



## Power Supply Restoration

This document presents theory and practical applications to facilitate restoring linear AC Line operated power supplies - specifically 13.80 VDC- that have failed. While not a simple step by step repair guide, enough detail is presented for technically savvy individuals to re-build non-functioning linear power supplies.

Rev C of this document was prepared in Sep 2013 based on input from numerous Hams who restored old Astrons. Hopefully, these updates clarify and expand on the previous version.

For more detailed and specific information see the [PS-15D-\( \)](#) on [bwcelectronics.com](http://bwcelectronics.com)

### Disclaimer:

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# Power Supply Restoration

## Introduction:

I have been involved with electronics since the 1950s and have been asked to repair a lot of linear AC Line operated power supplies, I have always enjoyed power supply work so I was glad to help. This document compiles some of that experience and knowledge, from which I hope someone else may benefit.

A lot of commercially built power supplies are designed and built well, however some - especially those intended for Amateur Radio use or consumer sale - are not very robust. I have seen a few that are very poorly designed - certainly **not** something I would connect to my several hundred dollar radio.

The two most common short comings seem to be; 1) the definition of ICAS (intermittent commercial and amateur service) and 2) the use of the old, very poor uA723 voltage regulator monolithic. Herein lies the cure for both - as well as several other afflictions.

ICAS is a simple fix. For a given size transformer, heat sink area, rectifier type and shunt capacitor the continuous and intermittent performance can be established. The problem seems to lie with the liberties taken by those marketing power supplies. This document presents sufficient engineering detail to establish actual performance based on the component ratings and environmental conditions to be experienced.

The uA723 removal is also pretty simple. A small, inexpensive, printed circuit board is available from [Far Circuits](#) that replaces whatever control circuit has failed in an old linear power supply. The control circuit on this board is all transistor (no monolithics), very simple, inherently stable with excellent regulation and robust in high RF and surge prone environments.

This document is also instructive for those planning to purchase a station power supply. SMPS (switch mode power supply) technology has matured sufficiently that good designs are now available that have cost, size and efficiency advantages over linear designs. Even though I designed SMPS for Rockwell/Collins, I still prefer a big heavy linear for my station power supply. Even though new SMPS are good, they still are more complex, contain high voltage switching artifacts (noise), operate with high levels of component stress, have more output ripple and poorer (though sufficient) regulation. The last failure I want in my station is the power supply and the linear design presented here supports that requirement.

The first section of this document covers the basic regulator circuit design, options and implementation notes. The second section covers ICAS rating and actual operational limits for linear power supplies. The third section covers a typical rework of a dead power supply.

## Regulator:

The simple but high performance regulator is a three transistor, 13.8 VDC controller with fold-back current limiting. Table 1 summarizes the regulator's features. See the PS-15D-( ) manual, [PS15D090](#), for complete specifications, List of Materials, and theory of operation.

**Table 1. Regulator Characteristics**

Extremely rugged
Tolerant of lightning induced current and voltage
RFI/EMI tolerant
Very simple
Grounded pass elements (if desired)
Excellent regulation, low noise + ripple, low output impedance, excellent transient response - not even specified for most Amateur Radio/Consumer products - and very stable under varying load conditions
Fold-back current limiting
Scalable from 3 to 30 Amps
Adjustable 12 to 14 VDC
Low reverse leakage (for charging secondary battery)
LDO (Low Drop Out) - operates with very low input - output differential improving low line performance
Can easily be reworked into most commercial power supplies
Simple 5 kW transient (surge) and reverse voltage protection

## Basic regulator circuit

See Figure 9, PS-15D-5 schematic.

The regulator is a low side, low-drop-out circuit. Several of this design's benefits are; option of grounded pass transistor cases, functional with low differential voltages, drive voltage is less than output voltage - thus no boost winding required, high transconductance, and inherently self starting even with transient conditions during power up.

Q1, an IRF520 power FET, is external to the regulator assembly and completes the basic 3 ADC driver for the pass transistors. A small gate voltage change on Q1 will result in a large source current change, so voltage regulation is easy to achieve for varying load (or line) conditions.

Q203 provides a high gain ( $h_{FE}$  of 600 to 1400) and inversion as the final stage of the control circuitry. C203 provides phase retardation to stabilize the control loop. R214 provides turn-on bias for Q1 thus ensuring start up with any sequence of AC power on/off, load condition, or during intermittent AC power failures. Q203 under, feedback control, draws the proper current through R214 to establish and maintain loop control.

Q203's base drive is either from Q201 or Q202 through R211. R211 only serves to protect Q203 in a fault condition where a path from the negative input directly to the positive input could establish its' self through Q203, Q201 and D202.

Q201 and Q202 are high gain ( $h_{FE}$  of 250 to 700) PNP input stages for the control loop. Q201 provides voltage regulation by comparing a fraction of the output voltage (through R201, R202

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and R203) to the reference voltage of D202, a 1N5232B zener diode.

The negative voltage coefficient of Q201 BE junction is partially compensated for by the positive voltage coefficient of D202, thus providing some temperature stabilization. Note D202 is biased by the output voltage, thus effecting a constant current feed for D202 and so eliminates input voltage fluctuations from effecting the reference voltage.

Voltage or current control is automatically switched between Q201 or Q202. If the output current is below the preset value Q202 will be turned off and Q201 will control the loop (voltage regulation) as described previously.

However, when output current becomes sufficient to bias on Q202, it will begin to conduct and take control of the loop (current regulation). R209 and R210 provide an emitter bias that is a function of the output voltage. This emitter bias will lower the effective current limit as the output voltage drops and therefore effects a current fold-back which protects the pass transistors.

D201 is used to bias Q202 up slightly so that only 300 mV is required across the sense resistor, R208. A secondary benefit of D201 is to provide some temperature compensation for Q202's BE junction. R206 and R207 set the initial current limit level and R209 and R210 set the fold-back current level (but with interdependence).

R208 is mounted on the Regulator Assembly for low current versions, but should be externally mounted for the PS-15D-5 (Astron refurbish).

With R208 externally mounted, strap S201 should **not** be used. R208 should be wired conveniently from the DC fuse to E202 (same as S201-B). E209 should then be wired directly to the (+) end of R208, near the body of the resistor. S201-A is wired directly to the (-) end of R208, again close to the resistor body. This method of wiring will preserve the accuracy of the current limit and monitoring and is referred to as a Kelvin or 4-wire connection.

If the Regulator Assembly is not mounted directly on the output terminals, some loss of regulation may occur due to the wiring resistance. Also, the output impedance and surge protection will be degraded as the lead length to C201 and D203 increases. It is highly recommended that the Regulator Assembly directly mount onto the output terminals.

In earlier versions I recommend the Negative output terminal be grounded to the chassis. This is appropriate in controlled applications of single point grounding, but I find that the typical ARS often does not lend itself well to this regimen and often is not understood well enough for proper installation.

I now recommend the Negative terminal be insulated from chassis. Proper single point grounding is still possible, but more importantly, there is far less chance of unintentional ground loops. For more information on grounding see <http://www.bwcelectronics.com/articles/WP30A190.pdf>

## Pass transistor(s)

I recommend the pass transistors be replaced with 2N5886 types. The 200 Watt, 25 Amp rating is a very good value at around \$4 each. With a minimum DC gain of 20, only 1.5 Amp (max) drive is required from Q1.

## Heat sinks

While Astron does a pretty good job, the heat sinking for the RS-35M, in Figure 1., is insufficient for true CCS (continuous commercial service) at 25 ADC output. At 117.0 VAC line input and 25 ADC output at 13.80 VDC, the pass transistors dissipate about 120 Watts. Astron's heat sink appears to be a Aavid-Thermalloy 11942 extrusion which is no longer listed in the OEM database. A 1990 vintage catalog lists the extrusion with a  $R_{\theta}$  of 0.8°C/W when mounted with the fins vertical and a 50°C sink to air differential, thus 50°C/(0.8°C/W) = 62.5°W capability. Interestingly enough, the heat sink measured 65°C with 12.0 ADC load in which case the pass transistors were dissipating (19.0 - 13.8V)12A or 62.4W for  $R_{\theta}$  = 0.7°C/W ( $T_A$  = 24°C).

For true CCS without forced air cooling requires an unbelievable large heat sink - much larger than found on consumer products. If 25 ADC output is required of an Astron RS-35M, forced air cooling must be used to control temperature rise.

## ICAS Ratings:

ICAS (intermittent commercial and amateur service) specifications can be misleading. Marketing types are quite liberal with the definition and do not seem too concerned about the engineering correct specification. Proper ICAS rating will establish the extended conditions under which a power supply can operate without excessively stressing any components and is related to the CCS (continuous commercial service) by Equation 1.

$$P_{ICAS} = P_{CCS} \sqrt{\frac{(T_{ON} + T_{OFF})}{T_{ON}}}$$

Equation 1.

Thermal equivalency can be used to predict ICAS performance if CCS is known (and vice versa). Basically when the duty cycle is reduced from 100% to 50%, the equivalent heating is reduced to 70.7% - not 50%. The above relationship is only valid for designs that ensure sufficient margin for all component stress levels at the ICAS power level.

This thermal equivalency would mean that a power supply rated at 35 ADC ICAS should operate at 25 ADC CCS. However, a necessary detail is often omitted in advertised specifications, that is, what is the maximum time the extended load can be applied and at what ambient temperature. The maximum "on time" is a function of the temperature critical components' thermal time constant and the permissible ambient temperature is a function of the design's thermal margins.



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Beware that many commercial power supplies sold into the retail Amateur Radio market will exceed +80°C at full load (even within the advertised specifications). The success of these sales result from the fact many applications are for SSB or other intermittent loads. But, if your application is FM, digital or other “brick on the key” modes, you will have problems with some of these “ICAS” rated power supplies.

For example, the RS-35M shown in Figure 1. was tested at 13.8 VDC and 25.0 ADC load (the Astron advertised CCS rating) and 117.0 VAC line voltage. After 30 minutes the heat sink rose to +81°C and was still rising. This is 178 °F - well above the recognized scalding temperature of water and while emersion is not the same as tactical exposure, this is still too hot for desk top equipment. Thermal analysis indicates 2N5886 replacements for the OEM 2N3771 are still within their SOA, but this is an unacceptable temperature rise.

When limited to +65 °C heat sink temperature the RS-35M is only capable of 12.0 ADC continuous output current at +24 °C ambient and 117.0 VAC line. With forced air cooling from a 4 inch square muffin fan (100 CFM) the power supply was able to run at 25.0 ADC output current and reach a stabilized heat sink temperature < 50 °C and a transformer core temperature of 82°C.

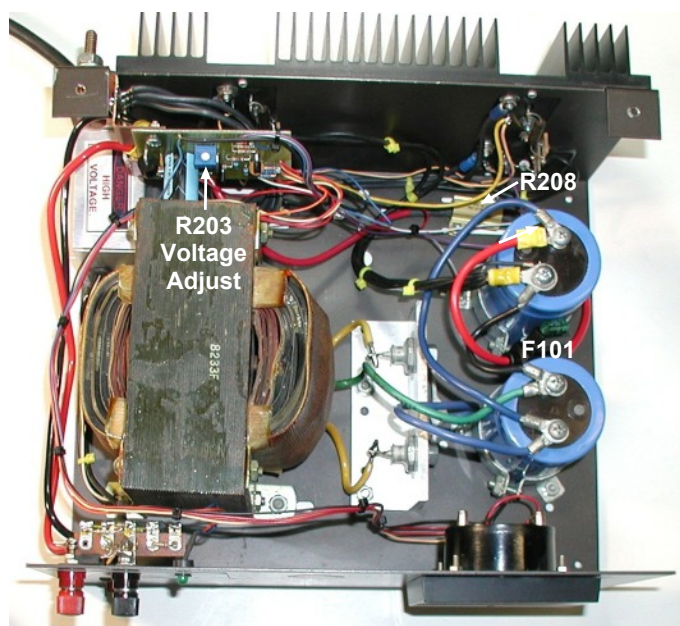


Figure 1. Astron RS-35M after rework.

## Restoring a power supply:

Restoring an Astron RS-35M power supply. The example in Figure 1. was damaged by a near-by lightning strike. When I was asked to help, I offered to refurbish it with the PS-15D-5 design which simplified and improved the power supply.

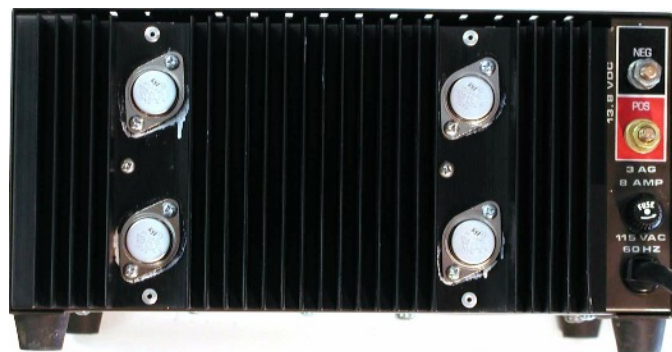


Figure 2. Astron RS-35M rear panel with new pass transistors.

### Clean it out

**Note: This is a refurbish project and NOT a drop-in replacement.**

The first task of restoration is to remove and discard the old regulator circuit and all boost voltage components - the PS15D102 regulator needs no additional voltage. Be sure the cut ends of the transformer's auxiliary winding are insulated and tucked away.

Next, remove the pass transistors and sockets. Replace with 2N5886, using insulator kits and thermal compound but NO sockets. These key components are worth the investment.

When I refurbish a power supply I actually strip it down to the bare chassis. I clean and paint, if needed, the chassis and then rebuild.

The PS15D102 contains a 5KP14 SAD (silicon avalanche diode) which provides very fast transient over-voltage and reverse voltage protection. It also provides steady-state over-voltage protection, however in so doing it normally fails shorted - protecting the load, but requiring replacement thereafter. I have had requests to include an SCR over-voltage crowbar to perform the steady-state protection. This technique, while somewhat prone to false trips, may be reset (for a non-hard failure) by cycling the AC power. The details of the stand alone SCR crowbar are included in Figure 10. The DC fuse may be eliminated in this configuration, but be sure the AC line fuse is a normal acting 8 Amp, 125 VAC type.

The older versions of the RS-35M power supply has 1N1184A stud rectifiers mounted to the chassis bottom. I suggest these be removed and mounted to a 0.25" thick aluminum bracket as shown in Figure 1. Note the rectifiers must be mounted with an insulator kit. If a complete tear-down is not required, an acceptable option is to leave the rectifiers mounted as-is and insulate the protruding studs with heat-shrink tubing.

Figure 3 shows the results from a rectifier analysis program, see <http://www.bwcelectronics.com/articles/WP10A190.PDF>, that reveals the Astron design is acceptable from a component

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## RECTIFIER DESIGN ANALYSIS

The older Astron RS-35M power supply design used 1N1184A rectifiers and a pair of CDE screw terminal filter capacitors. The results shown here indicate the component stress level is acceptable up to 35 Amp output, but only for restricted duty cycle operation.

The 1N1184A rectifier is rated for 40  $A_{av}$  forward current and the calculated forward current is 38.97  $A_{rms}$  (indicating the average current, which is lower than the rms current, is within spec). Note the peak repetitive rectifier current is 137 Amps. The  $I_{FSM}$  is 663 Amps, again within the 800 Amp spec. The in-rush limiter shown on the schematic was added to reduce this current. This not only limits the stress on the rectifiers, but it reduces the line surge at power on.

The capacitor ripple current is calculated to be 45.5  $A_{rms}$  for 35  $A_{DC}$  output. This exceeds the capacitor spec of 32.8  $A_{rms}$  for two parallel capacitors. However, if duty cycle limitation is adhered to the capacitors' stress level is acceptable. Note, ripple current and ambient temperature are the aluminum electrolytic capacitor's two major life-limiting factors.

The voltage and current plots are for the first six half cycles after power is applied (note the analysis assumes power is applied at a zero crossing of the input voltage - an unlikely event in practice). Even so, the first rectifier current peak is 325 Amps and the capacitor current peak is 300 Amps (the capacitor current is dashed).

A scope will not reveal the voltage difference between the rectified AC peak and the filter capacitor voltage (ripple voltage) because most of the resistance that causes the difference is internal to the components. A scope will show a distorted rectified voltage that tracks the ripple voltage during the portion of the cycle when the rectifiers are conducting.

For a more detailed analysis and definitions of terms used here see "Rectifier Design and Analysis" at <http://www.bwcelectronics.com/articles/WP10A190.PDF>.

Date Run  
8/9/2012

Rectifier Calculator  
FWCT and FWBR  
with shunt-capacitor filter

W5BWC Electronics  
Rev. A  
11/6/09

Input Circuit Values									
$V_i$	$R_L$	$C$	$f$	$R_s'$	$R_d$	$R_w$	$R_c$	$V_f$	$n$
15.9	0.51	6.40E-02	60	0.022	0.005	0.001	0.004	0.60	1
Calculated rms values					Calculated min/max				
$I_f$	$I_d$	$I_c$	$I_o$	$V_o$	$I_{fpk}$	$V_r(pp)$	$V_r(min)$	$V_r(max)$	Step size
55.105	38.965	45.532	35.067	17.70	136.982	3.08	16.09	19.17	2.50E-04
Last cycle values									
Initial $V_c$ : 0.00					$V_c(start)$ : 17.25 $V_c(end)$ : 17.37				

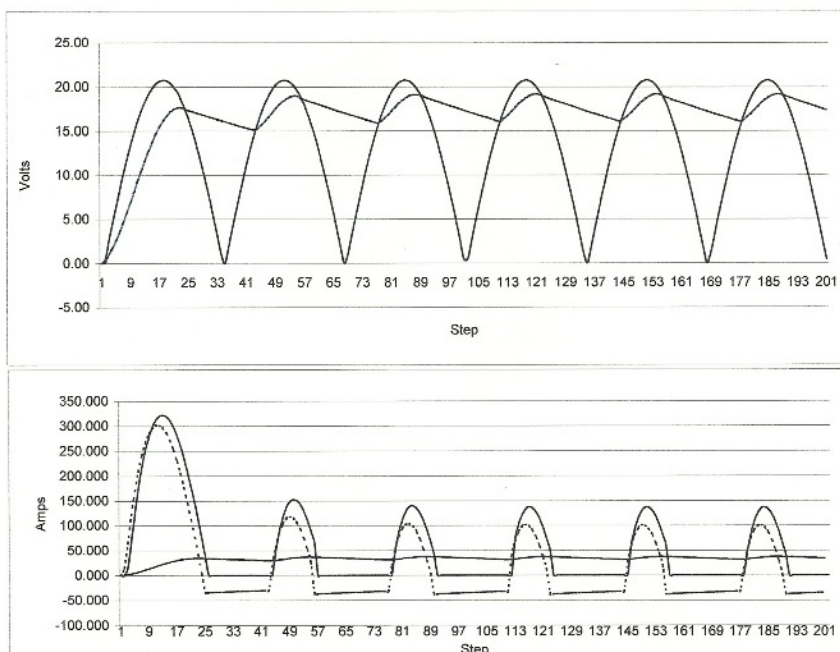


Figure 3. Astron RS-35M rectifier analysis.

stress level at 35 Amp output, as long as appropriate duty cycle limitations are observed.

## Restore it

Once the power supply is cleaned out, rebuild it using the schematic in Figure 9. Also see the PS-15D-( ) document at <http://www.bwcelectronics.com/articles/WP10A190.PDF> for additional details and options.

If not already done so, Install the new pass transistors, using insulator kits and thermal compound if a floating Negative output is desired or thermal compound only if the Negative output is to be grounded. The 35 ADC rating is not a problem for the PS-15D-5 (30 ADC) design because the 35 ADC is not continuous but rather an ICAS rating. **Caution:** Even though the 2N5886 pass transistors can tolerate up to 90°C heat sink temperature it is ill advised to operate above 65°C heat sink temperature. Use forced air cooling to extend the operational range of the power supply.

Most older power supplies use a high-side emitter follower (common collector) configuration that requires the pass transistors be insulated from the heat sink. The PS-15D-( ) design has low side

common emitter pass transistors providing for the option to ground or insulate them from chassis. The use of a thin coat of high quality thermal compound is required for either option.

Removing the mica or thermal-pad insulator reduces the case to sink thermal resistance which improves the heat transfer process. Proper single point grounding eliminates ground loops and the grounded Negative output enhances RFI/EMI performance, but typical ARS installations often do not adhere to "proper" single point grounding. If uncertain about the grounding in your application, insulate the Negative output terminal from chassis (ground). For more grounding information and additional references see "Amateur Radio Station Grounding and Lightning Protection" <http://www.bwcelectronics.com/articles/WP30A190.pdf>

Ensure the AC power is supplied by a NEMA 5-15P cord set in good condition and properly grounded to the chassis. The EMI filter capacitors will form a capacitive voltage divider across the AC line causing the chassis to rise to approximately 60 VAC if the ground is not in tact.

Note in-rush current limiting, thermal cut-out, MOV transient suppression and EMI/RFI filter capacitors are added to AC line



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input. Be careful to isolate the AC line wiring and components from all other parts of the power supply.

Refer to Figures 1, 4, 5 and 6. for details of installing the PS15D102 regulator assembly. This assembly is a complete regulator providing the output connections, current monitoring and pass transistor drive. F101 is an ATC automobile type pig-tail fuse holder wired from the positive terminal of the filter capacitors to R208 which is a chassis mounted 25 Watt 0.01 Ohm. Kelvin connections are used to connect R208 to the PS15D102. As shown on the schematic, the high current carrying wires, represented by darker lines, connect to R208's terminals separate from the sense wires that connect to E209 and S210A. This avoids the voltage drop, caused by the current carrying wire's resistance, from corrupting the current sense.

F101, a 30 Amp fuse is used even though the current limit is calculated to be 36 ADC. The RS-35M is rated 35 Amp ICAS, and the fuse will hold 35 Amp as long as the power supply can stand it (particularly based on the thermal test results!) The pig tail fuse holder specified connects from the filter capacitors to R208.

The PS15D102 Regulator Assembly is mounted to copper brackets with 6-32 screws. The brackets are formed on a shop brake from copper pipe that is split and flattened. Notice the brackets shown in Figure 4. hold the PWB further from the rear panel than is necessary (and closer to the transformer than desired) and so should be modified.

The side adjust version of R203 makes the voltage adjust easy to access with the top cover off. Q1 is a TO-220 mounted to the chassis under and behind the PS15D102 assembly in Figure 1.

The drain lead (tab) is insulated or grounded to match the options used for the pass transistors. The transistor leads have pig-tails attached with heat shrink to insulate them.

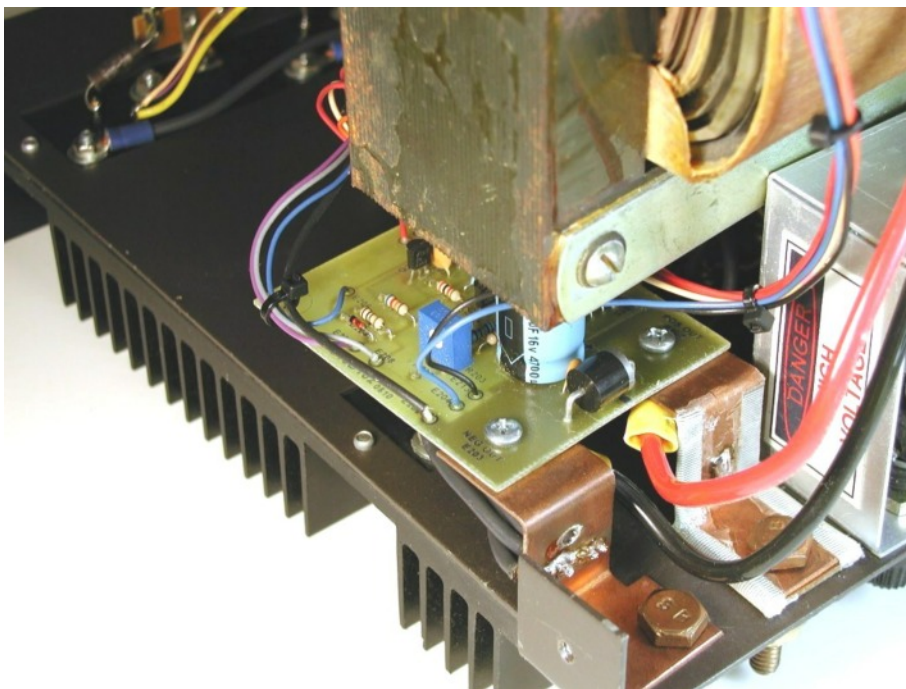
The pass transistors connect to R1 through R4, one emitter to each resistor, and then to the negative terminals of the filter capacitors. These leads should be approximately the same length, of AWG 18 (minimum), to equalize the emitter ballast. Paralleled transistors do not inherently share emitter current equally.  $V_{BE}$  and  $H_{FE}$  differences effects are reduced by the ballast, improving the current sharing. The base leads are not as critical, but a single wire to each base from E207 is worth while. The pass transistor collector's should connect to the Negative output terminal with approximately equal lengths, of AWG 18 (minimum), regardless of insulated or grounded pass transistor mounting.

**Caution:** Be sure E208 is securely and permanently connected to the negative terminals of the filter capacitors. Without this connection the output voltage cannot be regulated.

If the PS15D102 is not mounted on the output terminals with copper brackets, as shown in Figures 4, 5 and 6 the effectiveness of C201, C202 and D203 are significantly reduced.

## Testing

Use a current limited bench power supply to apply 20 VDC in place of the filter capacitor **with NO AC power applied to the power supply**. The output voltage should be in the range of 11 to 15 VDC and adjustable by R203. Trouble shoot any problems in this condition prior to applying AC power. Once the



**NOTE: This mounting technique REVERSES the Positive and Negative Output Terminals**

For other mounting options that leave the terminals in the original Astron configuration see Figure 5 and 6.

Figure 4. PS15D102 Regulator Assembly mounting details. The Copper brackets are formed from scrap copper pipe with the Positive Terminal insulated from the chassis with FR-4 spacer and an insulated shoulder washer - for non-grounded Negative output terminal, use same method for both terminals.

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Note the high side of the AC line, the fuse, line bypass and in-rush current limiter are insulated with heat-shrink tubing.

Astron does not provide sufficient isolation or insulation between the AC line input and the DC output to suit me.

**Use caution around both the AC line input and DC output.**

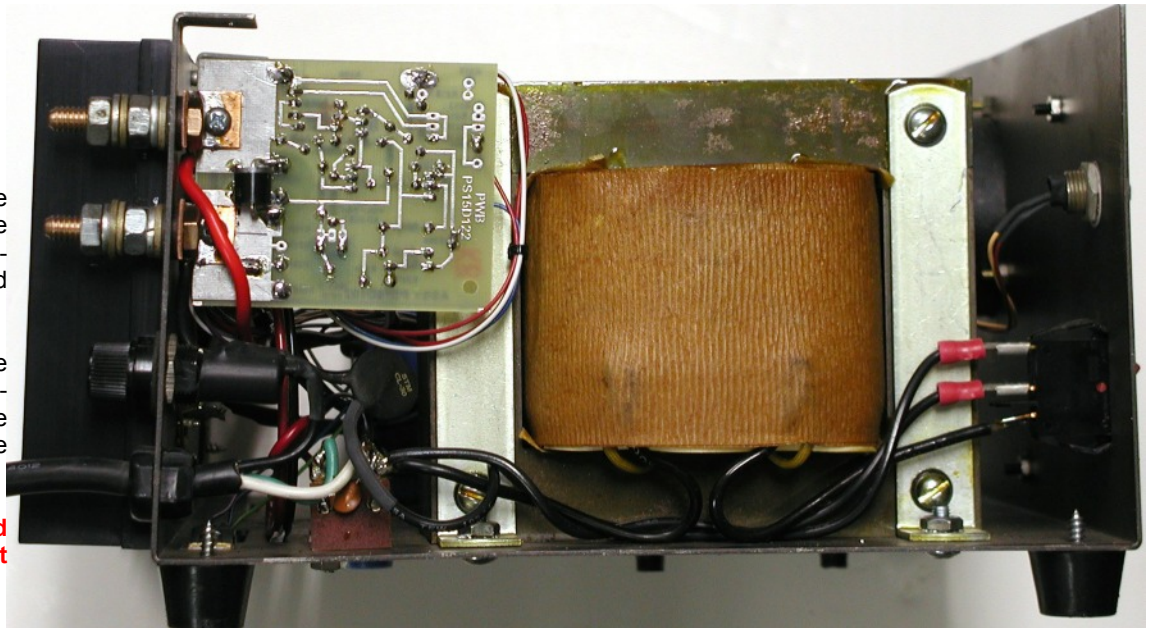


Figure 5. PS15D102 Regulator Assembly mounting that keeps the original Astron terminal configuration - Positive on top and Negative on bottom. Note D203 is moved to the back side of the circuit board and new holes are drilled to accommodate the Astron 1.00" OC mounting. The copper brackets are 0.50" wide by 1.00" long and bent to provide 0.375" length on the board side of the 90° bend.



Figure 6. View of Figure 5 from the other side. Note in this case R203 is a top adjust, allowing voltage adjustment to be made from the inside of the power supply. A side adjust pot can be used so the adjustment may be made from the top, however, the adjustment will be backward i.e., CW decreases output voltage and CCW increases output voltage.



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power supply is functional **remove the external bench power supply connections and reconnect the filter capacitor.**

Connect the **GROUND**ED NEMA 5-15P cord set to AC power. **Caution: the power line ground must be intact and proper connected to the chassis to prevent a low level shock and AC leakage hazard.**

**Warning: Line voltage is dangerous and is present on the power line components.**

**Warning: The rectifier output is low voltage but has dangerous current capability. Do NOT short the filter capacitor terminals and DO use caution working anywhere in the power supply.**

Once the power supply is operating from the AC line, recheck the output voltage and adjust as needed. If an electronic load is available check the performance using the PS15D090 "Characteristics" and the "Engineering Prototype Measured Data" shown below as guides. If a variable load is not available, use resistors or auto lamps to check for stable operation under varying load conditions.

Some designs do not work well with tungsten lamp loads, but the PS15D102 is well behaved with such or even reactive loads.

Figure 7. PS15D102 Regulator Assembly Component Locator. PWB PS15D122 is available from Far Circuits, or contact me at [jlk@bwcelectronics.com](mailto:jlk@bwcelectronics.com).

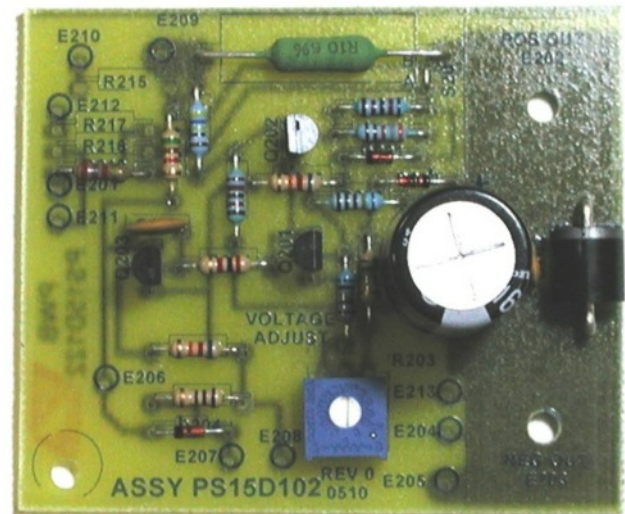


Figure 8. PS15D102 Regulator Assembly. Note for the Astron refurbish; R208 is mounted externally, strap S201 is not used and R203 is a side adjust not the top adjust shown - the board will accept either.

Engineering Prototype Measured Data	
Parameter	PS15D-5 Measured <sup>1</sup>
Input Voltage	Drop out at 100.5 VAC
Input Current	7.02 A <sub>RMS</sub>
Output Voltage Adjustment	10.57 to 14.93 VDC
Line Regulation	0.007%
Load Regulation	0.024% (0 to 25 ADC) 0.046% (0 to 30 ADC)
Ripple and Noise	120 $\mu$ V RMS (@ 25ADC) 80 $\mu$ V RMS (@ 30ADC)
Output Z	DC-1kHz 0.002 1-10kHz 0.017 10-100kHz 0.028
Load Step Response	- 200 mV recover in 15 $\mu$ S + 200 mV recover in 40 $\mu$ S
Current Limit	37.9 Amps folding back to 11.15 Amps into 0.005 $\Omega$
Thermal	$T_S = 81.0^\circ\text{C}$ at $T_A = 24.0^\circ\text{C}$ , 117 VAC Line and 25 ADC out- put  Transformer Core $T_C = 82.0^\circ\text{C}$ at $T_A = 24.0^\circ\text{C}$ , 117 VAC Line and 25 ADC
<sup>1</sup> Refurbished Astron RS-35M with 8233F transformer, 1N1184A rectifiers and two 32,000 $\mu$ F, 25 VDC 36DX filter capacitors.	



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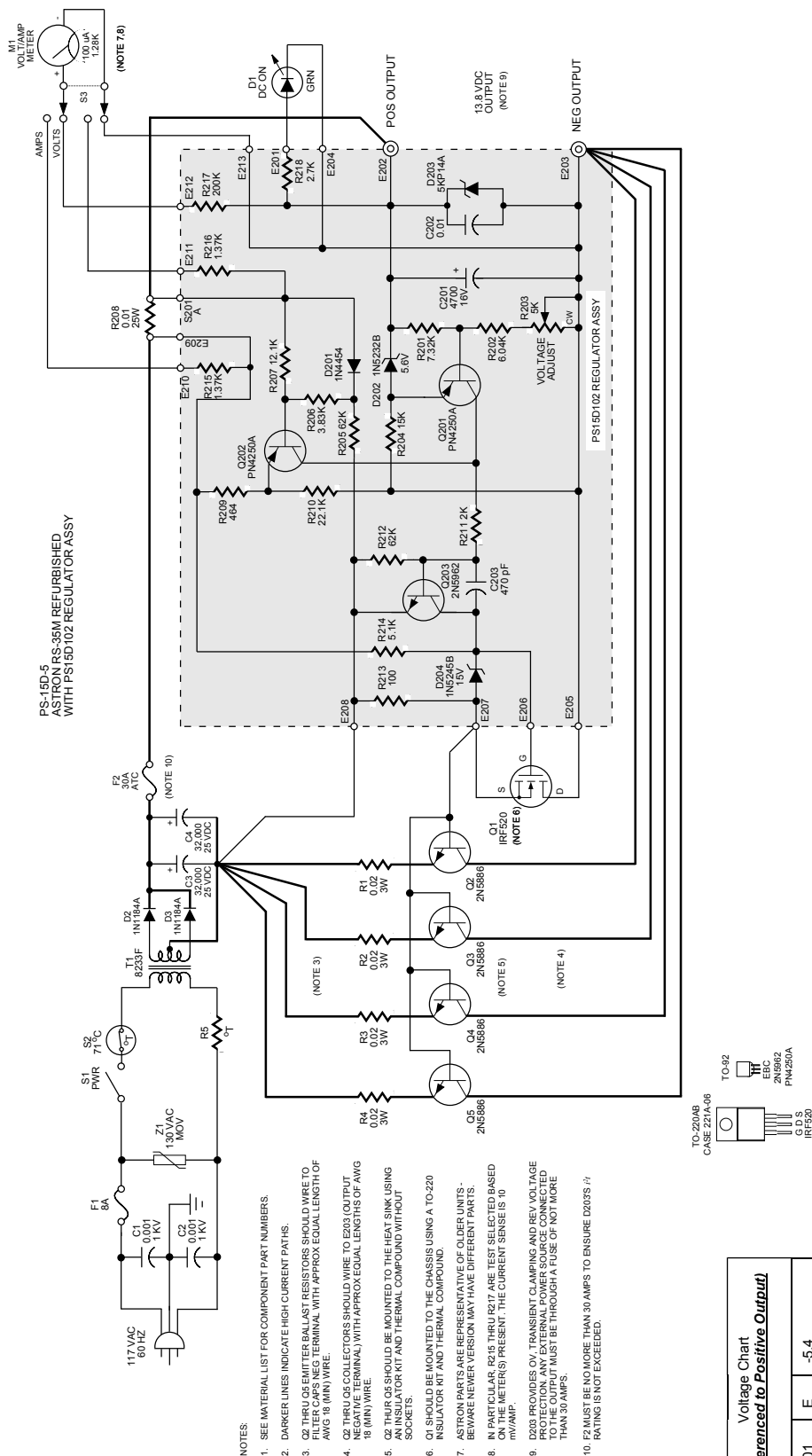


Figure 9. PS15-D-5 Schematic. See Figure 11 for alternate rework schematic.

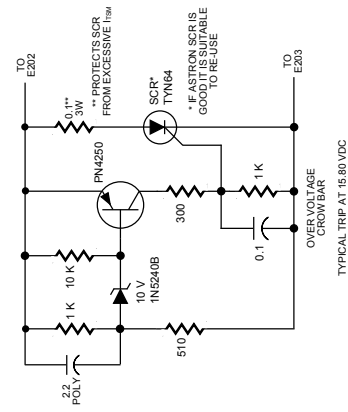


Figure 10. SCR Over-voltage Crowbar

Voltage Chart (Referenced to Positive Output)	
Q201	E -5.4
	B -5.8
	C -22.6
Q202	E 0
	B -0.3
	C -22.6
Q203	E -23.0
	B -22.6
	C -20.2
Q1	S -22.4
	G -20.2
	D -13.8
Q2 THRU Q5	E -23.0
	B -22.4
	C -13.8

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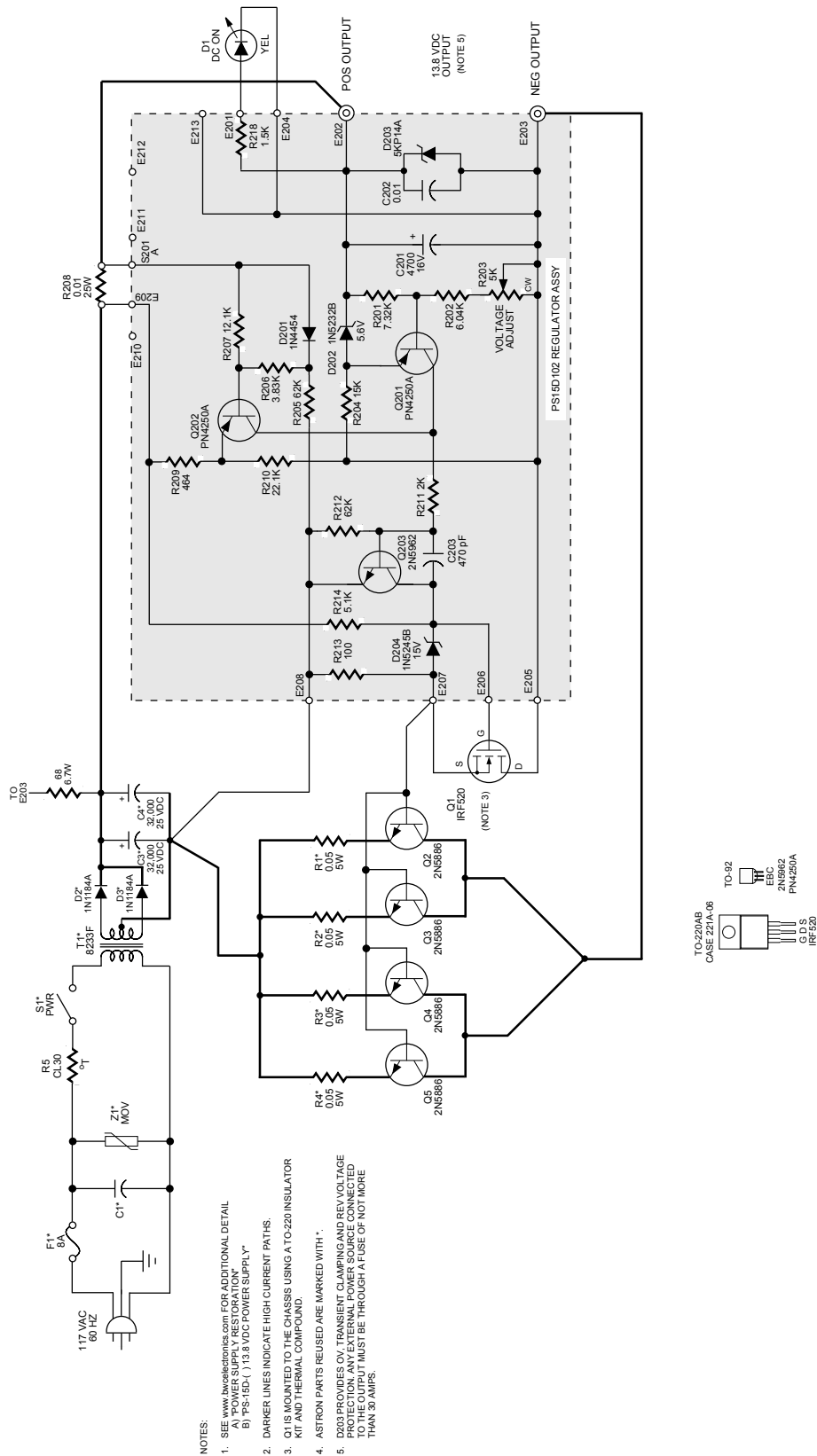


Figure 11. Astron RS-35A refurbished to PS-15D-5 using alternate technique that allows maximum reuse of the Astron design. Note SCR crowbar shown in Figure 10 may also be added.

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## Material List - Astron RS-35M Refurbish

Qty	Designator	Value/Type	Description	Part Number**	Supplier
2	C1, C2	0.001 $\mu$ F, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
2	C3, C4	32,000 $\mu$ F, 25VDC	Screw terminal Al electrolytic		Astron
1	D1	LED	Green	604-WP7113SGD	
2	D2, D3	1N1184A	40 Amp Stud Rectifier		Astron
1	F1	8 Amp	1 $\frac{1}{4}$ x $\frac{1}{4}$ Fuse		Astron
1	F2	30 Amp	ATC/ATO Blade Fuse	576-0257030.PXPV	
1	M1	100 $\mu$ A, 1280 $\Omega$	Panel meter		Astron
1	P1	3x18AWG Cord set	NEMA 5-15P		Astron
1	Q1	IRF520	Power FET	844-IRF520PBF	
4	Q2, Q3, Q4, Q5	2N5886	NPN Pwr	863-2N5886G	
1	R5	2.5/0.09 $\Omega$ , 8A	NTC Surge Current Limiter	527-CL30	
4	R1, R2, R3, R4	0.02 $\Omega$ , 3 W, 5%	Metal Film Power	66-LOB3R020JLF	
1	R208	0.01 $\Omega$ , 25 W, 1%	Chassis mount	71RH250.01	
1	S1	SPST Rocker Switch			Astron
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	S3	DPDT Rocker Switch			Astron
1	T1	16 VAC	115 VAC Power Transformer	8233	Astron
1	XF2	ATC/ATO Blade	Pig-tail Fuse Holder	441-R347A-GR	
1	XD1	LED T-1 $\frac{3}{4}$	Panel mount	606-4304MC	
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
2		Brackets	Copper mounting	Shop built	
*		Insulator	Brackets and output terminals	Shop built	
1		Assembly	Regulator	PS15D102	

\* One required for Negative grounded output terminal, two required for floating Negative output terminal.

Suggested replacements for the above listed Astron parts can be found in the PS-15D(-) document <http://www.bwcelectronics.com/projects/PS15D090.PDF>

## Material List - PS15D102 Regulator Assembly

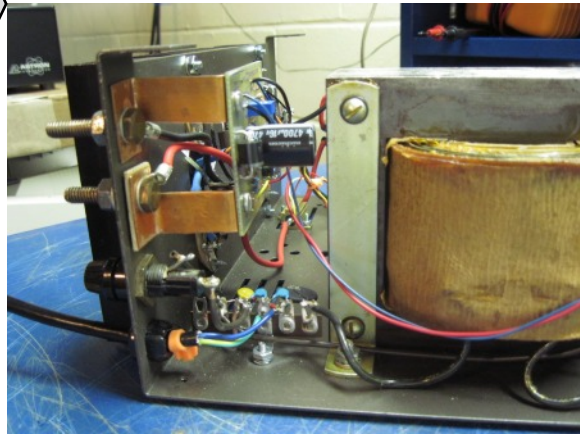
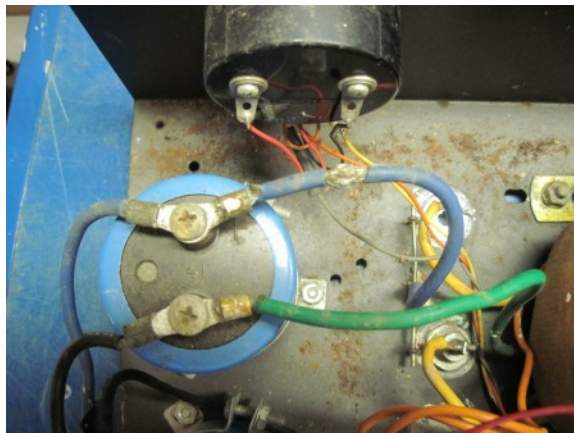
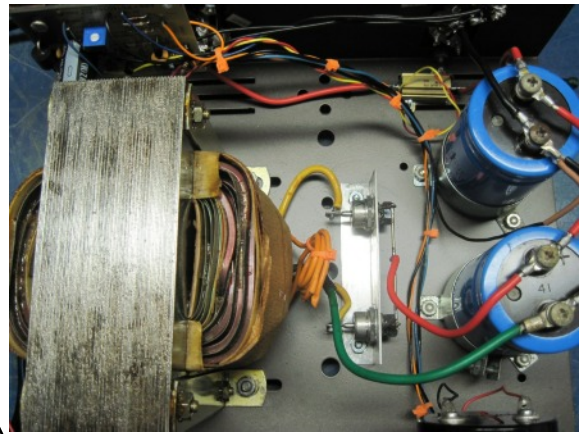
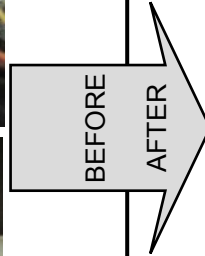
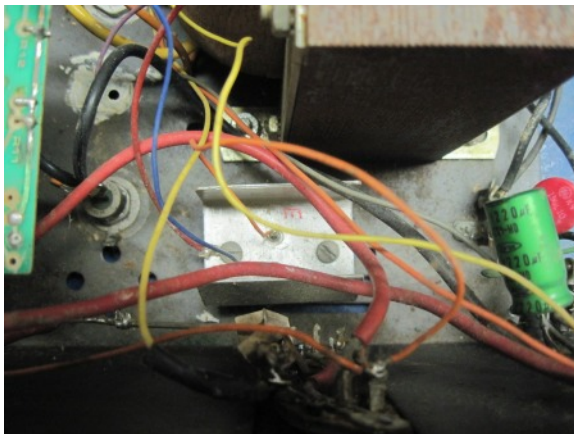
Qty	Designator	Value/Type	Description	Part Number**	Supplier
1	C201	4700 $\mu$ F, 16 V	Radial Al electrolytic	647-UVZ1C472MHD	
1	C202	0.01 $\mu$ F	Ceramic disk	140-50Z5-103M-RC	
1	C203	470 pF,	NPO Ceramic disk	140-50S5-471J-RC	
1	D201	1N4454	Switching diode	512-1N4454	
1	D202	1N5232B	5.6V, 0.5 W Zener	512-1N5232B	
1	D203	5KP14	14 V Silicon Avalanche	576-5KP14	
1	D204	1N5245B	15V, 0.5 W, Zener	78-1N5245B	
2	Q201, Q202	PN4250A	High gain PNP small signal	512-PN4250A	
1	Q203	2N5962	High gain NPN small signal	512-2N5962	
1	R201	7.32 k $\Omega$ , 0.25 W, 1%	MF	271-7.32K-RC	
1	R202	6.04 k $\Omega$ , 0.25 W, 1%	MF	271-6.04K-RC	
1	R203	5 k $\Omega$ , 0.5 W, 5%, Cermet Trimmer	Side Adj	652-3386W-1-502LF	
1	R204	15 k $\Omega$ , 0.25 W, 5%	CF	291-15K-RC	
2	R205, R212	62 k $\Omega$ , 0.25 W, 5%	CF	291-62K-RC	
1	R206	3.83 k $\Omega$ , 0.25 W, 1%	MF	271-3.83K-RC	
1	R207	12.1 k $\Omega$ , 0.25 W, 1%	MF	271-12.1K-RC	
1	R208	Chassis mount see Astron Refurbish List of Material			
1	R209	464 $\Omega$ , 0.25 W, 1%	MF	271-464-RC	
1	R210	22.1 k $\Omega$ , 0.25 W, 1%	MF	271-22.1K-RC	
1	R211	2 k $\Omega$ , 0.25 W, 5%	CF	291-2K-RC	
1	R213	100 $\Omega$ , 0.25 W, 5%	CF	291-100-RC	
1	R214	5.1 k $\Omega$ , 0.25 W, 5%	CF	291-5.1K-RC	
3	R215, R216, R217	As required	Voltmeter and Ammeter		
1	R218	2.7 k $\Omega$ , 0.25 W, 5%	CF	291-2.7K-RC	
1			PWB	PS15D122	Far Circuits

\*\*Supplier is Mouser unless otherwise noted.



# Power Supply Restoration

## Other Refurbish Projects:



The above pictures are from K9JWI, Clyde Mauck showing his very nice refurbish job of an Astron RS-35M. I suggest the rectifier bracket be made from 0.25" aluminum, but otherwise this is one of the best refurbish jobs that I have seen. Clyde completed this refurbish in just a few days in July 2012 using the PS15D102 Regulator Assembly.



The above pictures are of another refurbished power supply. This particular unit was of very poor design; the single (undersized) heat sink was mounted with horizontal fins, the filter capacitors were seriously undersized, the transformer runs hot even with no load (high core loss) and the regulator had several design flaws. For the refurbish, the heat sink was cut in half and rotated 90° so the fins are vertical. Only one transistor was mounted on each and another heat sink was added for the third pass transistor to make a PS-15D-4. One last heat sink was added for the bridge rectifier. The filter capacitors were replaced with 3 x 22,000  $\mu\text{F}$  and fused at 20 Amps. The advertised spec was originally 35 Amps which the design could not actually supply for anything more than just a few seconds at a time, but it is in a pretty box. After the refurbish, testing confirmed the 20 Amp output can only be sustained for duty cycles below 28% with  $T_a = +25^\circ\text{C}$ . This however, will power the average 100 Watt SSB fine, but 100% duty cycle load current is only 5.8 ADC.