

Please note that there are now two versions of circuit board available for this project. One layout is a single sided circuit board as published in QST, and the other is a double-sided circuit board available through www.farcircuits.net . Two additional resistors were added to the new circuit board R23 and R24, both 15K resistors (See included schematic). Also note that the layout and T1 transformer pin locations have changed for this new circuit board.

Transformer Disassembly and Inductor Winding

Once a scrap power supply has been located, the required parts can be removed. Start with the switching transformer. It is usually the largest transformer in the supply, and is covered with yellow tape. The transformer will probably be covered with electrical varnish, which will need to be removed. The easiest way to remove the varnish without damaging the core and bobbin is to soak the transformer in acetone. It may take a several days for the acetone to completely soften the varnish on the transformer. It may be a good idea to collect an extra transformer or two for the project. It is not unheard of to break a transformer during the disassembly process.

The toroid inductor core used to make L1 can be found on the 5 V section of the PC power supply. Look for the largest doughnut inductor in the supply. The core itself is approximately an inch in diameter; pale yellow, with one white axial surface. Usually the core is completely covered with 18 gauge or similar copper wire. All of the old wire will need to be removed and discarded.

It is not necessary to use the dual diode from the PC power supply, but several dollars can be saved by doing so. The diode used is a common cathode dual Schottky or other fast switching type diode in a TO-274 case. This diode is typically the largest three lead package in a PC power supply. You will find it attached to a heat sink, usually very close to the switching transformer. Often times this diode will show a dual diode symbol in common cathode configuration on the package. A simple diode checker will determine if you have a good part. If you find a dual diode in a TO-247 case in a PC supply, it will be the diode you want. The diode will also have a mica insulator or insulating pad between it and the heat sink. Save this item, as it will be needed later.

After soaking the transformer in acetone for several days, start disassembly by unwinding the yellow tape from around the E-I core. Usually the smaller piece of the ferrite core will fall loose from the top of the transformer when this tape is removed (Figure 3). If this does not happen, tap a small knife or chisel into the joint between the two sections of the core. It should pry apart easily. Be careful not to break the core or the bobbin used to hold the windings. Continue by gently pushing the E section of the core out of the bobbin. This should not be difficult. If it is, soak the transformer for additional time in the acetone.

After removing the ferrite from the bobbin, unwind all of the wire that is on bobbin. Leave about an inch of wire attached to the pins protruding from the bottom of the bobbin. The length can come in handy when removing the pins from the bobbin. Once the old windings have been removed, pull the pins from the bottom of the bobbin. Simply grab the pins with a pair of pliers and twist back and forth while pulling away from the bobbin (Figure 4). The bobbin is fragile and will break easily. If any of the pins are bridged by wire and solder, the wire will need to be removed before removing the pins.

Next, clean the bobbin and ferrite core with an old toothbrush and acetone, or a small wire brush. I have found that a rotary tool such as a Dremel tool with a wire brush attachment works well. Remove as much of the old varnish as possible from the ferrite and the bobbin (Figure 5). Pay special attention to the junction area between the two pieces of ferrite. This needs to be clean so that no air gap is left when the transformer is reassembled.

Transformer Winding Calculations

It can be assumed that the salvaged transformer will be big enough for the application. This supply will need to generate around 150 W of boost-power. Most PC supplies are rated for around 250 W, which is more than adequate.

To calculate the turns ratio and number of turns needed on the primary, the area of the transformer core (A_C) will need to be calculated. To obtain this value, simply multiply the dimensions of the center leg of the E section of the transformer core. The core area needs to be in square centimeters, so convert units as required. Typically, the center leg of the core will be around 1.15 by 1.15 cm, with a core area around 1.25 to 1.35 cm². If you

have a transformer that is significantly larger than this, you may want to look for a smaller transformer. Larger transformers can be used but may not fit easily between the inductor and capacitors on the board. Check the fit before winding the transformer.

To calculate the minimum number of turns needed on the primary of the transformer, simply divide 4.69 by the core area (A_C) in cm squared. For the transformer shown in the pictures, the minimum number turns per leg of the primary was calculated to be 3.55 turns ($4.69/1.32 = 3.55$ turns). The actual number of turns required will vary slightly with each transformer, but will usually be around 4 turns. Increasing the number of turns on the primary will not hurt anything, and may make winding easier. For the transformer shown, 5 turns per leg of the primary works well. The number of turns needed on the secondary can be calculated as 0.88 times the number or turns on the primary. Assuming 5 turns per leg on the primary, the number of turns on the secondary will be $5 \times 0.88 = 4.4$ turns. Keep in mind that the only thing that is critical about these numbers is the minimum number of turns on the primary. The switching controller will allow for small variations in the turns ratio and will compensate by adjusting the pulse width of the switching transistors to maintain the output voltage.

The current ratings of the primary and secondary are easily calculated. The transformer is designed to supply a boost of around 150 W from a 9 V dc input. The current in the primary winding can be calculated as $150 \text{ W}/9 \text{ V}$, or 16.7 A. Because of the push-pull configuration, each leg of the primary will see the 16.7 A for a maximum of 50% of the time. This means that each leg of the primary winding can be sized to 50% of the 16.7 A... or 8.3 A.

The secondary current is simply the same as the rated supply current. This is because all of the current that passes through the supply is seen in the secondary winding. Assuming a maximum current of 25 A with a 50% duty cycle, the secondary current per leg can be calculated as 12.5 A. When the supply is off, the secondary legs of the transformer are in parallel, so this 50% current rating will hold true.

Winding the Transformer

UPDATE: Please Note that for the Double sided board layout available from Far Circuits (www.farcircuits.net) that there is a change in the transformer design. This change involves swapping the physical location of pins 1 and 2 on the transformer pin layout (figure 6).

An updated copy of Figure 6 was included in this zip file: “Figure 06_New.gif”. The original Figure 6 was renamed to “Figure 06.gif_old”.

Winding the transformer is the most difficult task in building the supply. Given a little patience and preparation, the job should not take more than about an hour. I have built several of these supplies and I prefer to use paralleled 24 gauge enamel copper wires for the current carrying conductors. The paralleled 24 gauge wire has proven to be the easiest to work with. I use three 24 paralleled for the primary and four paralleled 24 gauge wires for the secondary. The primary and secondary windings require roughly 40 inches of wire per strand. This works out to be around 24 feet of wire for one transformer. Again, the total length of wire needed may vary slightly with each transformer.

Because of relatively low voltages involved, this design relies solely on the enamel insulation on the wire to serve as insulation between windings of the transformer. A clear plastic tape (Scotch or similar) is used to hold down each of the windings after they have been wound. Kapton or similar Polyimide Film dielectric tape could be used for this purpose, if it is available. The same tape will also be needed to hold the transformer core together after the bobbin and core have been assembled. After the supply has been tested, it would be a good idea to use some silicone rubber or similar glue to hold the core and bobbin together, as well as to secure them to the main circuit board.

Figure 6 shows the pin layouts of the transformer. Looking from the top side of the transformer (with its pins pointing downward), pin 2 is the center tap for both the primary and secondary windings. Pins 1 and 3 are the legs of the primary and pins 4 and 5 are the legs of the secondary. All of the windings are wound in a counter-clockwise direction looking down onto the top of the transformer. Keep all of the windings of the transformer as tight as possible. Gaps between the windings can result in increased flux leakage around the wires. Any leaked flux acts as inductance within the transformer. This leakage

inductance, coupled with the fast turn off of the switching transistors, can generate transient voltages that can damage the switching transistors. If the transients prove to be excessive, the transformer will need to be rewound.

To wind the transformer, start with the primary winding. Use three of the 24 gauge copper enamel wires cut to length and start at pin 1 (shown in Figure 6). Wires will be wound in a counter-clockwise direction, looking from the top of the transformer. Wind 5 turns and bring the winding out at pin number 2. Secure the winding with some tape. Fold the wire back into pin number 2, leaving a one to two inch long loop. Continue winding 5 more turns in the same direction as before, stopping at pin number 3. Again secure the winding with tape. The primary is now complete (Figure 7).

For the secondary, use four 24 gauge copper wires. Start at pin number 5 with the secondary winding and wind four and a half turns, stopping again at pin number 2. Secure the winding with tape. As before, make a loop back into pin number 2 and continue to wind four and a half more turns stopping at pin 4. This time, add some additional tape to help secure all of the windings. Trim the windings at each of the pins to about an inch and a half in length. Reassemble the core, securing it with tape. Try to pre-stress the tape when attaching the top section of the core. This can be accomplished by attaching the tape to each of the sections of the core, so that it pulls tightly when fully assembled (Figure 8). Trim any excess tape from the core (Figure 9). The core should now be complete.

The last step is to strip and tin the leads of the transformer. The preferred method is to strip the enamel wire by scraping it with the tip of a knife or similar sharp object. Do not use acetone or other solvents because they can wick into the transformer and dissolve the enamel. Strip the enamel to the base of the transformer so that it can be soldered tightly onto the circuit board. After stripping the transformer leads, twist them together and then tin them with solder.

Notes on Assembly of the Circuit Board

There are a few items to note before building the supply. The pads for the switching transistors (Q5 and Q6) and the Schottky diode (D7) have been placed about 1/4 of an inch away from the edge of the supply. The leads will need to be bent to allow the devices to be mounted onto a vertical heat sink surface. It is best to shape these leads before soldering these devices into place. Also, it will be easier to do some of the initial testing of the supply with these devices removed, so postpone soldering them temporarily.

Between the edge of the board and devices Q5, Q6 and D7 is a ground trace. It will be necessary to add additional current carrying capacity to this trace. A piece of 12 gauge solid copper wire works well. Bend the wire so that it fits down on the copper trace, forming a path between the input and output ground leads. Solder the wire along the entire length, leaving enough room to solder Q5 and Q6 later. Also, leave room for the mounting hardware at the corners of the board.

There are two jumper wires shown on the component layout. They reside on the board next to Q3 and Q8. Be sure that wires are soldered in place at these locations on the board. The extra clipped leads from a resistor or capacitor works well for these jumpers, since they do not require any insulation.

The fuse, F1, is mounted with a pair of crimp style female spade connectors soldered into the board. Although the crimp style connectors were not designed for this purpose, they work very well for this application. There are several sizes, and most should work. It will help have a fuse at hand when selecting the connectors. Try to select connectors that hold the fuse securely. The plastic sleeve will need to be removed from some of these connectors, so check for any extra retaining rings or hardware that may get in the way.

High current wire for both the input and output circuits will be needed. I have had good luck with high-end automotive speaker cable. Most of this is available in sizes as large as 10 or 12 gauge. This wire is more flexible than most stranded wire. It can usually be purchased by the foot from any car audio supplier. Choose at least 12 gauge wire for the battery leads and size the output leads according to the load.

The holes left in the circuit board for high current components are intentionally small. The lead sizes of these components may vary. Components, including the transformer, input and output leads, fuse connectors and inductor, will need to be drilled to size. It is easier to drill these out before starting assembly of the board. A #6 bolt is used for mounting the supply, and the holes should be drilled accordingly.

Assembly

Mount all of the components to the circuit board, with the exception of Q5, Q6 and D7. These components will be added after the initial testing has been done. Tin all of the copper on the high current traces between the input and output of the supply. Liberal application of solder is recommended. Do not forget to add the extra copper wire to the ground trace running from the input ground to the output ground past Q5 and Q6. When mounting the fuse, it is usually easiest to stick the fuse clips onto a fuse and then insert and solder them in the board.

After mounting the components, it is best to run a quick check of the low voltage protection circuit, switching regulator, RF detection and enable circuits. To test these circuits a frequency counter and voltmeter or an oscilloscope will be needed. A 12 V battery or low current variable voltage bench supply will also be needed. If the bench supply has current limiting capability, set it to 1 or 2 A. If using a battery for this testing, it is advisable to fuse the supply leads from the battery at about 2 A.

Figure 3—Salvaged switching supply transformer before disassembly. Shown with “I” section of core removed.

Figure 4—Transformer bobbin, showing removal of pins from the bobbin.

Figure 5—Foreground: Salvaged transformer core cleaned up and ready to go. Background: transformer core soaking in acetone.

Figure 6—Transformer pin layout looking down onto transformer (Pins pointing away from viewer).

Figure 7—New switching transformer with primary winding completed.

Figure 8—Assembling the transformer core. Note the tape being pre-loaded to hold the two sections of the core tight together.

Figure 9—Fully assembled transformer shown with excess tape being trimmed from the core.

Figure 10—Positive board layout, copper side.