

How To Use 5V Tap to Convert from 115V Primary to 120V Primary (Mark Fowler)

First, this idea is not mine... I got the idea from here: <http://www.solorb.com/elect/musiccirc/liltiger1/>. Here I am just trying to explain it in more detail and explain how/why it works!

In many old amps the PT has a primary designed for a 115V mains voltage (sometimes they are 117V but the basic idea is the same). The problem is that when you use these with a 120V mains voltage that is more the “standard” today you will get slightly higher secondary voltages. This is mostly a problem on the 6.3V heater tap. For example, a PT that is designed to give 6.3V with a 115V mains will give, when connected to a 120V mains, a heater voltage of $6.3 \times (120/115) = 6.6 \text{ V}$. High heater voltages can decrease the life of the tube; although the consensus seems to be that heater voltages within 10% are fine. Nonetheless, many strive to get the heater voltages as close to the 6.3 value as possible. This will also increase the high-voltage secondary’s voltage. As an example consider a 630 V secondary (e.g., a PT with 315–0–315), which will increase to $630 \times (120/115) = 660 \text{ V}$ and will cause an increase in all the B+ voltages created by the power supply. When using “harvested” PTs (e.g., from organs or other sources) it is typical to have a spec’d PT secondary that is already too high... so the mismatch on the mains voltage just makes this worse. Thus, it is often desirable to do something to mitigate this problem.

Using a Bucking Transformer

One approach is to use a separate 120-to-6 transformer in a “bucking” configuration to bring the 120V mains down to $120 - 6 = 114\text{V}$. This is shown below.

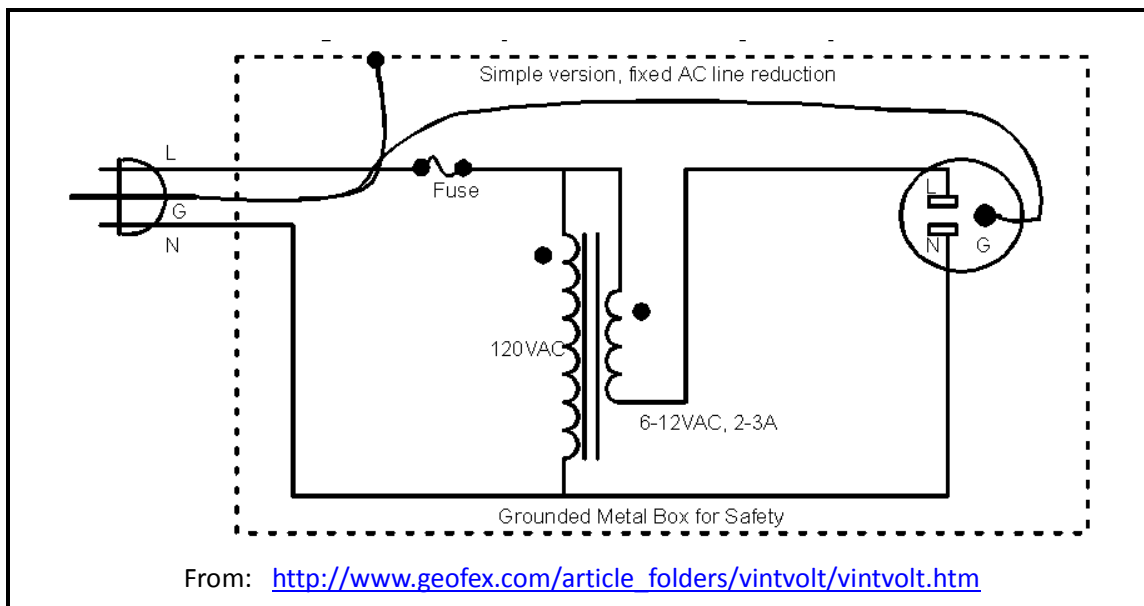


Figure 1

Briefly, this works like this (assuming for example that the transformer secondary is 6V). The 120 V mains on the primary creates 6V on the secondary. This 6V is then connected out-of-phase with the primary (that is what the dots next to the coil symbols are showing). This means that when the 120 waveform is at its most positive value the 6V waveform is at its most negative value; thus the 6V coil

subtracts from the 120V mains to give a 114V pseudo-mains voltage on the outlet on the right. The fact that the 6V coil is in opposite polarity to the 120V coil is why this is called a “bucking” transformer.

Using an Unused 5V Secondary

If you choose to not use a tube rectifier and use a SS rectifier approach then you no longer need the 5V rectifier heater winding on the typical PT used for amps. This opens up another way to account for the larger modern-day mains voltages. Although the author of <http://www.solorb.com/elect/musicirc/liltiger1/> calls this approach a “buck winding” it really is NOT bucking! Here is the power supply part of the circuit from that author’s webpage:

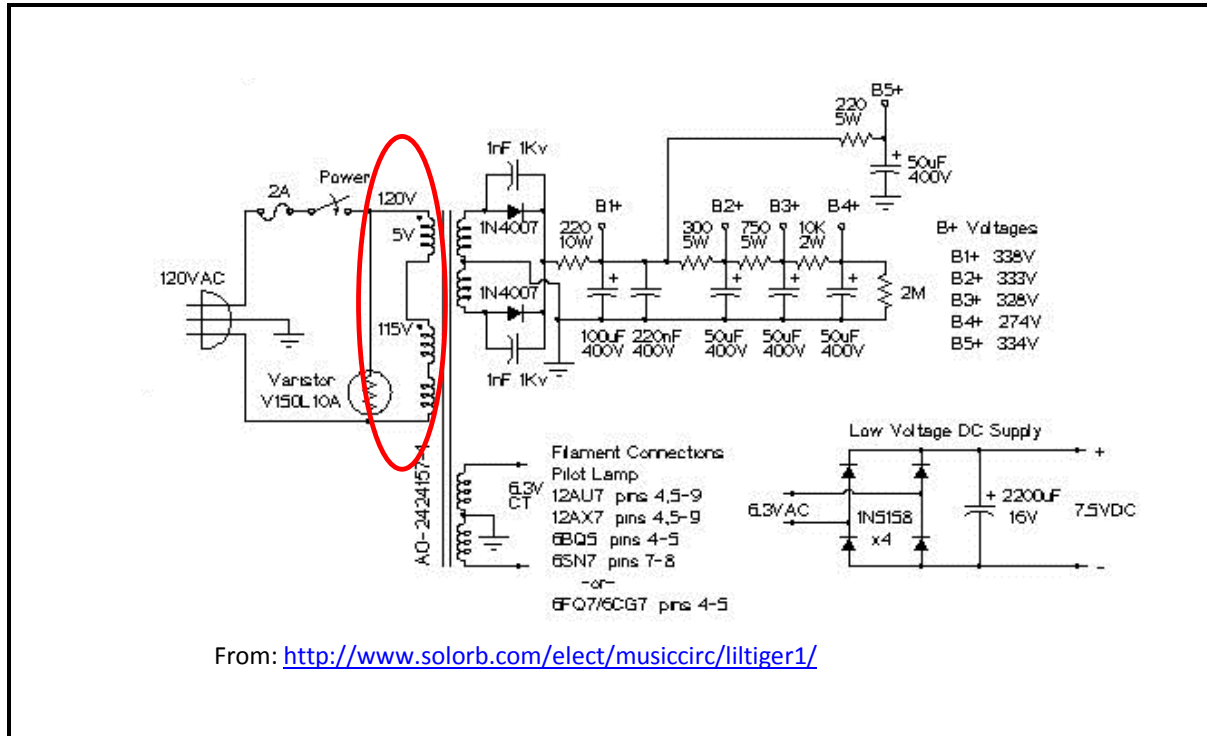


Figure 2

The part circled in red shows how the 5V tap is connected IN-phase with 115V primary... that is different from the OUT-of-phase connection in the bucking transformer approach! Also notice that in the bucking approach the mains is not applied to the bucking coil. Clearly this is a different connection and understanding how/why it works is a bit harder than the bucking approach (which is pretty straightforward... the mains induces the 6V in the secondary and that is used to “buck”). ***The bottom line is that connecting the 5V coil this way simply adds more turns to the primary... nothing more than that.*** But it is possible to figure out precisely what effect this has on the transformer’s voltages.

I will analyze how this works for the case of a PT that has a 115V mains and secondaries of 630V (really 315–0–315 but it is not important that it is center-tapped), 6.3 V for the heater, and the needed 5V coil. First we need some symbols to represent the (unknown) number of turns in each coil of the PT.

N_{115} = # of turns on the primary
 N_5 = # of turns on the 5V secondary
 N_{630} = # of turns on the high-voltage secondary
 N_6 = # of turns on the 6.3V secondary

Because the PT is designed for 115V mains we know that

$$\frac{N_{115}}{N_5} = \frac{115}{5}$$

$$\frac{N_{115}}{N_{630}} = \frac{115}{630} \quad (1)$$

$$\frac{N_{115}}{N_6} = \frac{115}{6.3}$$

although we do NOT know any of the actual number of turns. From the first of these we can re-write

$$N_5 = \frac{5}{115} N_{115} \quad (2)$$

Now with the 5V coil connected as shown in Figure 2 what we have really done is added N_5 coils to the N_{115} coils of the primary. Thus, with 120V applied across this new “extended” primary our new high-voltage secondary will be

$$V_{HV} = \left[\frac{N_{630}}{N_{115} + N_5} \right] 120V \quad (3)$$

Now inserting (2) for N_5 in (3) gives

$$V_{HV} = \left[\frac{N_{630}}{N_{115} + \left(\frac{5}{115}\right) N_{115}} \right] 120V = \frac{N_{630}}{N_{115}} \left[\frac{1}{1 + \left(\frac{5}{115}\right)} \right] 120V \quad (4)$$

Now substituting using the middle equation in (1) gives

$$V_{HV} = \frac{630}{115} \left[\frac{1}{1 + \left(\frac{5}{115}\right)} \right] 120V = \left[\frac{630}{115 + 5} \right] 120V = 630 \quad (5)$$

which shows that the transformer transforms 120V into 630V. In other words, and this is the big idea here: **connecting the 5V coil as shown in Figure 2 creates a PT with a primary 5V higher than it originally had!**

A Few Comments

The dots in Figure 2 indicate that the 5V tap must be connected so that the “direction of winding” of the 5V tap is the same as the primary coil. If it is connected the other way it actually creates a primary winding that is 5V lower than what it originally had. In practice, you can determine which way is correct by trial and error: connect it one way and check to see if it reduces your heater voltage – if it does then it is connected correctly and if it does not then swap the leads and it will be correct.

Also, when doing this you need to make sure that the current handling capability of the 5V coil is sufficient to handle the primary current. Given that the 5V coil is designed to carry the rectifier’s heater current it is usually rated at more than enough current capability to be able to handle the current on the primary side. But it is always good to do an accounting of the currents to make sure this holds true.