KPS-20 dual power supply
by Karl Shoemaker

K7SRG

Introduction:

This document is written to include interested people in serious construction of a quality product. Its rather technical however, if you have a basic electronics background with some repeater building experience this should not be an issue. Some of it's dry reading however, you need to spend time on this to better understand advanced circuits, later on. Understanding schematic drawings is required. If you are new at the repeater operation you might want to seek experienced help. Allow plenty of time to construct each unit, especially the first one. No free technical support is available however, some printed documents are available on an occasional bases, for a modest cost for P & H. The project is designed for amateur radio (not commercial) and is open for discussing, changes and improvements without notice. Should you feel qualified you are welcome to deviate from the Author's design. Images in this document may be used to illustrate a point only and may have been taken at different stages of research and development therefore, may not show the end "product" in some cases.

Overview:

This is a dual supply of 10 volts at 20 amps and 12 volts at 3 amps made for operating SRG's system remote transmitters. These ratings are rather conservative thus, continuous duty. Intermittently, current demands can exceed 10% safely. The main 10 volt supply component placement inside the chassis is engineered to accommodate variables, such as part substitution (and sizes) and ease of repairing. The 12-volt supply is mounted inside the chassis, as well, in a corner, out of the way. Filtering is used to work with most RF harsh site conditions. All the connections and indicators are on the front panel. Separate output terminals strips are provided for both supplies. The IEC AC line input cord is removable for easy transport (no snagging) and storage. The chassis is mounted in a 3 RU steel 19" panel. It has a removable top cover for good access of the components. Normally, the high current section does not blow the fuses in the event of an AC surge. The fuse holders on the left are for the AC and lower power DC sections, with indicators in the event of a trouble. This way the technician can immediately see what the (possible) source of the problem is when accessing the remote site.

Specifics:

The 12-volt section is for running the exciter sections of the Micor, or Mitrek transmitter. It can run both models of radios (for some sites) and be under the rating for this supply. The 12-volt output is protected with a high power stud mounted 16v zener diode in the even of a malfunction, causing over voltage it would blow the fuse in the unregulated section. Even though the supply is "bad" this would protect the transmitter exciter and the other (optional) station equipment. Be aware the earlier builds (version 1) did not use this diode. As time permits it will be installed in the older units.

The 10-volt section is for running the "large red" lead for the Micor (PA) or any link Mitrek's PA at the station. The idea of running lower voltage for the PA/large red lead is to reduce the IR (heat) generation and losses normally found with the conventional 12v high current supplies, such as the "stock" Micor station supply. Typical voltage for the 10-volt section is about 15.0 with no load however, pulls down to about 10~11 volts, with less than 15 mV of ripple while drawing 20 amps, for a +50 dbm (100 watt) PA (at rated power). Note: For repeater operation most PAs should be at reduced power, i.e. 2-3 db down from rated power and use a fan to push some air over the heat sink.

Inside the supply chassis there is a fan to draw air across the stud diodes, controlled with two N.O. bimetal thermo switches mounted on the heat sink. They operate on the "ground" side (low) of the fan and close at 120° F. Be aware some of the old units still have the 100° F switches in them. They will be replaced as time permits.

The windings on the secondary side of the transformer are removed twice, going each way. Half the bridge diodes are mounted on the chassis, with the anodes to the stud. The rectifier diodes are special "reverse" type stud, hence, the part number shows "R" in the "HFR" for reverse polarity. The other half is on the insulated heat sink and is conventional polarity. This reduces the need (by half) for floating heat sinks. To insulate this half, mica type insulators are installed between the L brackets and the aluminum heat sink surface. The insulators are doubled up to insure no chance of a short to ground. Nylon screws and nuts are used as well as shown here.

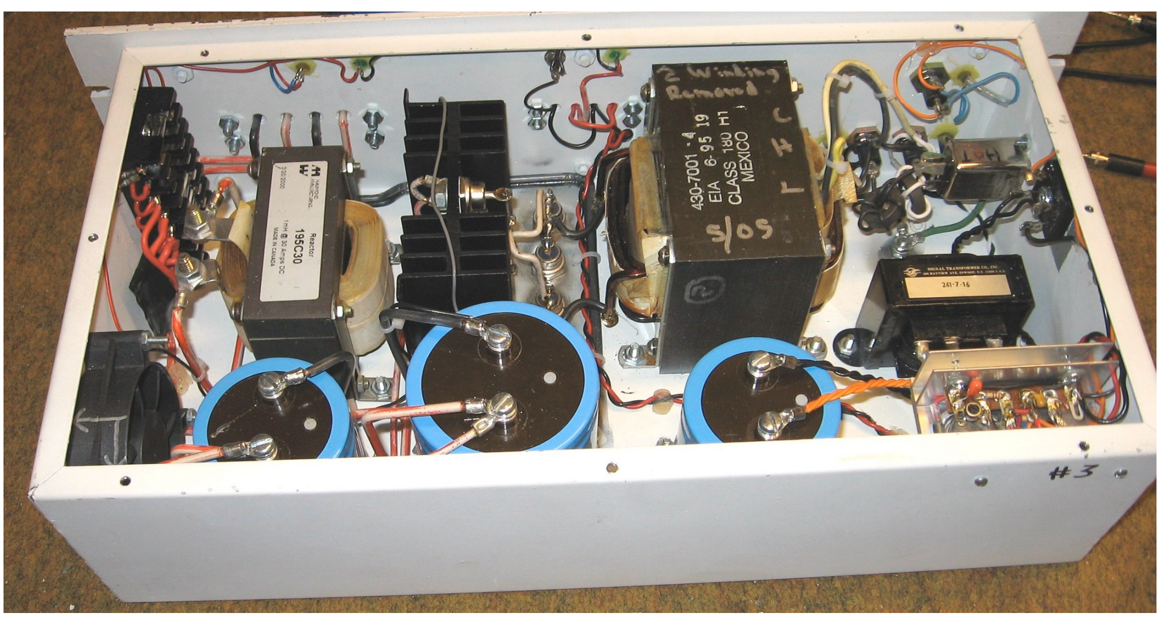
In the future, if a transformer with a center tap was found all this could be simplified with two half wave "normal polarity" stud diodes mounted on the chassis, with the center tap now being the positive. Some of these windings would need removal as well.

The line fuses (hot and neutral) and the 12 volt unregulated section are accessed at the front panel. The 10-volt section and fan fuses are inside the chassis.** All but the fan fuse have fault indicators. ** Lack of fan activity would indicate a problem there. Since there is no regulation in the 10-volt section there is little to no risk of the PA being damaged by an over-voltage condition.

Except for the prototypes and serial #1, the line cord socket and fan vent are on the sides of the chassis to allow maximum rear clearance, in the event of installing the supply in a shallow cabinet. Serial # 2~4 are almost identical, except for a few minor hole locations (such as the clamps) and routing of the DC wiring. Serial 5~on will have two fans on the side.

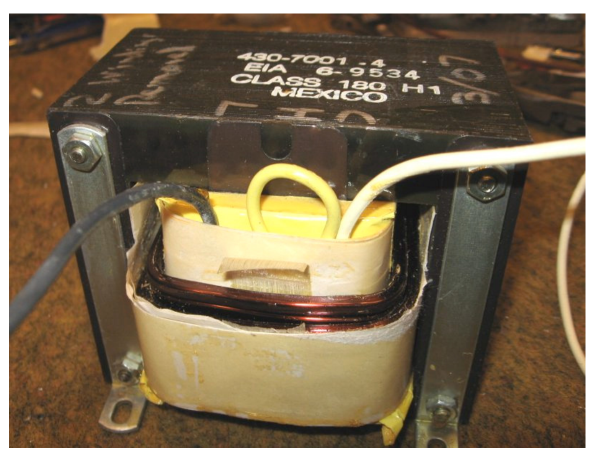
The completed power supply is then load tested for a minimum of 24 hours, typically 2 days, continuous. This is for both the 10 and 12-volt sections, running a station transmitter or DC load.

Shown below is a typical completed unit. The cover was off only for the photo. This was taken after a routine load test with typical equipment attached to it (Micor transmitter and Mitrek radio) running a +48 and +41 RF output, respectively.

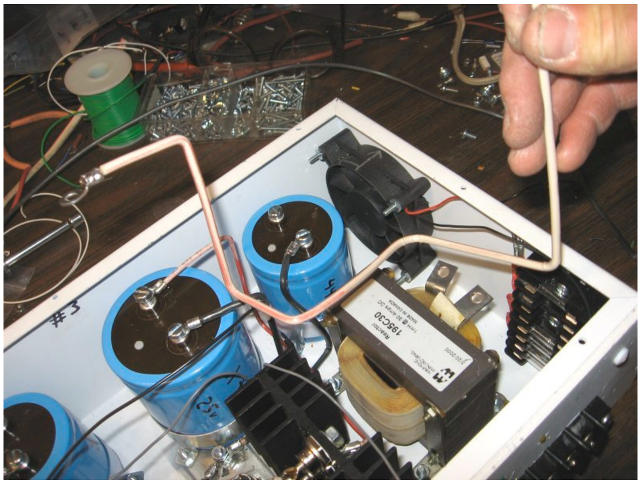


Shown is the rear and the side vent for the fan which is controlled by thermostats mounted on the heat sink of the diode rectifier of the 10-volt supply section. Yes, the Author drilled all those little holes by hand drill. Now, it will be different with version 2.

The other side has the AC power input which is an IEC (International Electromechanical Commission) "plug" type C14 with RFI filtering built-in. "Plug" because it's a male type; load side of a device because of it's filtering its actually a PEM (Power Entry Module). This type of plug is very common and will accept type C13 socket on a cord, widely used in PC and many other electronic devices today. The cord used is a 90° right angle to clear most cabinet sides. Originally, they were installed up towards the front. It was later discovered the rack's rails prevented ample room to plug in the power cord. Therefore, the AC plug was moved towards the rear while installing a plate over the old hole as shown here.

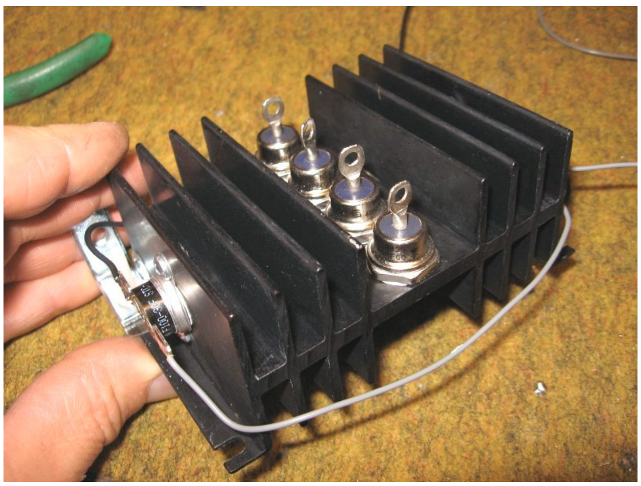


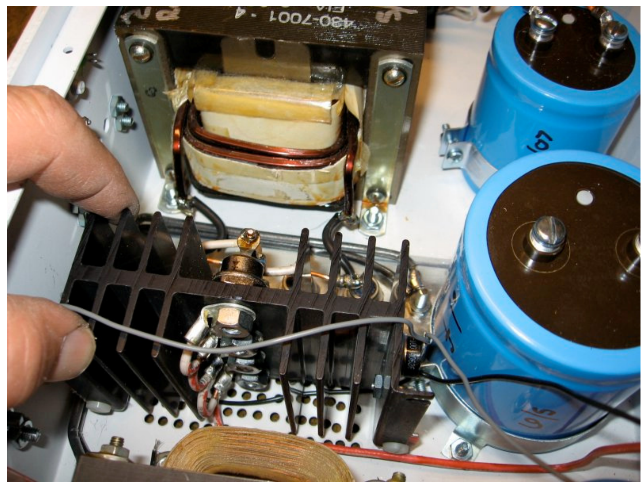
The large "7001" transformer is the "heart" of the supply (right mage). What makes this one nice is its open-frame design makes it somewhat easy to remove the secondary windings to obtain the (proper) 10 volts for this design. After this the leads may be a little loose and vibrate under high current so some RTV is dabbed on the exit points to stabilize them.

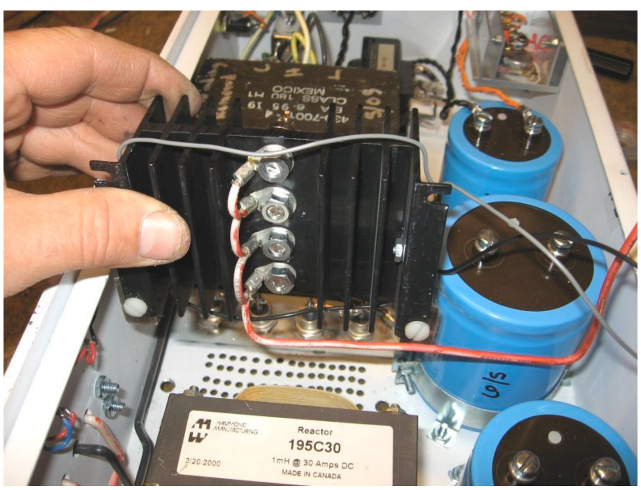


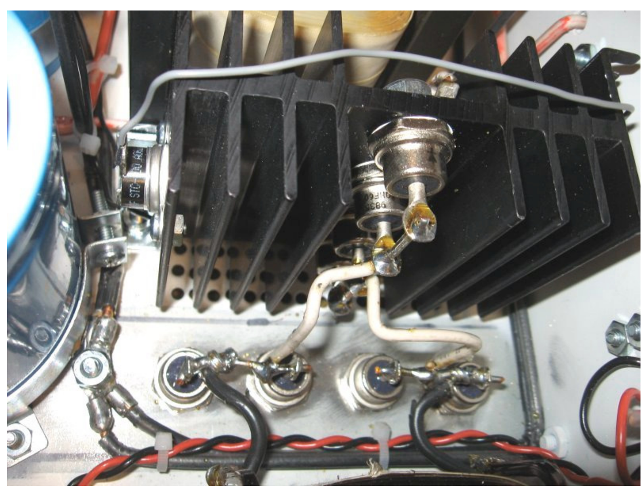
Being assembled here is the ripple filter section for the 10-volt section, with a 1mh/30-amp choke in the center. This was the most expensive part of the whole project.

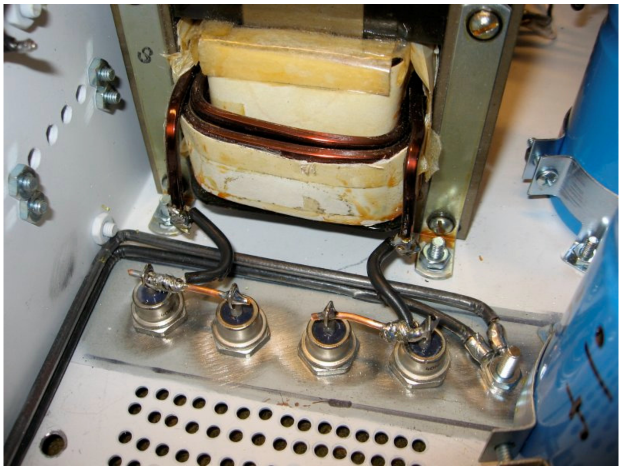
One of the most research and engineering area is airflow for cooling the rectifier diodes. A nice heat sink for half of them was found years ago as shown here. You can see the thermostats to control the fan. They are normally open and close upon temperature rise. During past 20-amp load tests it was found the 100° F ones stayed on the entire time. Therefore, version 2 uses 120° F ones. Two of them are paralleled for additional reliability. In the event you do not wish to obtain and use these (hard to find) thermostats you could leave fan running full time. The Author choose not to do this, to reduce dust contamination and increased fan life.

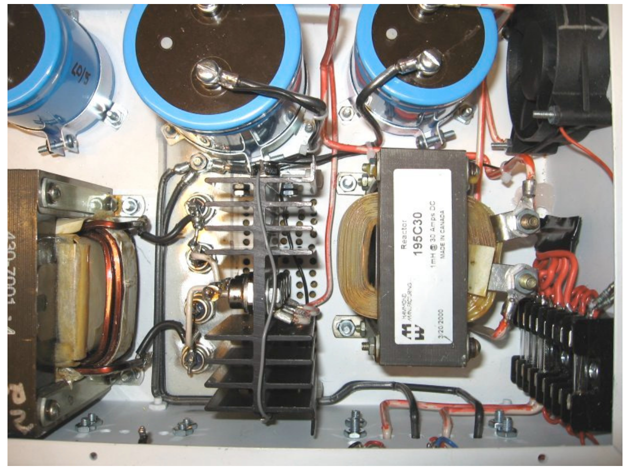




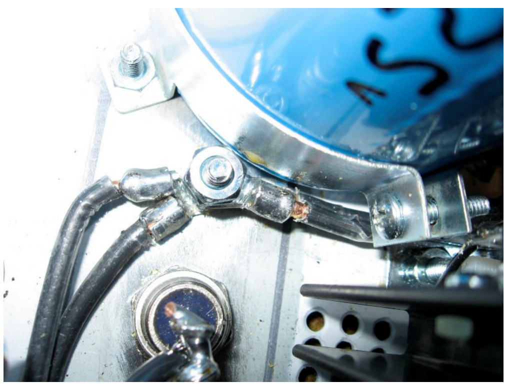


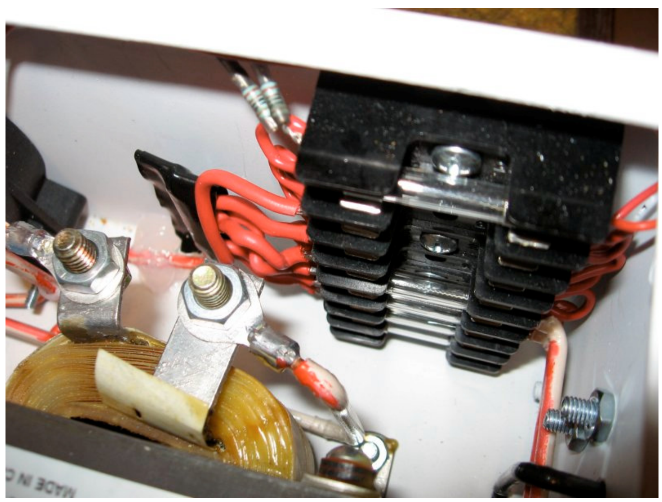






This is the other side of the rectifier. The heat sinking is done directly to the chassis. As previously mentioned, special type of reverse set of diodes are used so the anode goes to chassis ground. The common ground point is shown on the lower left image. On the right is the 10v fuse array. Version 2 with have an ATC fuse external on the DC (red) line cord.



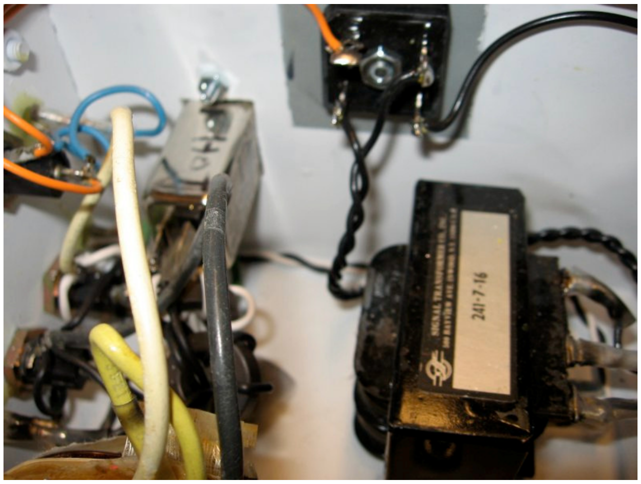


A word about the filter capacitors.

The 10-volt amp C-L-C section uses two. The primary (C1) is a .12 F (120 mF), then feeds a 1 mH choke, then to a second 33 mF* capacitor (C2). This design will supply the proper power to the radio transmitter’s PA, which draws about 20 amps for the +50 dbm rating of RF output. At this draw causes less than 20 mv of AC ripple. This is an outstanding value, considering the simplicity of the whole supply circuit. The first capacitor and choke values were necessary to maintain this specification. If you have trouble finding a source for C2 you can deviate from the above value, say between 47 ~ 33mf. Going any higher does not have any advantage for the ripple but may satisfy the distributor's limitation of quantities. Your biggest challenge will be finding a capacitor that stays within the physical limitations, which was designed for a 2" diameter and a 3 1/2" length component. You'll get the part numbers from the part list on another document on SRG’s site.

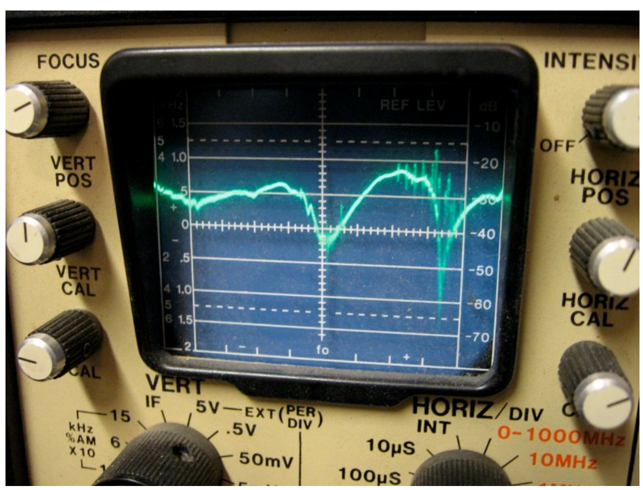
*33mF = 33,000uF. Optionally, a 47mF cap can be used as shown in the schematic diagram.

As of 2023 C1 was found in smaller cases and will be replacing the larger ones as they reach end of life.

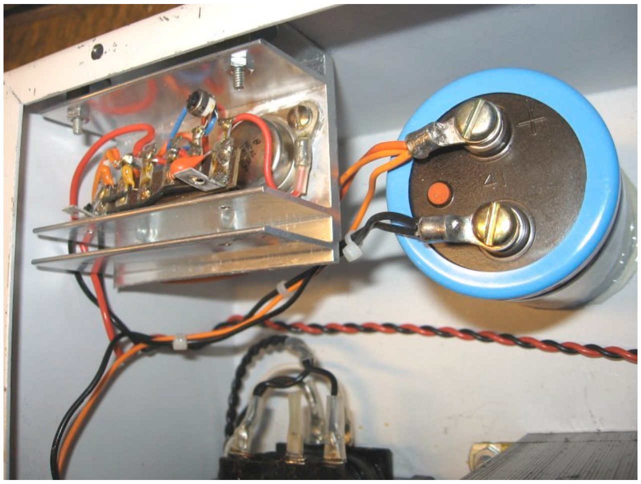


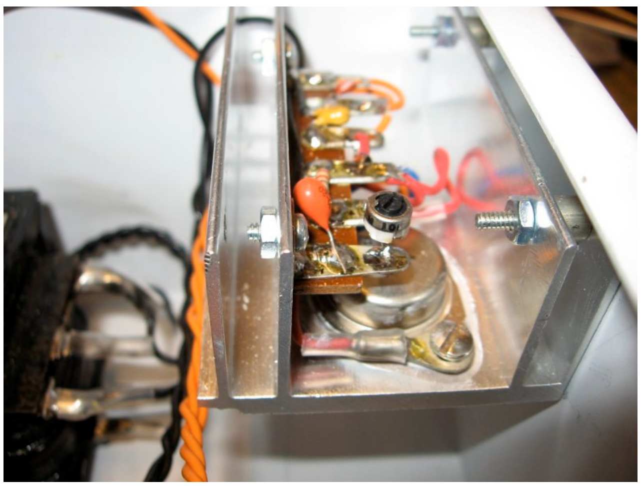
This is the AC entry area and the 12-v section. T2 was easy to find, by "Signal Transformer". The picture below is another view of the 12v transformer, plus shows the AC entry IEC (RFI filter) point. Some surge protection was used. with some MOVs on the AC input.

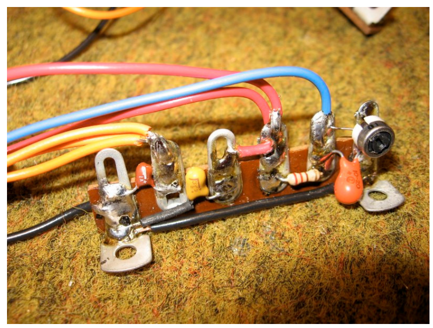
Then the line wires are looped through a set of toroid rings for FM-broadcast sites. The number of turns were determined by sweeping the area of 88~107 MHz. As shown on the right image.



Here’s the 12-volt regulator section. The main device is the LM338 IC in a TO-3 (K) case with a smaller heat sink. It's a really slick device requiring a few components to operate and is adjustable. Obviously, the 12-volt section does not need much heat sinking or dissipation. The bottom left is the control strip for the regulator I.C. In 2023 a TO-220 case was found for the regulator.







You might have noticed some of these pictures are of another serial being built, with some of the parts in different locations, but electrically, the same. This may be necessary should you have a problem obtaining the proper sizing of capacitors, as discussed before.

Here’s the unit being load tested of the 10v section at two different drains; 17 and 20 amps. This also checks fan cycling.

The lights were mounted in rows on a box, with a terminal strip and jumpers to select what current draw to test with. The test set is capable of a 40 amp. draw, however, the normal tests are performed in the 18-22 amp range. The one exception is the overload test for version 1. For this, 40 amps are drawn to purposely blow the fuse array, which is rated at 32 amps. (4 x 8 amp MDL fuses). This test insures the overload protection works properly. The low cost of the fuses is worth the test.

To measure currents greater than 30 amps (as the fixture is set for) the Author built and calibrated a shunt device to work with the Fluke 77 meter, as a 10:1 converter. Therefore, 1 amp on the meter = 10 amps on the test circuit, etc. The Author used automotive headlights (in parallel) to provide a safe, effective load for this test.

Most (old) fuse holders are not designed properly for high, full duty current draw. Two designs are the "Motorola Micor" AO1 and A02 type (inline) fuse holder, while GE's version is the "AGU" type holder. Both work pretty well for mobile (part time transmit) applications however, can have a heat problem for 100% duty cycle applications. Most fuse holders actually touch the fuse's housing only in a small portion, either on the ends (as in Motorola's case) or with "clips", thus, on each side of the round part of the fuse's housing (in GE's case). This is a rather small area to pass (up to) the supply's rating; in our case, 20 amps. Obviously, you'll be fusing the power supply for something higher; typically 30 amps for the blowing point.

For this version (1) of design the Author choose to use four (lower rated) MDL fuses, in parallel, for a few reasons:

1. The current will be better (shared) distributed over more surface area, over the several fuse's housing's surfaces.

2. MDL fuses are easier to obtain, even at most any hardware store. The idea is, if a short should occur it would take all four fuses out. The cost is about the same as one (large) AGU fuse replacement. Several (bench) tests have been performed with this arrangement, such as a 1-day continuous load test of 20 amps with no problem with the fuse section. One site is running this fuse arrangement since (about) 2003 with no problems as of printing date of this document.

3. Large fuses (such as the AGU size) are expensive and hard to find in the slo-blow version.

Therefore, SRG Specifications are:
Input: 110~125 volts AC, 60 Hz, IEC type C13 connector, Input filtering: C-L for RFI protection.
Output-1 is 12 volts DC (adjustable); Rated output-1 is 4 amps continuous, 5 amps intermittent.
Output-2 is 10 volts DC (typical 10.5~11.5).
Rated output-2: 20 amps continuous, 25 amps intermittent, ripple typically 10 mV @ 20 amps.
Fuses: AC input 5 amp MDL (hot and nuet); 12v supply 5 amp MDL; 10v 8 amp MDL x 4 (in parallel)
Size: 17" wide x 9.25" deep (with ¼" front panel) x 4.75" high.
Weight: 35.5 lbs.
Storage temp: -30° ~ 130°F
Operating range: 20° ~ 110°F
Chassis: Mild steel, 16 gauge, with top cover and screws
Panel: Mild steel, 16 gauge or thicker (.065"), 3 RU and mounted to the chassis (box).
Color: Typically white or cream.

Version 2 will have one 10v DC fuse, box depth will be increased by 1", no panel but mounting ears, two fans, more indicators and weigh slightly more.

On May-15-2007, Serial #3 was load tested with measurements. For the 10v side:

AC line voltage: 121.0 volts. AC line current: 2.67 amps; Therefore, AC power consumption was 323.07 watts of power. DC output ripple was 14 mV. Voltage was 11.68 volts. Current (six lamps): 24.8 amps; Therefore, DC power consumption was 289.664 watts of power (11.68 x 24.8 = 289.664) therefore, AC to DC conversion efficiency of this unit was at 90% (289.664 div by 323.07= .8965982, or 90%) which is very good.

The 12v side was separately measured with no AC figures at that time and only 3/4-rated test (one small lamp). The DC (adjusted) voltage was 13.03. Current was 1.46 amps. Ripple was less than 1 mV which is excellent.

More general notes:

For the load test some of the components do get hot, such as the large diodes and eventually T1. Having said that they still operate within safe temperatures. For observation and testing you can work with the top cover removed, however, for long term loads it should be left installed as not to disrupt the airflow (for cooling). Air is sucked from the bottom holes, across the diodes and out the right side, with the fan. The fan runs off the 10v-side and is fuse protected with a 1-amp, located inside the box.

Most of the items are obtained with the usual mail-order stories, such as Mouser, Digi-Key and Jameco Electronics. The main transformer, T1 for the 10 volt section, was very difficult to obtain at a reasonable price with a rating of 35 amps at 12-14 volts. One vender of Hosfelt Electronics carried these around the turn of the century, then ran out of stock. Several were eventually found before the source ended. Take this into considering if planning this project. After some searching and posting on news groups the Author found them on ebay and a store in Ohio, with some help from a "local" there to mail them. Three of them were about 40 pounds to ship. There's two "versions" of T1 found, with either the number of "430-7105" or "430-7001". It's unknown if both are the same 35 amp rating. The 7001 appears to be slightly larger in width. Both are rated for high temp (180° F), and there's a slight difference in the primary leads; one has one more lead for more variance strapping for different secondary voltage however, by removing some of the secondary windings this is insignificant. Also, there's a difference in the mounting holes. If you are building several units you may consider choosing to use all the same transformer type. For this project the Author choose the 7001s. Four units (not including the prototypes) were built. Perhaps more units may be built in the future when a good source of chassis is found. This will be version 2.

Remember to take your time and measure the holes with a straight edge to produce a good-looking front panel. The side holes (for mounting components) are not as necessary to get completely straight. A good example is the many holes for the fan and heat sink airflow. Without a template it's difficult to get them all lined up. As of 2025 the Author found a vender with automation for the holes.

If you have more than one supply to build it's more efficient in lots. Kind of like an assembly line, which is the bases for most manufactures and factories. The Author's last "batch" was in a lot of two units. Last note: Earlier design called for a 22-amp rating, since then it has been reduced to the 20-amp rating. There may be some drawings or other document reflecting the old rating. Even though the supply will run 22 amps (or more) a more conservative figure was decided in 2014. This is mainly for better control of the heat generated on the diodes and reliability.

It's best to have an "example" unit already made up, so you can see all that needs to be done. Take your time and you'll "duplicate" a nice unit or units. In this "batch" the Author built two more additional units, to finish the power supply project. The 3 RU panels were commercially made, and obtained from surplus leftovers therefore, would need some painting, etc. The boxes were custom made from a metal shop (as donation) from mild steel with a top cover. The corners were "sealed up" for strength, by lightly welding the edges, then grinding the rough areas.

First, mount the panel on the front of the box. Then with the "example" (completed) supply, all the holes (and each of their sizes) can be transferred, marked, drilled and cleaned up for each unit on the assembly line. When the front panel holes are done, remove it from the panel. Then clean (rim out) the holes. This can be done with a larger bit

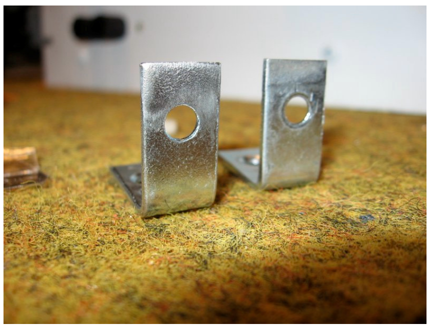
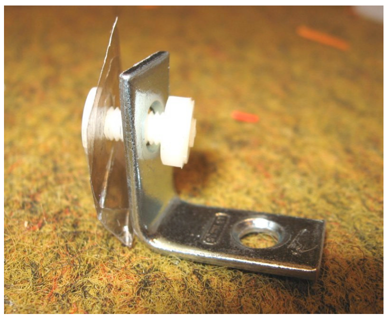
The (side) connector for the AC input will need to be drilled with a 3/4" bit then cut out with a recep saw, then filed for a clean hole for the connector.

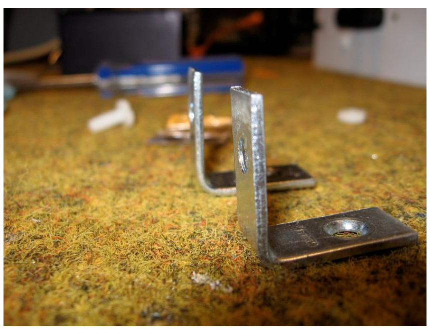
With the holes drilled on all sides, you will be ready to install the components and wire them up.

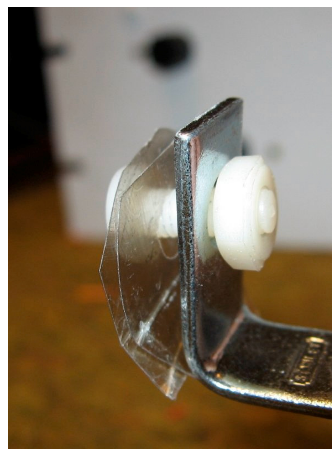
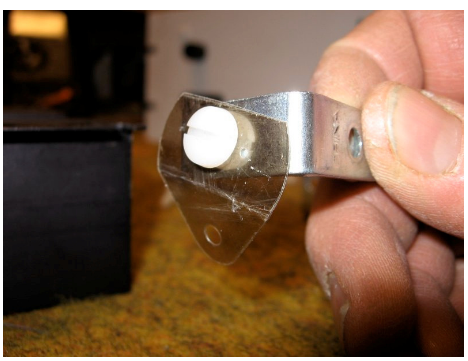
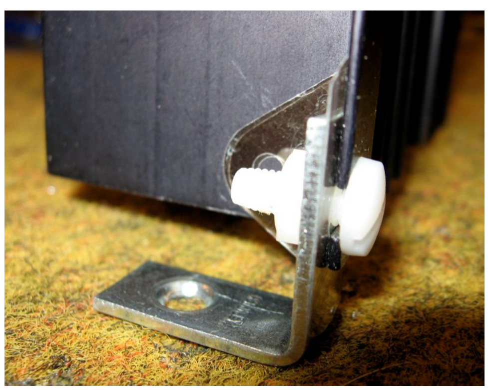
For the total holes, in the front there will be three 1/2" holes (for fuses). There's eleven 3/16" holes, plus, holes for the terminal strips that you choose to use. Tip: drill over sized holes for the wires behind the terminal strip to insure the wires clear the holes without abrasion. There's twenty on the bottom, less the airflow holes, which, again will depend on the density you choose for them. This should add up to 32 holes total for the front. There are two 1/8" holes for the rear.

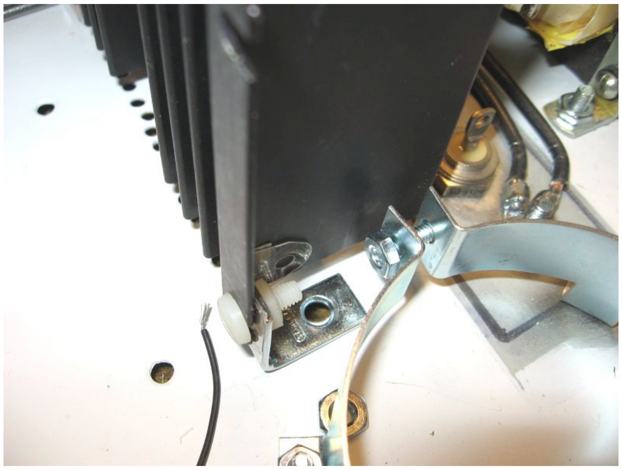
Also, there's three on the left side (less the rectangle hole) and nine holes on the right, less the numerous ones for the fan airflow. That will depend on the density you choose for them. As mentioned before, the location on the power plug was later changed and moved towards the rear.

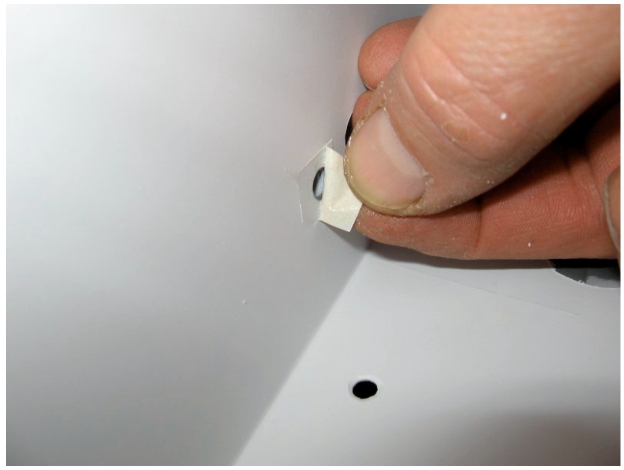
Here are some additional images concerning the heat sink for the 10-volt section. Also, shown are some details on the heat sink isolation from chassis ground.







There's twenty on the bottom, less the airflow holes, which, again will depend on the density you choose for them. For the ground connections you'll need to mask off so the painting keeps it clean. This is for the heat sinking for the diodes and a few ground connections. For the latter, you might hit them with a wire brush to ensure a good electrical connection. This can be done before or after painting. For version 2 the hole count may be different.

As you can see some of the filter caps brackets were a close fit being near the other areas. Version 2 will be a one inch deeper to ease up this challenge.

** As of 2025, there will be a design change of some items:

- A second fan on the right side. This makes better air flow, plus some redundancy.
- A "fans running" indictor in the form of a green LED on the front panel.
- Each fan will have fuse fault yellow indicator on the front panel.
- Additional, other indicators, mostly likely.
- The front panel is not use, but a set of "ears" for each side for 3 RU mounting. This also will save on labor to ream out two sets of holes (panel and box front).

Another: Due to changing times with the industry the LM338K (TO3 case) and some heatsinks are no longer available therefore, more research and changes will be made for future builds on this product. The T type (TO220 case) is still around so that will be used for version 2 and version 1 repairs if they perform correctly.

The Author felt some clarification was needed in 2025. As described earlier, the AC power connections use IEC (International Electromechanical Commission) C13 and C14 types. This type of receptacle and plug is very common and will accept type C13 socket on a cord, widely used in PC and many other electronic devices today.

On the lower left shows the cord from the grid with this C13 end to power equipment which plugs into the (C14) connector as shown on the upper left, that's normally part of the equipment. Shown here is the chassis mount type as use in this power supply project. The only difference for this project is that it uses a filter unit with the C13 arraignment.

C13

For comparison this is a typical power cord showing the AC grid side using a 8-15P plug. It also shows the standard wiring arraignment as shown above.

In 2023 some more research and test were performed. This was concerning the first two filter capacitors in the 10-volt section of C1, C2 and the 10-volt output. The tests were performed at three different output loads of 0, 17 and 20 amps approximately. The middle load is typical for SRG's remote transmitters.

As seen on the next page, the (slightly) best combination is a 120 mF and 44 mF for C1 and C2 respectively, for a ripple output of only 10 milli-volts running at the supply's rated output of 20 amps.

As C1 may be difficult to obtain in the 120 mF a 100 mF value would be a reasonable substitution at only a slight cost on the output ripple as shown on the first test.

Both of these points are using L3 value of 1 mH at 30 amps. All three components are selected for filtering of 120 Hz, which is the result of a full-wave rectifier from USA line frequency of 60 Hz.

C1 dark blue			C2 light blue			
C1 value in mF >		120	C2 value in mF >		44	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.59	14.67	14.67	2	1	1
17.2	12.36	12.10	11.98	227	10	8
20.0	11.95	11.67	11.51	265	11	10

C1 light blue			C2 light blue			
C1 value in mF >		100	C2 value in mF >		44	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.58	14.57	14.63	2	0	0
17.5	12.15	11.96	11.79	260	10	10
20.0	11.94	11.68	11.47	294	11	12

C1 black			C2 light blue			
C1 value in mF >		100	C2 value in mF >		44	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.60	14.57	14.59	3	1	1
17.2	12.14	11.88	11.77	305	12	11
20.0	11.92	11.66	11.47	344	14	13

C1 dark blue			C2 dark blue			
C1 value in mF >		120	C2 value in mF >		30	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.58	14.57	14.63	2	1	1
17.2	12.13	11.91	11.72	236	14	14
20.0	11.91	11.68	11.65	268	17	16

C1 black			C2 dark blue			
C1 value in mF >		100	C2 value in mF >		30	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.58	14.57	14.63			
17.2	12.43	11.94	11.84	308	19	18
20.0	11.97	11.73	11.59	344	21	20

C1 Black			C2 light blue			
C1 value in mF >		150	C2 value in mF >		44	
Load In amps	C1 DC In volts	C2 DC In volts	DC Output In volts	C1 AC In mV	C2 AC In mV	AC Output In mV
0	14.87	14.86	14.87	0	0	
17.2	12.22	12.04	11.83	239	10	Not tested
20.0	12.04	11.79	11.62	255	11	Not tested

Spokane Repeater Group's web site: http://www.srgclub.org