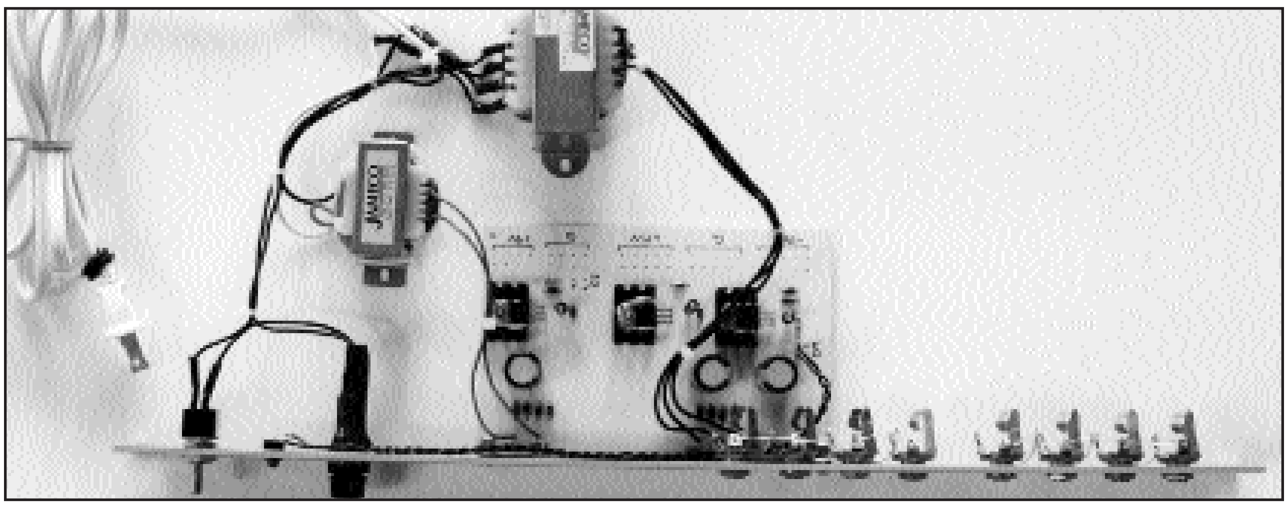
by Thomas Henry

Power Supplies for Electronic Music

A good quality power supply is essential for homemade electronic music equipment. And yet, do-it-yourselfers often give short shrift to this important module. The general attitude seems to be that the power supply is an annoyance; you've got to have one, but since it doesn't make any neat sounds, it frequently fails to get the attention it deserves.

This article addresses the problem by explaining why, in fact, power supplies are crucial to good performance from electronic music equipment. It then goes on to show you how to construct your own.

Actually, kit companies haven't helped the situation much. Many of the power supply kits currently available are lacking in one regard or another. For example, at the time of this writing, one company offers a bipolar power supply which isn't even regulated, while another lists a regulated one, but the available current is minuscule. Build your own power supply and you can easily overcome these hurdles!



DESIRABLE FEATURES

Power supplies for electronic music should be regulated and there are several good reasons why. First, hum caused by supply ripple is nipped in the bud. Since the regulator clamps the filtered DC to a fixed level, any residual bumps are neatly truncated.

Next, the output voltage will remain relatively stable, even if you start adding more modules to your system. (Most homemade music equipment is modular in nature, with all of the individual circuits being powered by a main supply.)

Another advantage to regulation relates specifically to voltage-controlled oscillators (VCOs) used in music synthesizers. By powering the VCO from a regulated supply, you can be sure that the tuning won't drift all over the place. This will keep your listeners from having to suffer through "clinkers" or sour notes!

Finally, regulated supplies typically have a great deal of safety protection built into them. With a modern design, it is possible to guard against input or output short circuits, as well as overheating.

With regard to current, a decent power supply should be able to provide at least a half amp or so on each output. As hinted at above, a modular system may consist of a dozen or more separate circuits, each

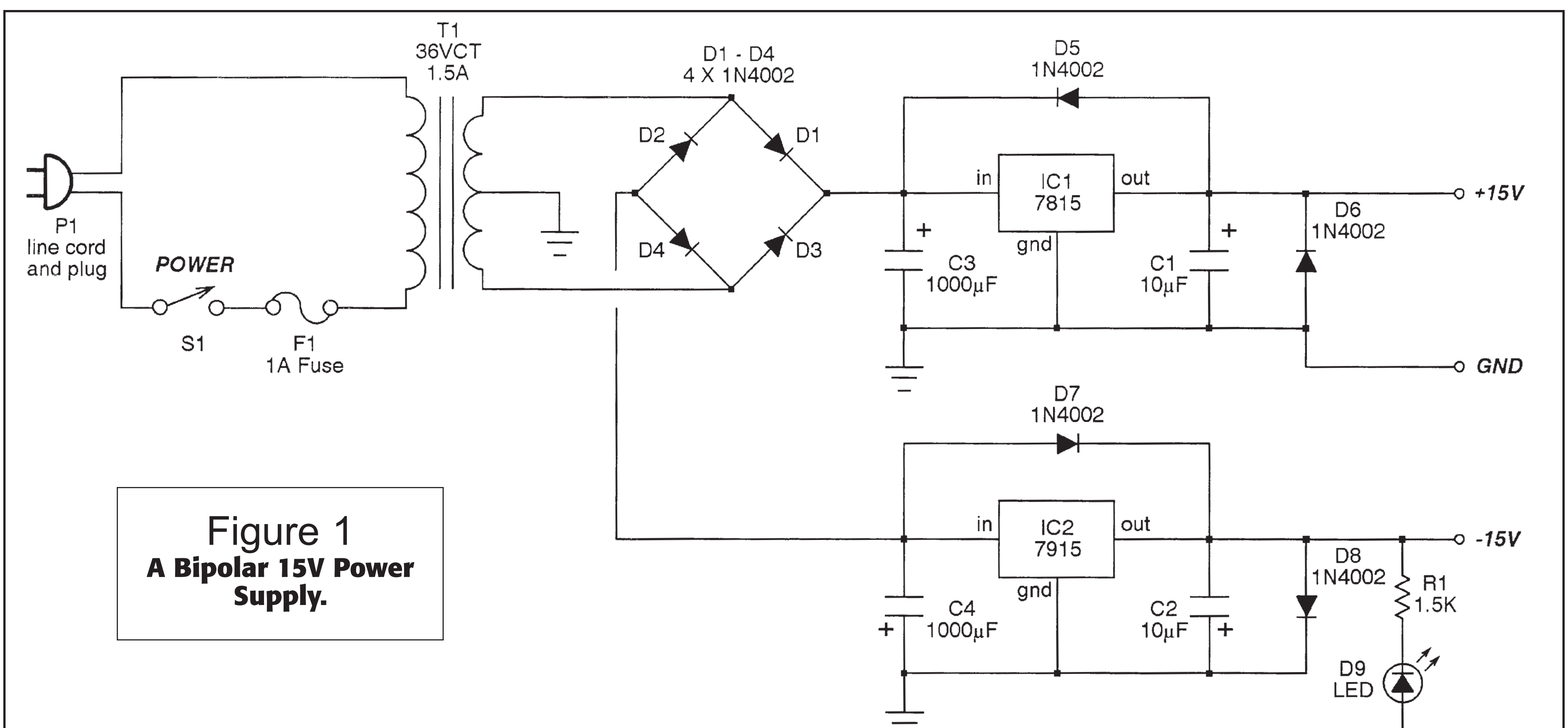


Figure 1
A Bipolar 15V Power Supply.

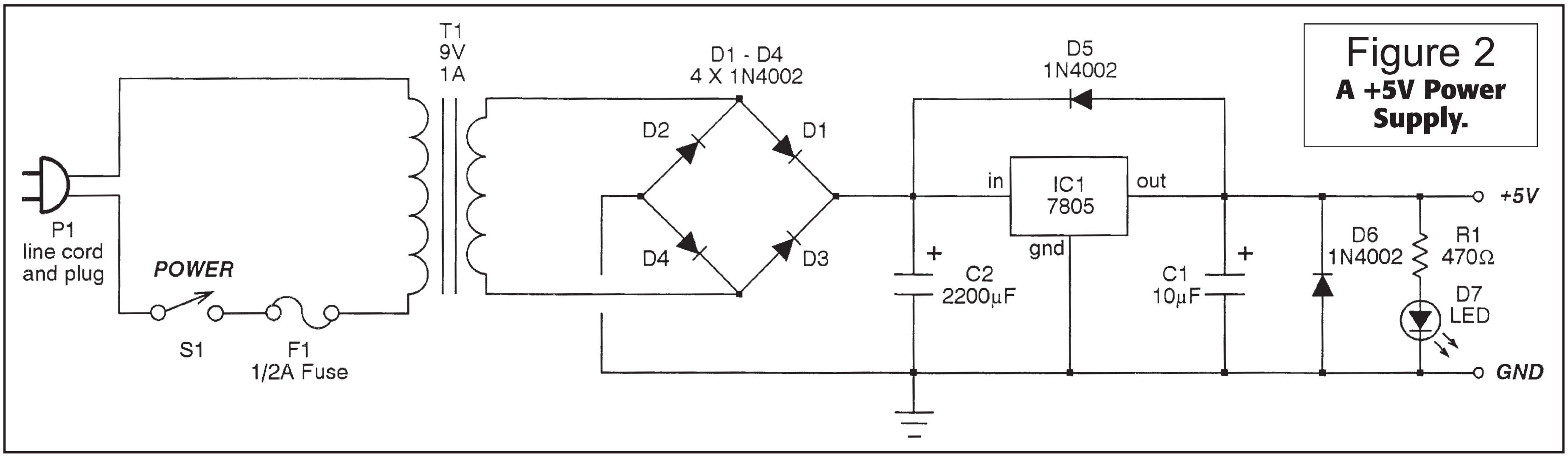


Figure 2
A +5V Power Supply.

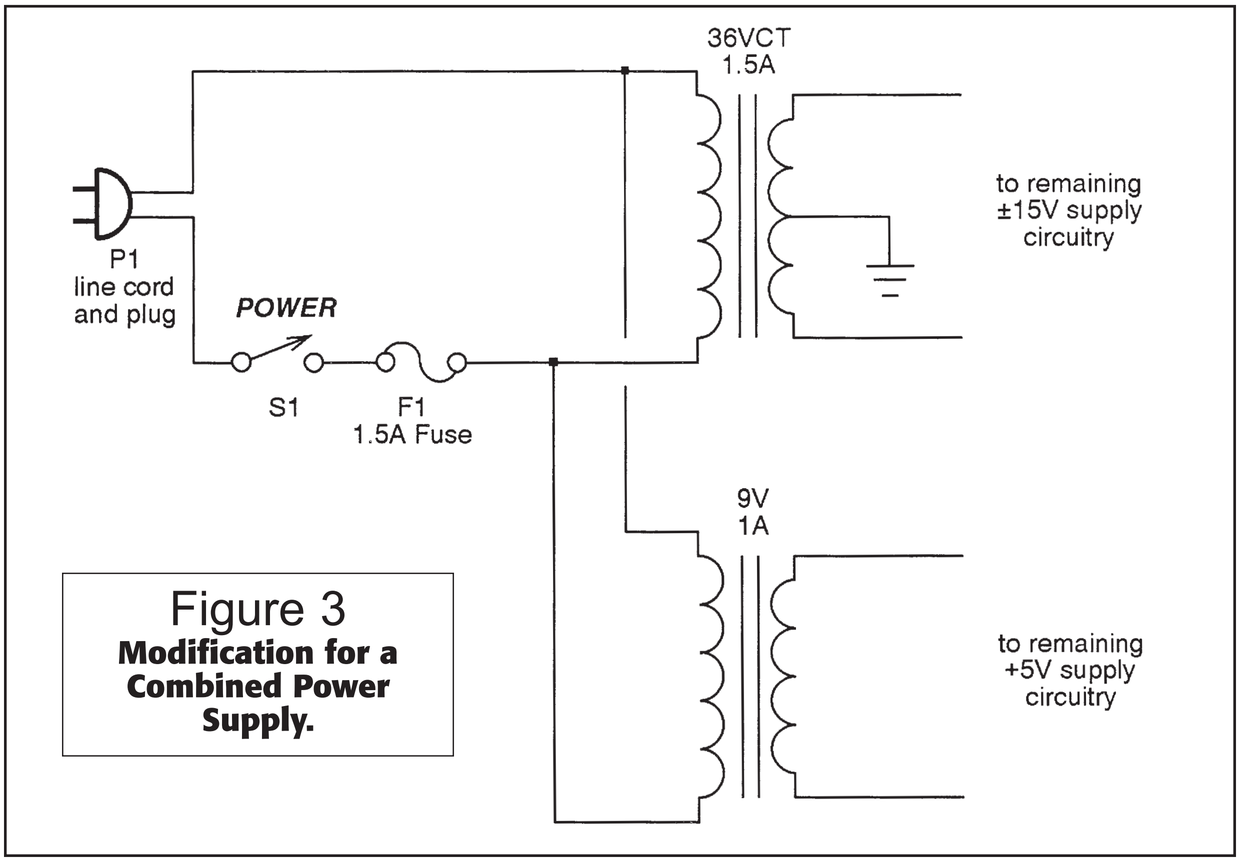


Figure 3
Modification for a Combined Power Supply.

one drawing current from the supply. The idea here, then, is to build a power supply once making sure that it has enough beef to handle a number of modules.

What voltages are needed for electronic music devices? Well, for analog circuitry, history has shown that a bipolar 15V supply is best for a variety of reasons. Perhaps the most important is that many of the classic special-purpose synthesizer chips require this. It is not uncommon to encounter music ICs which operate only on a bipolar 15V, or perhaps just a single +15V line. But even for discrete or homebrew op-amp designs, these voltages are a good choice.

Here's why. By using a bipolar 15V instead of, say, a bipolar 9V supply, you attain much greater headroom throughout the circuit before clipping occurs. In audio circuitry, as a general rule, the greater the headroom, the better the distortion and noise figures will be.

It's no secret that modern music is being invaded by microprocessors. Hence, it would be wise to also have a source of +5V available. This is a pretty standard voltage for most microprocessors, as well as TTL circuits.

We can put these factors all together to come up with a design plan. We will shoot for a regulated power supply, capable of providing +15V, -15V, and +5V, with 0.75 amps available from each line. Moreover, we will demand excellent safety requirements like short circuit and overheating protection. These goals are easily met with just a tad of care. So, let's see what it takes.

DESIGN ANALYSIS

Refer to Figure 1 which shows the schematic of a bipolar 15V power supply. A standard 110V AC enters the circuit from the left, via wall plug P1 and an 18-gauge line cord. This passes through the main power switch, S1. More importantly, it also goes to fuse F1.

A fuse is essential not just for your safety, but also for the well-being of any other gear connected. By the way, this is a 1A fast blow fuse, but we'll wait just a bit before seeing how that value was arrived at.

T1 is a 36V center-tapped transformer rated at 1.5A. Theoretically, since we'll be using a bridge rectifier arrangement across the entire secondary, we should be able to draw 1.5A from both the +15V and -15V sides.

However, we'll introduce a good safety margin here by specifying the supply as 0.75A per side. This puts less stress on the transformer, permitting it to run cooler and you to breathe easier.

The bridge rectifier composed of D1 through D4 creates pulsating DC voltages of both positive and negative polarities. These two voltages will be referenced to the ground established by the center tap of T1's secondary.

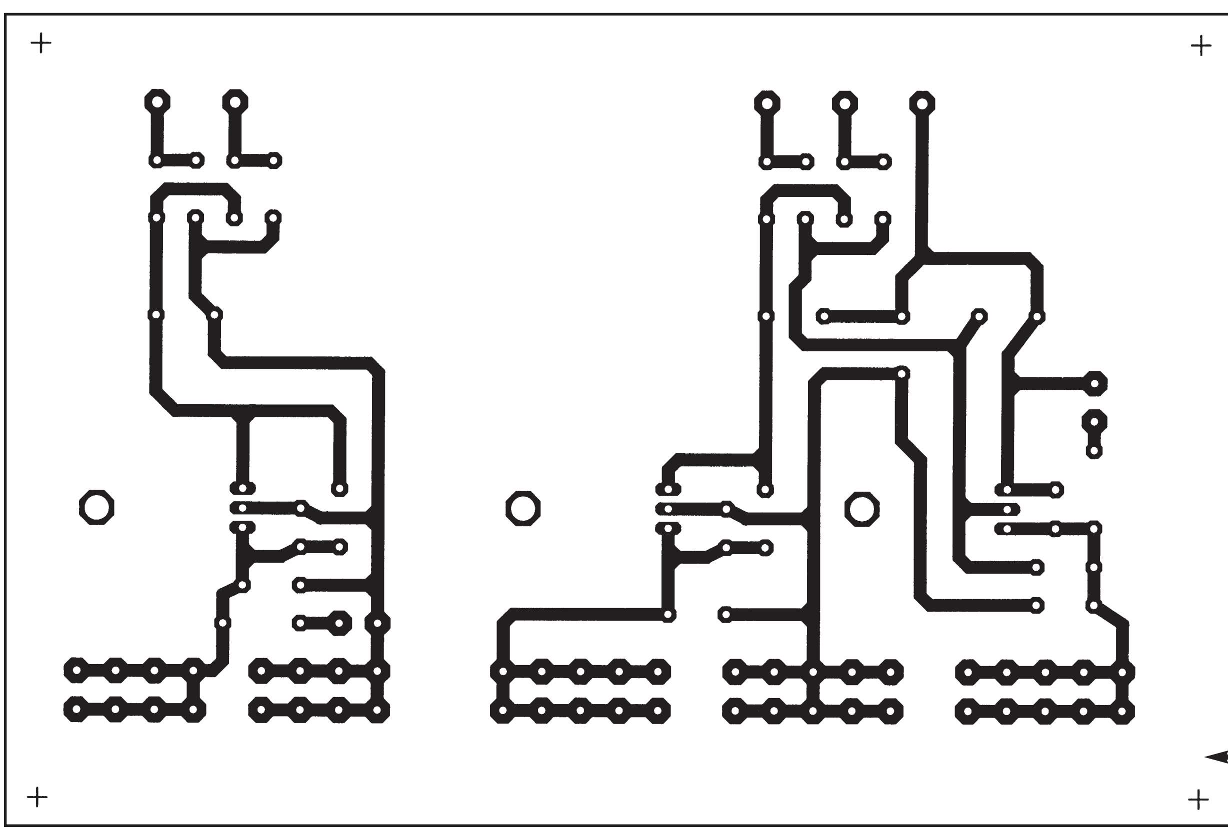
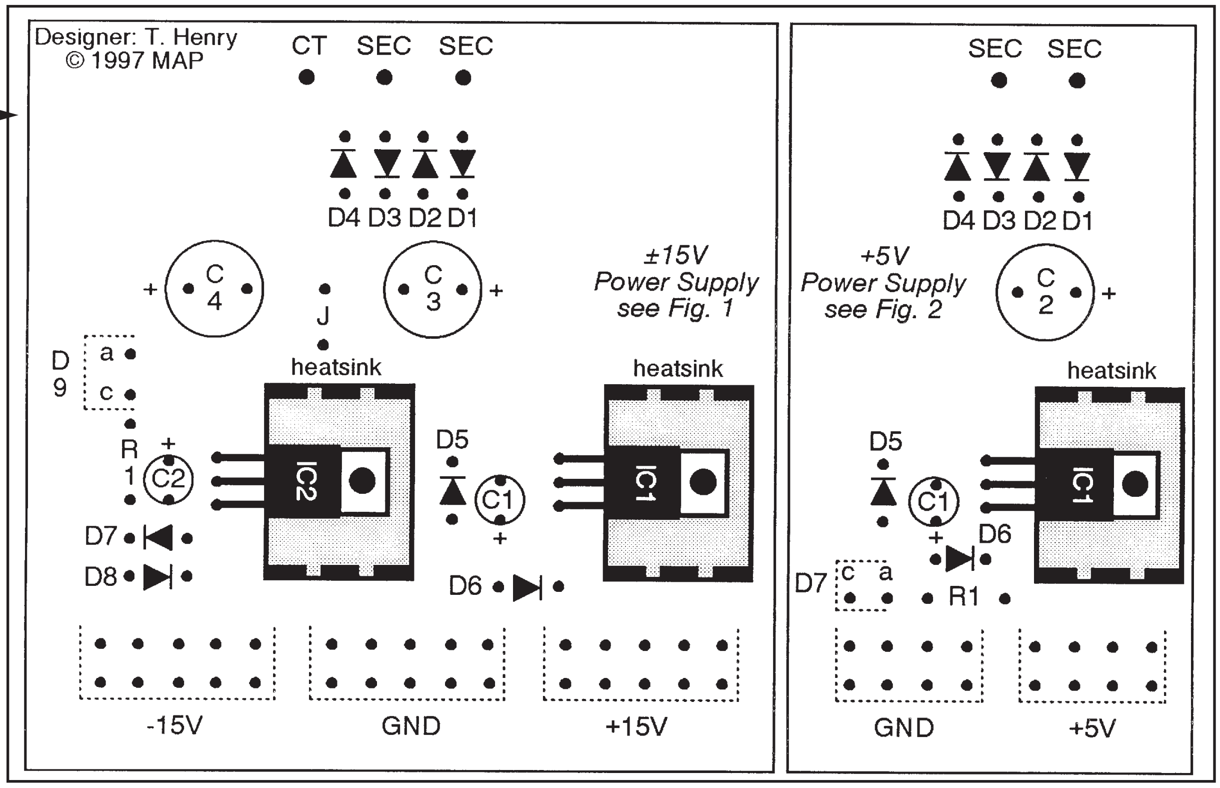


Figure 4
1:1 Foil Side Artwork

Figure 5
Parts Placement Guide.



Notice that the bridge implements fullwave rectification. This is an extremely efficient approach, since both the positive and negative portions of the AC input are used. Also, the pulsating DC will have a frequency of 120 Hz now (twice the 60 Hz input) which is easier to filter.

By the way, all of the rectifiers in this circuit should be rated for a peak inverse voltage of at least 100V and a current capability of 1A. The 1N4002 is a good choice here. The positive output is found at the junction of D1 and D3. This is applied to filter capacitor C3.

Most text books have standard formulas for determining the optimal value of power supply filter capacitors; it turns out that 1000 mfd works well here. But watch the voltage rating! The capacitor will store the peak value of the pulsating DC which, in the worst case, will be about 25V. Thus, for a good margin of safety, choose C3 to have a working voltage of double that. (Curious about that 25V? Well, transformers are rated in volts RMS; multiply this by 1.414 to determine the peak voltage. Doing so shows you that T1 will generate a peak voltage of about 50V. Divide that by two to get the value for each half of the secondary.)

The next step is to regulate the voltage on C3 and that's the purpose of IC1, the well-known 7815. The input voltage to this chip should be higher than the desired output voltage. If the input is too low, say 18V or below, then you'll drop out of regulation. And if it's too high, then the regulator will run hot. (Essentially, the 7815 "throws away" any excess energy in the form of heat.) Of course, the voltage on C3 fluctuates as the output load changes, but typically will lie between 20V and 25V. Even though the input is moving about, the output will hold rock solid thanks to the 7815.

By the way, don't be surprised if the output of IC1 doesn't hit +15V on the button. According to the manufacturer's spec sheet, the output for a given 7815 may lie anywhere between +14.4V and +15.6V. This doesn't matter, in general. What's important is that the output be locked into some voltage whatever it may be (as long as it's reasonably close to +15V).

The input and output pins of IC1 should be stabilized, especially if there's any messy wiring leading up to them. So, it's generally a wise idea to attach bypass capacitors very close to the pins.

Since we'll probably be building this on a printed circuit board (which is inherently tidy), and will locate C3 close to IC1, there's really no need for a cap on the input. However, the output could be feeding a variety of other modules through a tangle of wires. So we'll tack on capacitor C1 to the output pin. This will improve the transient response of the chip.

The 7815 regulator is pretty neat in that it has some internal protection circuitry. If the IC overheats for any reason, it simply shuts itself down until the condition is corrected. Notice that this covers output short circuits as well.

And speaking of heat, it is essential that IC1 (and the other two voltage regulators mentioned in this article) be properly heatsinked. That extra surface area really helps to keep things cool!

But there are two other ways we can easily augment the protection. For starters, imagine that filter cap C3 is accidentally shorted to ground. Maybe a washer rattled loose inside the cabinet, or perhaps you slipped with a pair of pliers. In that brief instant of time, the output voltage of IC1 will be higher than the input which is now at 0V due to the short across C3. And that's all it takes to fry the chip!

However, notice rectifier D5. Normally, this will be reverse-biased and just sits there doing nothing. But, if that slip of the pliers really happens, then the cathode drops to 0V. The rectifier goes into forward bias and clamps the output to more or less the same level as the input. To put it another way, it is now impossible for the input of IC1 to ever drop substantially lower than the output.

D6 performs another useful task. Its purpose is to ensure that the output line feeding all of the other modules can never go negative. Of course, this would normally be impossible. But imagine that some other module in your system goes haywire or that you accidentally cross the supply lines in some fashion. D6 snaps to attention and safely dumps the negative voltage to ground.

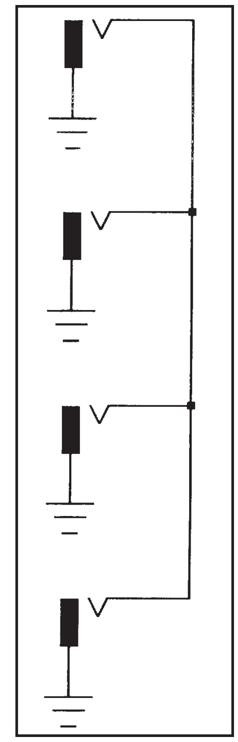


Figure 6
A multiple is nothing more than several jacks wired in parallel. Acting like a "Y-cord," it's a utility device that lets you split a single patch cord into several outputs. There is room for two of these (four jacks each) on the 1U rack panel fronting the power supply.

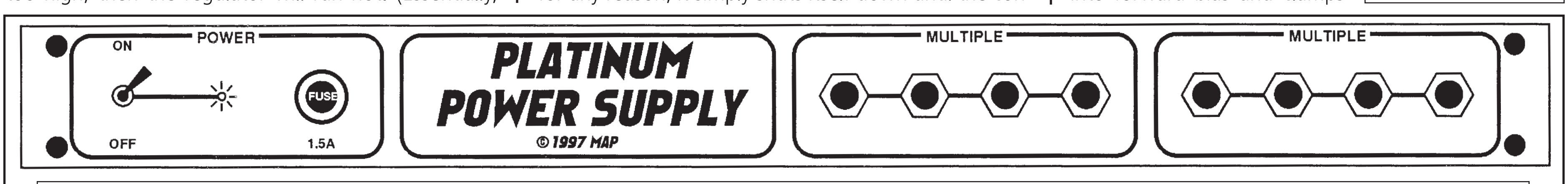


Figure 7 - **The switch, LED, and fuse for the power supply fit behind a standard 1U rack panel, leaving plenty of room for two multiples.**

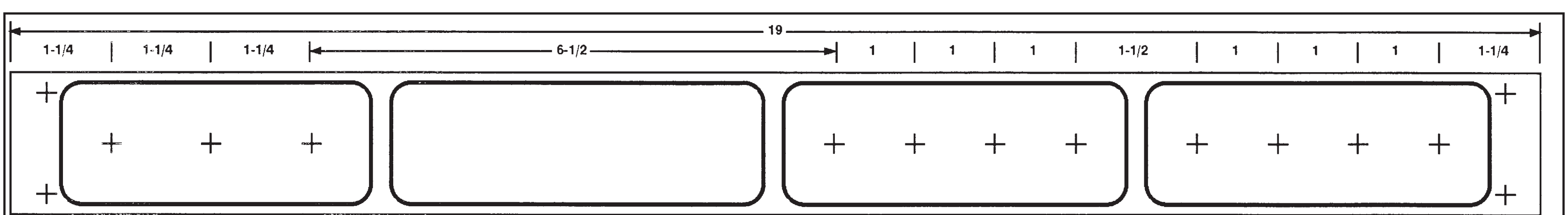


Figure 8
Drilling Guide for the 1U Rack Panel.
All dimensions in inches.

Pause for a moment to really consider what we have accomplished so far. We now have a decent regulated +15V at our disposal, and it can handle a whopping 0.75A. Overheating and output short circuits are no longer part of our nightmares. And best of all, we've protected the supply itself, as well as any other potentially expensive equipment in our system.

With just a little extra care, we have truly come up with a platinum power supply!

Generating a -15V is just as easy, if you keep a few simple component orientations in mind. Refer again to Figure 1. The junction of D2 and D4 spits out a negative pulsating DC voltage. This is filtered by C4 and then tamed by IC2, the 7915 negative voltage regulator. C2 then stabilizes the output of the regulator. However, observe carefully the polarities of both C2 and C4; they're the reverse of what appeared in the description for the positive supply. D7 and D8 provide goof-proofing, but again notice how the orientation is flipped here. An easily missed point is that the 7815 and 7915 regulators have different pinouts. Keep this in mind, unless you enjoy fireworks!

A panel LED is always nice to give visual indication that the circuit is on. This is the purpose of D9 and its current limiting resistor R1. Incidentally, in most electronic music equipment, the positive supply gets more of a workout than the negative. So, we put the LED on the -15V side just to even things out a trifle.

Now about that fuse, F1. Its value depends on the total power dissipated by the circuit. Recall that some of this power will be in the output of the supply, but some will also be in the heat generated by the regulators. And then we have to allow for losses in the transformer, as well as the rectifiers.

We don't have to be slavish about this, so a quick estimation shows that the bipolar power supply might draw as much as 60 watts. This suggests a total current drain of 0.5A (60W divided by 120V).

To avoid blowing fuses repeatedly, and yet provide good protection from serious conditions, we'll double this to arrive at a final suggested rating of 1A.

As mentioned earlier, if you plan on using any microprocessor or TTL circuitry in your rig, then you will definitely want to have a source of +5V. We can use many of the same techniques to carry out this plan. Refer to Figure 2 now.

The line voltage is applied to T1 by way of switch S1 and fuse F1. In this case, F1 is a 1/2A fast blow type. sT1 is a 9V transformer, rated at 1A. As usual, we'll derate things a bit just to permit a decent safety factor. So, instead of turning this circuit into a toaster oven, we'll specify the maximum output current at 0.75A. For best efficiency, a bridge rectifier arrangement is used again. But since we're only creating a single supply voltage (+5V), the transformer doesn't need a center tap on the secondary. Instead, the junction of D2 and D4 creates the ground reference.

The positive pulsating DC voltage at the tie point of D1 and D3 feeds into filter capacitor C2. The voltage on C2 will vary from about +10V to +13V, depending on the load conditions. A few standard calculations come up with a value of 2200 mfd at 25V for this capacitor (once more allowing for a margin of safety).

If a clean printed circuit board pattern is used, and C2 is kept close to the regulator, then no bypass capacitor should be needed on the input pin of IC1. But we definitely want to stabilize the output a bit, and that is the purpose of C1.

And always mindful of things that can go wrong, we plop in D5 and D6 to guard against nasty voltage reversals and short circuits. Finally, panel LED D7 provides visual indication that the unit has been energized.It is highly likely that you will want both a +5V and a bipolar 15V power supply in your electronic music rig.

In this case, refer to Figure 3 which shows how to combine them. Essentially, you simply parallel the primaries of the two transformers, eliminating the redundant switch, fuse, and line cord. Notice, though, that the fuse should now be rated at 1.5A to cover both supplies. Finally, you can ax one of the LEDs, if desired.

PARTS LIST

BIPOLAR 15V POWER SUPPLY

Resistor
R1 1.5K, 1/4W

Capacitors
C1, C2 10 mfd, 25V electrolytic
C3, C4 1000 mfd, 50V electrolytic

Semiconductors
D1 - D8 1N4002 rectifier
D9 Red LED
IC1 7815 voltage regulator
IC2 7915 voltage regulator

Other Components
T1 36VCT, 1.5A transformer
S1 SPST heavy duty toggle switch
F1 A fast blow fuse
P1 18 gauge line cord with plug

Miscellaneous
Printed circuit board, heatsinks, panel mount fuse holder, heat shrink tubing, LED clip, #4 hardware (nuts, bolts, lock washers), wire, heatsink grease, solder, etc.

+5V POWER SUPPLY

Resistor
R1 470 ohms, 1/4W

Capacitors
C1 10mfd, 25V electrolytic
C2 2200mfd, 25V electrolytic

Semiconductors
D1 - D6 1N4002 rectifier
D7 red LED
IC1 7805 voltage regulator

Other Components
T1 9V, 1A transformer
S1 SPST heavy duty toggle switch
F1 1/2A fast blow fuse
P1 18 gauge line cord with plug

Miscellaneous
Printed circuit board, heatsink, panel mount fuse holder, heat shrink tubing, LED clip, #4 hardware (nuts, bolts, lock washers), wire, heatsink grease, solder, etc.

ORDERING INFORMATION

The following kits are available from Midwest Analog Products:

+5V Power Supply — Kit of parts includes an Assembly Guide and all items mentioned in the Parts List except heatsink grease and solder. Part Number PPS-1, $24.95 (plus $3.00 shipping and handling).

Bipolar 15V Power Supply — Kit of parts includes an Assembly Guide and all items mentioned in the Parts List except heatsink grease and solder. Part Number PP2-1, $39.95 (plus $4.00 shipping and handling).

Combo Power Supply — Includes both kits (+5V and Bipolar 15V) as described above. Part Number PPS-3, $59.95 (plus $6.00 shipping and handling).

Blank Rack Panel Kit — includes an unfinished 1-3/4" by 19" by 1/8" aluminum panel, angles, and hardware for mounting a circuit board, and instructions on how to drill, cut, and work with rack panels. Part Number K901, $8.95 (plus $3.00 shipping and handling).

Shipping is by First Class Mail. Prices shown in US dollars. Remit US funds only. Write for shipping information to other countries. MN residents add 6.5% sales tax. Money orders and checks only. Prices and terms subject to change without notice.

Order from:

Midwest Analog Products
P.O. Box 2101
North Mankato, MN 56003
E-Mail: map@prairie.lakes.com
WWW: http://prairie.lakes.com/~map

BUILDING YOUR OWN POWER SUPPLY

CAUTION: Power supplies, like this circuit, use 110V AC which can be dangerous and even lethal! Do not attempt this project unless you are skilled at working with 110V AC.

Let's assume that you want to build both power supplies mentioned above and house them as a single unit. To simplify things, we'll juxtapose the two circuit boards in the illustrations. Refer to Figure 4 which shows the foil side artwork for the joint project. Obviously, if you only need one or the other, simply delete the unwanted portion. If you enjoy etching printed circuit boards, then have at it!

On the other hand, if you would just as soon avoid messing about with chemicals and wish to simplify the task of locating all of the components, then check the Parts List for kit availability via mail order.

There are three interesting things to notice about the printed circuit board. First, observe how fat the traces are; this not only permits greater current flow, but also helps draw heat away from the rectifiers.

Next, three large pads stand out from the rest. These are drilled to a 1/8" diameter, which then permits you to secure the heatsinks to the board with #4 machine bolts and nuts. Lastly, the various outputs feature a large number of paralleled pads for powering a multitude of modules.

Now, you'll have to take care of running down all of the parts. Most of these are easy to find, but the 36VCT transformer rated at 1.5A might take some digging in the catalogs. Even though this is a standard size, it isn't nearly as common as the "filament" types. And when you do find it, don't be surprised at the cost! These are always fairly expensive, but keep in mind that you'll only need one to handle quite a few modules in your system.

When you're shopping, don't forget the niceties like heat shrink tubing, tie bands, panel mount fuse holder, hefty power switch, line cord, etc. In particular, you'll want to be especially mindful of how you're going to handle the 110V AC side of things.

Remember the cardinal rule: ***All joints carrying 110V AC must be completely covered and insulated!*** If you're ready to build, then refer to Figure 5 which shows the parts placement guide for the printed circuit board. This is pretty straightforward. But here are a few tips to help you along.

When loading the board, take great pains to see that you orient the capacitors and rectifiers properly. And don't forget that there is one jumper on the board. This is denoted by the letter "J." You can use a leftover snippet of a rectifier lead to form the jumper.

Before soldering any one of the three regulators in place, smear a thin layer of heatsink grease across the underside. (Small, inexpensive tubes of heatsink grease are readily available at your local Radio Shack.) Then bolt the regulator to its heatsink. It probably ought to be said for emphasis: In order to draw the requisite 0.75A from each line of the power supply, heatsinks and heatsink grease are mandatory.

With regard to how the transformer secondaries attach to the board, consider the bipolar supply first. Two of the pads are marked "SEC;" these connect to the outer legs of the secondary winding. The third pad denoted "CT" attaches to the secondary's center tap.The +5V supply is simpler; just connect up the two secondary lines (in either order) to the pads marked "SEC."

Finally, the anodes and cathodes of LEDs D7 and D9 are called out on the parts placement guide by the letters "a" and "c," respectively.

Apart from making sure that you've left ample room for air flow and that none of the 110V AC connections can come in contact with the remaining circuitry, it really doesn't matter how you mount or enclose the power supply. Most musicians prefer to use rack-mounted equipment. In this case, you would install the power supply at the bottom of your cabinet, so that the heavy transformers can be bolted to its floor.

Now power supplies don't require much in the way of front panel real estate; room for a switch, a fuse holder, and an LED is about all it takes.

It's a shame to waste any of the remaining surface area, so you might want to consider adding in some simple utility options. One of the most useful is a "multiple." This is nothing more than a bunch of jacks that have been wired in parallel, sort of like a rack-mounted "Y-cord." See Figure 6. Multiples are extremely handy in the studio, since they allow you to drive several different devices from a single source.

If this approach appeals to you, then refer to Figure 7 which illustrates one possible layout. Everything fits readily behind a standard 1U panel (1-3/4" by 19").

Figure 8 shows the associated drilling guide. The printed circuit board mounts behind the completed panel on little angles, secured in place by some #4 bolts, lock washers, and nuts.

CHECKING THINGS OUT

And that's it! There are no adjustments to be made before using your new power supply. But do take a few extra moments to inspect your handiwork once more before you first plug it in.

If everything looks hunky-dory, take the plunge and fire up the circuit. Assuming you successfully pass the smoke test, get out your multimeter and verify that you have voltages reasonably close to +15V, -15V, and +5V available.

While this may have seemed a bit of detour from your usual activity of creating cool sounds, it will have all been worth it. For you now have the confidence that your valuable music gear is being powered by a stable and steadfast unit. And, with a full 0.75A available on each of the three lines, you shouldn't have to build another power supply for quite some time. So, start hooking up your sound modules and get back to doing what you like best: making music! **NV**