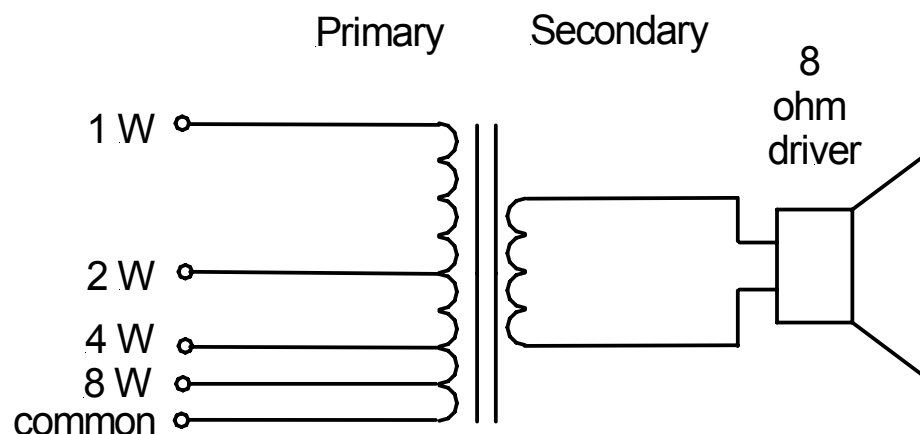
It can also be shown that the copper loss itself is a minimum when the primary and secondary windings each occupy half the winding area, preferably in a side-by-side configuration, so that both windings have the same average turn length. However, this construction does not give the maximum winding area and the least leakage inductance, so it is not often used for line transformers. It is used for mains transformers because it provides very good insulation between the windings.

So, for minimum losses in a transformer with primary taps, we need to have the same winding area for the *lowest-power* primary winding and for the secondary winding. When we set the power to the highest, the losses are *not* the minimum possible. With a tapped secondary winding, we are using the *whole* primary winding and the *whole* secondary winding in the highest-power configuration, which is, or should be, the minimum loss condition, with equal winding areas.

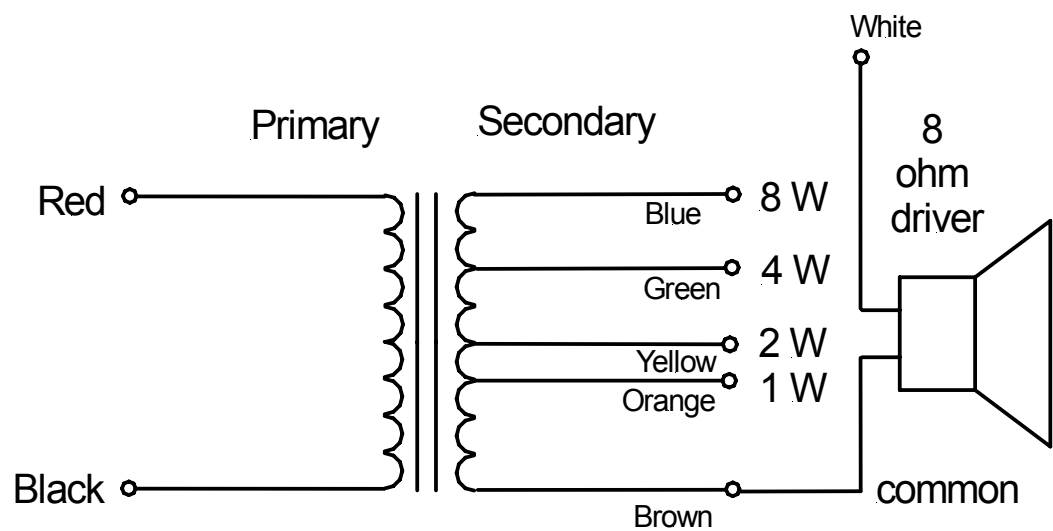
In addition, we need to have a certain number of turns on the primary winding so that the applied 100 V does not produce more magnetic induction than the iron core can accept. With a tapped primary, the *high-power* winding, with the least number of turns, must have this number of turns, so the lowest-power winding has *far more turns than necessary*. This problem does not occur with a tapped secondary. However, with a fixed number of primary turns, the primary inductive reactance, while sufficiently larger than the transformed load impedance in the high-power condition, may not be large enough in the lowest-power condition, when the transformed load impedance is higher. Yet, this actually doesn't matter too much, unless the amplifier is really struggling to supply sufficient power.

There is also a 'killer' disadvantage of the tapped primary, although we hope it isn't literally. When we put 100 V across a quarter of the primary winding, *we get 400 V across the whole winding!* Believe me, I've measured it. (Actually, you get a bit less than 400 V, because there are losses, but 380 V is quite typical.) And some transformers have taps offering more than a 16:1 power ratio. thus generating a correspondingly higher voltage.

There IS a disadvantage associated with secondary taps, but it's easily overcome. If you have four primary taps, you can fit a five-core cable and allow the installer to connect between 'common' and whichever wire corresponds to the wanted power. With secondary taps, you *just need an extra core in the cable*. You then always connect your 100 V line to, say, 'red and 'black', and you connect the 'white' core to whichever of the other cores corresponds to the power you want. If you add another wire in the cable, you can offer a selection of low-impedances, including 8 Ω , as well as 100 V line operation!



Configuration of a line transformer with tapped primary winding



Configuration of a line transformer with tapped secondary winding

You connect white to orange, yellow, green or blue for power taps. You do not need brown. For 8 Ω , connect the amplifier to white and brown. For 4 Ω , connect white to green and connect the amplifier between brown and blue. For 16 Ω , connect white to blue and connect the amplifier between brown and green. Other impedances can be obtained.