PS-15D-( ) 13.8 VDC Power Supply

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PS-15D- ( )	Output Current (ADC)
-1	3
-2	6
-3	15
-4	20
-5	30

The common regulator assembly (PWB) along with the appropriate transformer-rectifier-capacitor assembly and pass transistors produce power supplies capable of 3 to 30 ADC.

The assembly is a simple three transistors circuit, containing no monolithics, that is robust, stable and highly reliable, providing excellent voltage and current regulation (including fold-back), low noise output, excellent transient response and low output impedance.

While sufficient information is included in this document for a design from scratch, it may be more important facilitating the repair of dead power supplies, especially those with the old unreliable uA 723 monolithic.

PS-15D-( ) 13.8 VDC Power Supply

Contents:

PS-15D-( ) 13.8 VDC Power Supply

Applications:

- Designed specifically for continuous, unattended charging of a secondary battery or as a stand-alone continuous duty, high reliability power supply. See warnings this page and next.
- Excellent for powering remote systems and intended to operate in or near RF fields such as those in the proximity of an Amateur Radio transmitting antenna.
- Intended as the AC power supply of a DC power system using a Monitor & Control such as the MC-20A-1 Power Monitor which will provide a complete system for under voltage disconnect, over voltage shutdown, and DC buss monitoring.

Figure 1. Typical construction for PS-15D-4, front side view.

Figure 2. Typical construction for PS-15D-4, rear side view.

Features

- no minimum load
- excellent voltage regulation
- excellent load step response
- very low ripple and noise DC output
- adjustable output voltage
- very low reverse leakage current (drawn from the battery during AC off conditions)
- load sharing that does NOT require series diodes
- fused in both AC and DC sections
- output reverse voltage protection
- output transient over voltage protection
- RFI/EMI immune output
- RFI/EMI input filter on AC line
- status indicator that allows two LEDs to indicate that AC power is providing the DC output or that the secondary battery is providing the DC output.
  (with PS15D103 Buss Status Indicator)
- 100% duty cycle output at ambient temperatures up to +40 ^{o}C
- simple rugged circuit with no high voltage switching or noise generation that requires complex filtering and shielding
- excellent for resurrecting non-operational commercial power supplies

Caution: Connection of the PS-15D-( ) output to another power source or battery must be through an appropriately sized **external** fuse to prevent serious damage if a fault condition occurs.

Failure to head this caution can result in equipment damage and or fire.

Applications:

PS-15D- ( )				
Common Assy:	PS15D100	Components X1 - X99		
	Sub-Assys:	PS15D101 -109	Components:	X101 - X199 X201 - X299 . . . x901 - X999X
		PWBs:	PS15D120-129	

Table 1. Part number hierarchy for the PS-15D- ( ) power supplies.

Power Supply PS-15D- ( )	Output Current (ADC)	Common Assy	Regulator		Rectifier		Power Monitor	
			Assy	PWB	Assy	PWB	Assy	PWB
-1	3	PS15D100	PS15D102	PS15D122	PS15D101	PS15D121	PS15D103	PS15D131
-2	6	PS15D200	PS15D102	PS15D122	PS15D201	PS15D221	PS15D103	PS15D131
-3	15	PS15D300	PS15D102	PS15D122	PS15D301	PS15D321	PS15D103	PS15D131
-4	20	PS15D400	PS15D102	PS15D122	PS15D401	PS15D421	PS15D103	PS15D131
-5	30	PS15D500	PS15D102	PS15D122	PS15D501	PS15D521	PS15D103	PS15D131

Table 2. PS-15D- ( ) part numbers and assemblies.

Caution: Connection of the PS-15D-( ) output to another power source or battery must be through an appropriately sized **external** fuse to prevent serious damage if a fault condition occurs.

Failure to head this caution can result in equipment damage and or fire.

The PS-15D-( ) will trickle charge a secondary battery, such as a lead acid or AGM even gelled, but will not equalize a battery. I have found from experience that this is not a serious issue, but if absolute peak performance is requited from a battery, a more sophisticated charge system may be desired.

When charging a lead acid battery, dangerous gases can be expelled. **If a cell fails during charging this risk is exacerbated and the battery can become extremely hot. If a charging battery is not monitored by personnel, it should be equipped with a thermal alarm or automatic shut down.**

Characteristics: PS15D102 Regulator Assembly (Note 1.)

Size	2.30" X 2.75" (58.42mm X 69.85mm) 1.05" (26.67mm) tallest component	
Material	0.063" (1.60mm) FR-4 fire retardant glass-epoxy 1 oz copper clad with tin plate	
Mounting	Designed to mount on the Output terminals of the power supply with 6-32 screws	
Input Voltage	40 VDC (max), no minimum - stable from operational to drop out	Limited by 2N5962
Output Current	For -1 and -2 (up to 6 ADC) R208 can be board mounted. It is recommended for -3 thru -5 (15 to 30 ADC) R208 be mounted externally - see Figure 17 for details	
Strapping Options	See text and Figure 17 for S201 strapping information - allows accurate current monitoring with externally mounted R208	
Volt and Amp Meter	See text for appropriate selection of R215 thru R217 for scaling of external meters	
Output Voltage Adjustment	11 to 15 VDC (nominal) 12 to 14 VDC (worst case)	Designed for 12 to 13.8 VDC
Output Voltage Regulation	Better than 0.10% (~13.8 mV) for load changes from no-load to rated output current Better than 0.10% for line changes from maximum to drop out (Both slightly dependent upon transformer-rectifier-capacitor assembly)	Measured at the output terminals
Output Voltage Temperature Coefficient	Less than 0.04%/°C (nominal)	
Current Limit	See text and fold-back current limiting equations for details - typically on-set of current limit is 15% above rated output current, folding back to 30% of rated output current into a short	
Current Limit Temperature Coefficient	Less than 0.6%/°C (nominal)	
Pass Transistor Drive	0 to 3 mA with 15V compliance	Note 2.
Regulator Current	< 4 mA (excluding 100 Ω base resistor on -2 thru -5)	

Characteristics: PS15D103 Buss Status Indicator Assembly

Size	0.95" X 0.95" (24.13mm X 24.13mm)	
Material	0.063" (1.60mm) FR-4 fire retardant glass-epoxy 1 oz copper clad with tin plate	
Mounting	Designed to mount on the leads of panel mounted LEDs	
Input Voltage	15 to 30 VAC from rectifier transformer 10 to 15 VDC from DC Buss	
Indicators	Green LED indicates AC power ON - works correctly even with battery input Yellow LED indicates DC power ON without AC power present (with battery back-up)	

Notes:
1. Characteristics apply to PS15D102 assembly with an external pass transistor - see PS-15D-1 thru -5 for specific details.
2. Designed specifically to drive the high gate capacitance of a power FET, but also stable driving a bipolar darlington
3. PS15D103, Buss Status Indicator, introduces a very small 60Hz component into the DC output.
4. Current limit is a function of output voltage - see Figures 8 and 9 for current limit vs output voltage.
5. Initial current limit is the current at which the output voltage drops 1% and the fold back current is into a load resistance that produces < 1 VDC output.

Characteristics: PS-15D-( )Common Characteristics

Parameter	Conditions	Value	Notes
Input Voltage	60 Hz Line I_O = 0 to Rated Full Load	105 to 125 VAC	
Output Voltage Adjustment	117.0 VAC Line I_O = 0 to Rated Full Load	11 to 15 VDC (nominal) 12 to 14 VDC (min)	Designed for 12 to 13.8 VDC
Line Regulation	105 to 125 VAC Line 13.80 VDC Output I_O = 0 to Rated Full Load at any fixed level	< 0.10%	Measured at the output terminals
Load Regulation	117.0 VAC Line 13.80 VDC Output ΔI_O = 0 to Rated Full Load	< 0.10%	Measured at the output terminals
Ripple and Noise	117.0 VAC Line 13.80 VDC Output I_O = 0 to Rated Full Load	<500 µV RMS	Note 3.
Output Impedance	117.0 VAC Line DC to 1 kHz 13.80 VDC Output 1 kHz to 10 kHz I_O = 0 to Rated Full Load 10 kHz to 100 kHz	< 0.005 Ω < 0.005 to 0.035 Ω < 0.035 Ω	See Figure 4.
Output Voltage Temperature Coefficient	117.0 VAC Line 13.80 VDC Output I_O = 0 to Rated Full Load at any fixed level	Less than 0.04%/°C (nominal)	
Current Limit Temperature Coefficient	117.0 VAC Line 13.80 VDC Output	Less than 0.6%/°C (nominal)	
Reverse leakage current	0 VAC Line Output Voltage 12.7 VDC (from external source)	<2 mA	
Operating Temperature Range	117.0 VAC Line 13.80 VDC Output I_O = 0 to Rated Full Load at any fixed level	-20 °C to +40 °C	
Fault Protection	Input Line fuse	GMA Fast acting	Fuse selection and use is critical for component protection as well as facility protection.
	Input Surge	130 VAC MOV	
	DC output fuse	ATC 32V Blade Fuse	
	DC output Surge	14 VDC, 5 kW SAD	
Duty cycle	117.0 VAC Line 13.80 VDC Output I_O = 0 to Rated Full Load	100%	

Duty Cycle Warning.

The MFJ transformer specified for the -3, 15 ADC version, has 50 °C temperature rise in 15 ADC CCS (commercial continuous service) which means with +40 °C ambient the transformer will be at +90 °C. From a transformer insulation stand point this is acceptable, but I prefer to keep the rise below 40 °C which requires forced air cooling. As can be seen from the schematic I suggest a thermostatically controlled fan, which only runs on demand improving reliability and reducing noise.

This same transformer is specified for the -4, 20 ADC version where the fan is required for CCS 20 ADC service. Without forced air cooling the transformer rise is in excess of 77 °C - totally unacceptable.

MFJ advertises this transformer for 30ADC output which it is capable of. As for as low line and peak current this transformer is fine and seems to be

MFJ 406-3800 Transformer ICAS de-rating		
DC Output Current	**Duty Cycle**	**Conditions**
15 ADC	100%	Natural convection cooling and core rise of 50 °C
20 ADC	100%	Forced air cooling sufficient to contain core rise.
20 ADC	50%	Natural convection cooling and core rise of 50 °C Dwell time (full load) of 10 minutes maximum
30 ADC	25%	Natural convection cooling and core rise of 50 °C Dwell time (full load) of 5 minutes maximum

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Characteristics: PS-15D-( ) version specific Characteristics

Parameter	-1	-2	-3	-4	-5
Input Current 117.0 VAC Line 13.80 VDC Output I_O = Full Load	0.75 A_{RMS}	1.50 A_{RMS}	3.75 A_{RMS}	5.0 A_{RMS}	7.50 A_{RMS}
Load Step Response 117.0 VAC Line 13.80 VDC Output	Δ I_O 0 to 1.0 A -100 mV recover in 25 µS +200 mV recover in 5 µS	Δ I_O 0 to 2.0 A -150 mV recover in 25 µS +100 mV recover in 25 µS	Δ I_O 0 to 5.0 A -150 mV recover in 25 µS +100 mV recover in 25 µS	Δ I_O 0 to 5.0 A -150 mV recover in 25 µS +100 mV recover in 25 µS	Δ I_O 0 to 10 A -250 mV recover in 25 µS +250 mV recover in 50 µS
Current Limit 117.0 VAC Line 13.80 VDC Output Initial Limit[1] Fold Back[2]	 3.6 ADC 1.0 ADC	 7.2 ADC 2.0 ADC	 18 ADC 5 ADC	 24 ADC 6.7 ADC	 36 ADC 10 ADC

[1] Current at which output voltage drops 1%

[2] With output voltage < 1 VDC

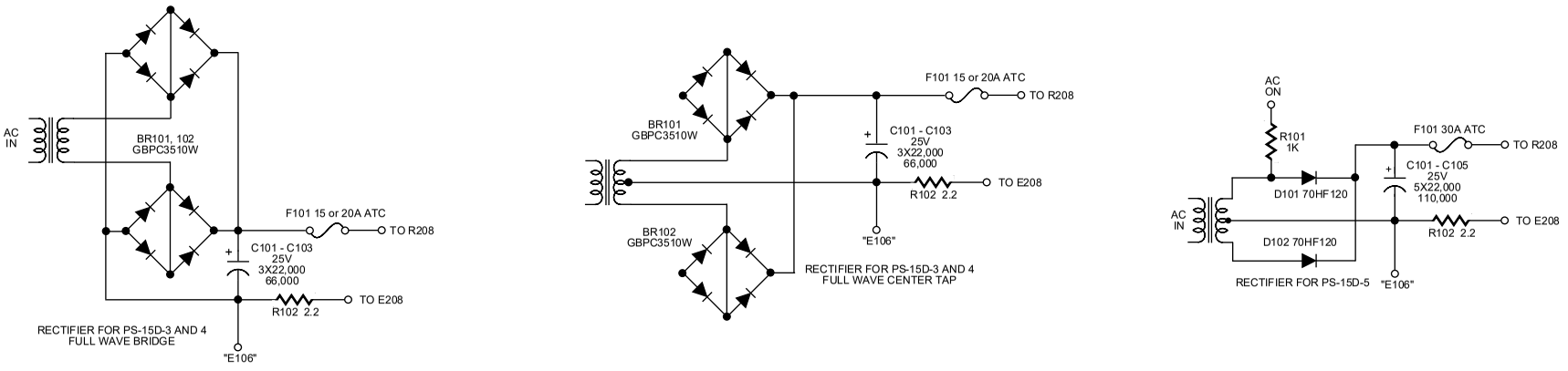

Figure 3. Rectifier options.

Characteristics: Typical performance and engineering prototype data.

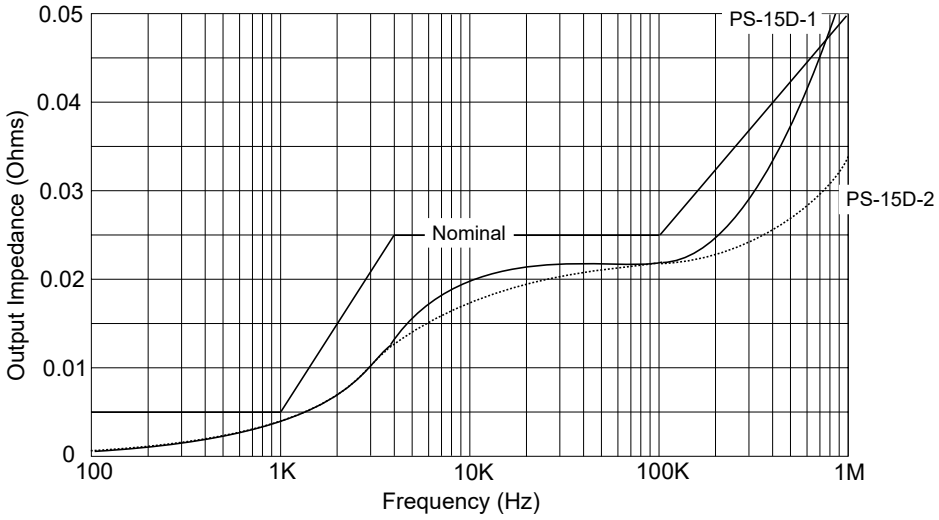

Figure 4. Output Impedance. Nominal is the expected performance, but is dependent upon actual construction techniques and components. Plotted data from engineering prototypes.

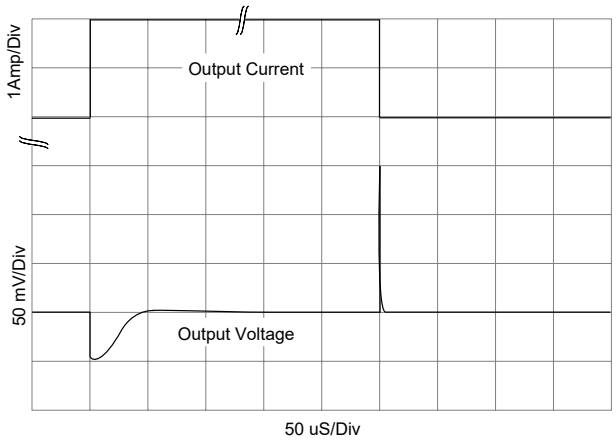

Figure 5. PS-15D-1 Transient Response of engineering prototype.

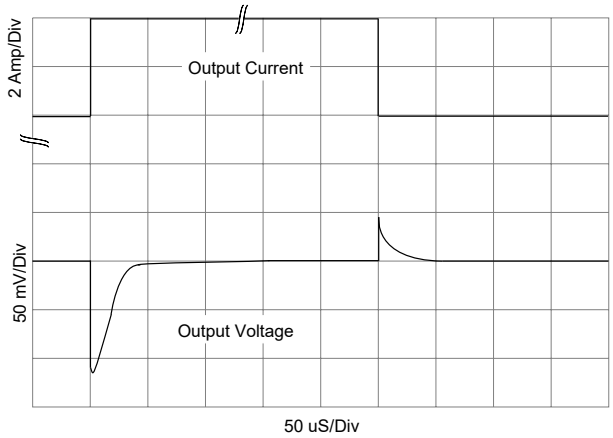

Figure 6. PS-15D-2 Transient Response of engineering prototype.

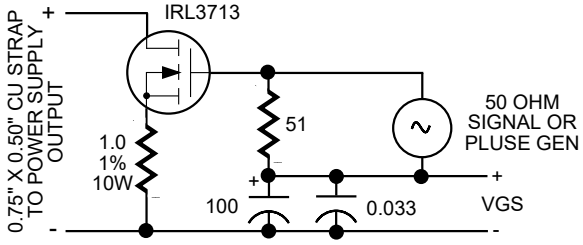

Figure 7. Transient Response and Output Impedance measured using a terminal mounted FET with low inductance copper straps. For transient response, the FET is driven with a pulse generator - VGS and the pulse amplitude are adjusted for the desired current pulse. For output impedance, the FET is driven with a signal generator and VGS is set for 1 ADC bias current - measured as 1 Volt across the 1 Ohm source resistor.

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Characteristics: Typical performance and engineering prototype data.

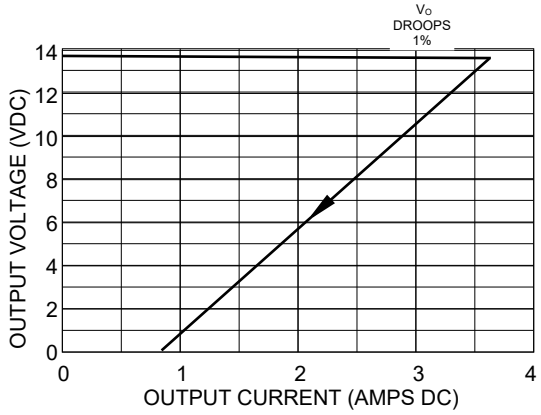

Figure 8. PS-15D-1 Output Current Limit of engineering prototype. Arrows indicate current change as the output Load Resistance decreases.

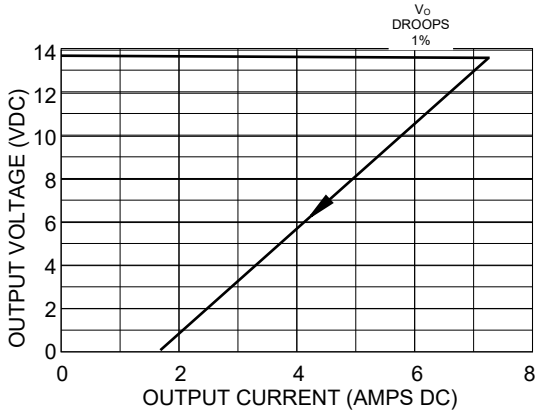

Figure 9. PS-15D-2 Output Current Limit of engineering prototype. Arrows indicate current change as the output Load Resistance decreases.

Table 3.

Engineering Prototype Measured Data (Conditions as specified in Characteristics)				
Parameter	**PS15D-1 Measured**	**PS15D-2 Measured**	**PS-15D-4A**	**PS15D-5 Measured**[1]
Input Voltage	Drop out at 97.7 VAC	Drop out at 103.5 VAC	Drop out at 94.3 VAC	Drop out at 100.5 VAC
Input Current	0.74 A_{RMS}	1.45 A_{RMS}	5.34 A_{RMS}	7.02 A_{RMS}
Output Voltage Adjustment	10.58 to 14.94 VDC	10.57 to 14.93 VDC	10.57 to 14.47 VDC	10.57 to 14.93 VDC
Line Regulation	0.004%	0.017%	0.01%	0.007%
Load Regulation	0.02% (0 to 2.5 ADC) 0.05% (0 to 3.0 ADC)	0.02% (0 to 5 ADC) 0.06% (0 to 6 ADC)	0.12% (0 to 20 ADC) 0.06% at Board terminals	0.024% (0 to 25 ADC) 0.046% (0 to 30 ADC)
Ripple and Noise	25 µV RMS 130 µV RMS	65 µV RMS 320 µV RMS	340 µV RMS 250 µV RMS	120 µV RMS (@ 25ADC) 80 µV RMS (@ 30ADC)
Output Z DC-1kHz 1-10kHz 10-100kHz	0.004 Ω 0.0195 Ω 0.022 Ω	0.002 0.018 0.022	0.001 0.022 0.030	0.002 0.017 0.028
Load Step Response	-50 mV recover in 50 µS +150 mV recover in 2 µS	-120 mV recover in 25 µS +40 mV recover in 25 µS	-400 mV recover in 30 µS +900 mV recover in 5 µS	- 200 mV recover in 15 µS + 200 mV recover in 40 µS
Current Limit	3.72 ADC 0.95 ADC into 0.02 Ω	7.16 1.90 into 0.23 Ω	24.2 6.8 into 0.17 Ω	37.9 11.15 into 0.005 Ω
Thermal	With 3" Aavid/Thermalloy 61090 extrusion and 125 VAC Line at T_A = 24.0 °C heat sink stabilized at +64.0 °C	Tested with 40 °C/45W extrusion	Tested in a rebuilt commercial enclosure with OEM xfmr, heat sink and meter panel.	T_S = 81.0 °C at T_A = 24.0 °C, 117 VAC Line and 25 ADC output Transformer Core T_C = 82.0°C at T_A = 24.0°C, 117 VAC Line and 30 ADC output with 50CFM

[1] Refurbished Astron RS-35M with 8233F transformer, 1N1184A rectifiers and two 32,000 µF, 25 VDC 36DX filter capacitors.

Basic Operation:

AC Line Input

Input AC power is supplied through fuse, F1, power switch, S1, and thermal switch, S2, to the primary winding of T1. To reduce incoming RFI each AC line input is bypassed to ground with a 0.001 µF, 1 kV capacitor. **Caution: these small capacitors form a voltage divider between the hot and common line inputs. If the power line ground is not in tact, this causes the chassis (and output) to float up to approximately 60 VAC. Be sure incoming AC power is supplied through a NEMA 5-15P cord set in good condition and properly connected.**

The fuse size is determined by the output current rating - see "Characteristics" for actual values. **Proper fuse size is essential for protection of the rectifiers.** The input fuse does more than protect wiring and related components from excessive rms current. As importantly, it protects the rectifiers from excessive peak energy that is described as I^2t - the "Joule integral", it assists in lightning induce current and output over-voltage protection when D203 avalanches. **Do NOT dismiss the fuse selection as a trivial matter - it is important to install the correct size and type fuse.**

The thermal switch is heat sink mounted providing thermal shut down during fault conditions or excessive ambient temperature. Input surge protection is provided by Z1, a 130 VAC MOV (metal oxide varistor) . In-rush current protection for the higher current versions is provided by R1, a NTC (negative temperature coefficient) thermistor.

Rectifier and Filter

Transformer, T1, and the rectifier/filter assembly are selected based on the output current. Either full wave bridge or full wave CT rectifiers may be used, see Figure 3. Topology and component selection for custom designs can be made using the "Rectifier Design and Analysis" article and free spread sheet calculator on bwcelectronics.com. PWB assemblies can be used for the lower current versions, but chassis mounted components are recommended for the higher current versions.

Voltage and Current Regulation

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

For the 3 ADC version, only a single IRF520 power FET is required external to the regulator assembly. A small gate voltage change on Q1 will result in a large output 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 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 and so eliminates input voltage fluctuations from effecting the reference voltage.

Voltage or current control automatically switches between Q201 and 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. Note also, setting the output voltage lower than 13.8 VDC lowers the initial output current limit by the ratio shown in the fold back curves, see Figures 8 and 9 .

D201 is used to bias Q202 up slightly so that only 300 mV is required across the sense resistor. A secondary benefit of D201 is to provide some temperature compensation for Q202's BE junction. R206, R207 and R208 set the initial current limit level and R209 and R210 set the fold-back current level (but with interdependence). See Figure 17. for additional details.

R208 is mounted on the Regulator Assembly for -1 and -2 (3 and 6 ADC) but should be externally mounted for -3, -4 and -5. The higher current versions can generate sufficient heat in R208 to damage a PWB as well as being too bulky for the PWB.

When R208 is externally mounted, strap S201 should be not 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.

If the Regulator Assembly is not mounted directly on the output terminals, some loss of regulation may occur due to the wiring

Basic Operation:

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.

An external current meter can be connected to E210 (+) and E211 (-). Resistor values are selected to calibrate the amp meter over the 3 to 30 Amp range. The use of both R215 and R216 will protect the meter and wiring from the high current potential of the output. For a hi-Z DPM a third resistor is added from E210 to E211 providing the correct scaling for the desired range.

An external voltmeter can be connected to E212 (+) and E213 (-). R217 provides scaling and current limit protection. If a voltage divider is required, e.g. for a DPM, a shunt resistor is added from E212 to E213, with values selected for the required scaling.

Pass transistor(s)

Refer to the schematic to see pass transistors details for the different output currents. The number and type of transistors are selected to ensure each version has sufficient margin to meet the output current and current limit specifications. If this material is being used to rework a dead Amateur Radio power supply, be sure to pay attention to the thermal design. A lot of products are specified using a very liberal interpretation of ICAS (intermittent commercial and amateur service), but in continuous duty and high ambient temperature will actually not perform anywhere near the advertised specification.

Thermal

Probably the most difficult task associated with the PS-15D, or any linear power supply, is managing the thermal design. Most Amateur Radio power supplies use some form of ICAS rating and few if any have a true CCS rating advertised.

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

Equation 1.

Thermal equivalency can be used to predict ICAS performance if CCS is known (and vice a versa). Equation 1. shows the relationship mathematically. Basically when the duty cycle is reduced from 100% to 50%, the equivalent heating is reduced to 70.7% - not 50%.

This thermal equivalency means 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 full-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.

The PS-15D-( ) thermal design provides safe operation with heat sink temperatures of +65°C up to +40°C ambient and full 100% CCS. However, +65°C is very HOT (149°F) and unsuitable for human contact. Forced air cooling is highly recommended for the -3, -4 and -5 versions.

Also, 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 must 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 are likely to have problems with some of these “ICAS” rated power supplies.

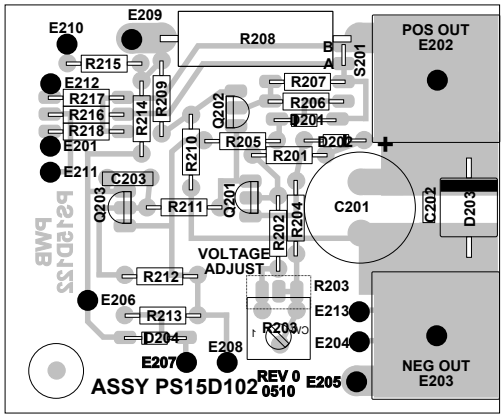

Figure 10. PS15D102 Regulator Assembly component locator.

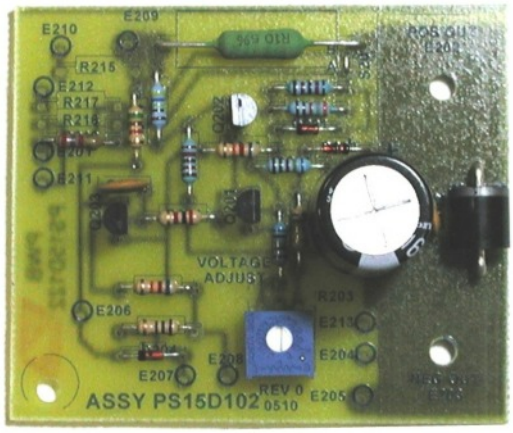

Figure 11. PS15D102 Regulator Assembly. Available from Far Circuits or contact bwcelectronics.com.

Figure 12. PS15D103 Buss Status Indicator.

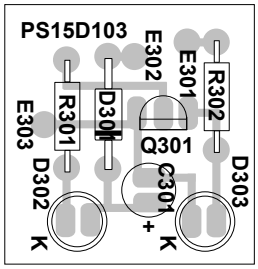

Figure 13. PS15D103 Buss Status Indicator Assembly component locator.

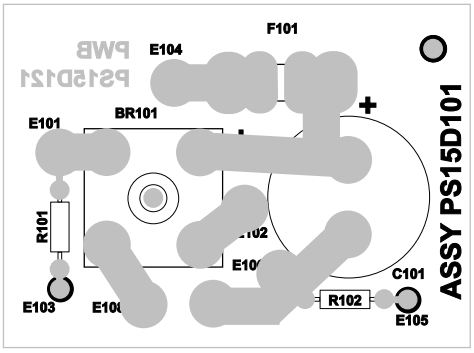

Figure 14. PS15D101 Rectifier Assembly component locator.

Figure 15. PS15D101 Rectifier Assembly. Note BR101 is mounted on foil side of PWB for heat sink attachment.

PS-15D-( ) 13.8 VDC Power Supply

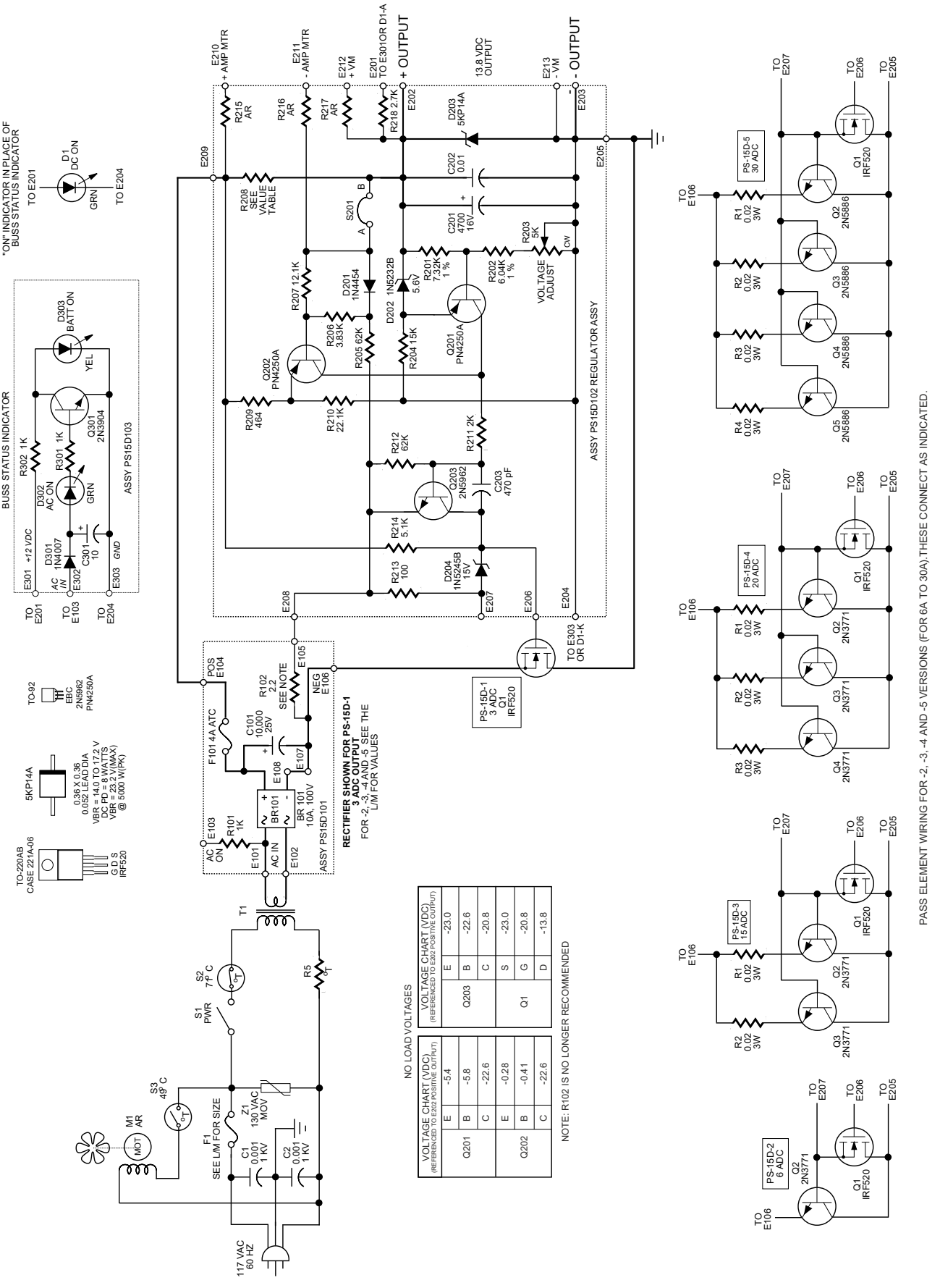

Figure 16. PS15D-( ) schematic. Shown with -1 (3 ADC rectifier). Darker lines indicate high current connections.

PS-15D-( ) 13.8 VDC Power Supply

Material List - PS15D102 Regulator Assembly for all versions

Supplier is Mouser unless otherwise noted.

Qty	Designator	Value/Type	Description	Part Number*	Supplier
1	C201	4700 µF, 16 V	Radial Al electrolytic	647-UVZ1C472MHD	
1	C202	0.01 µF	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 kΩ, 0.25 W, 1%	MF	271-7.32K-RC	
1	R202	6.04 kΩ, 0.25 W, 1%	MF	271-6.04K-RC	
1	R203	5 kΩ, 0.5 W, 5%, Cermet Trimmer	Side Adj	652-3386W-1-502LF	
			Top Adj	652-3386F-1-502LF	
1	R204	15 kΩ, 0.25 W, 5%	CF	291-15K-RC	
2	R205, R212	62 kΩ, 0.25 W, 5%	CF	291-62K-RC	
1	R206	3.83 kΩ, 0.25 W, 1%	MF	271-3.83K-RC	
1	R207	12.1 kΩ, 0.25 W, 1%	MF	271-12.1K-RC	
1	R208	See Table 4. R208 Values			
1	R209	464Ω, 0.25 W, 1%	MF	271-464-RC	
1	R210	22.1 kΩ, 0.25 W, 1%	MF	271-22.1K-RC	
1	R211	2 kΩ, 0.25 W, 5%	CF	291-2K-RC	
1	R213	100 Ω, 0.25 W, 5%	CF	291-100-RC	
1	R214	5.1 kΩ, 0.25 W, 5%	CF	291-5.1K-RC	
3	R215, R216, R217	As required	Voltmeter and Ampmeter		
1	R218	2.7 kΩ, 0.25 W, 5%	CF	291-2.7K-RC	
1			PWB	PS15D122	Far Circuits

Material List - PS15D100 Chassis Assembly for PS-15D-1

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	C1, C2	0.001 µF, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
1	D1	LED	Green	604-WP7113SGD	
1	F1	2 Amp, GMA Fast Acting	5mm x 20mm Fuse	504-GMA-2	
1	P1	3x18AWG Cord set	NEMA 5-15P	562-311007-01	
1	Q1	IRF520	Power FET	844-IRF520PBF	
1	S1	250 V, 6 Amp	SPST Rocker Switch	642-FMC12A220	
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	T1	16 VAC 80VA	115 VAC Power Transformer	RL-2260-80-16 Renco www.rencousa.com	
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
1	XF1	5mm x 20mm Fuse Holder	Panel mount	441-R3-12-GRX	
1	For Q1 and BR101	Heat Sink	ΔT_{SA} = 40 °C at 25 Watts	3.25" length of 61090 extrusion	Aavid Thermalloy

Material List - PS15D101 Rectifier Assembly for PS-15D-1

Qty	Designator	Value/Type	Description	Part Number*	Supplier
1	BR101	BR101	100 V, 10 A Bridge Rectifier	583-BR101	
1	C101	10,000 µF, 25VDC	Al electrolytic	598-SLPX103M025A5P3	
1	F101	4 Amp ATC	Blade Auto fuse	576-0257004.PXPV	
1	R101	1 kΩ, 0.25 W, 5%	CF	291-1K-RC	
1	R102	2.2Ω, 0.25 W, 5%	CF	291-2.2-RC	
1	XF1	ATC Fuse clip	PWB Mtg	534-3522	
1			PWB	PS15D121	Far Circuits

Material List - PS15D103 Buss Status Indicator Assembly for all versions

Qty	Designator	Value/Type	Description	Part Number*	Supplier**
1	C301	10 µF, 25VDC	Al electrolytic	647-UVR1E100MDD	
1	D301	1N4007	1 Amp rectifier	512-1N4007	
1	D302	LED	Green panel mtg	604-WP7113SGD	
1	D303	LED	Yellow panel mtg	604-WP7113SYD	
1	Q301	2N3904	NPN switching	512-2N3904	
2	R31, R302	1 kΩ, 0.25 W, 5%	CF	291-1K-RC	
1			PWB	PS15D131	Far Circuits

Material List - PS15D200 Chassis Assembly for PS-15D-2

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	C1, C2	0.001 µF, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
1	D1	LED	Green	604-WP7113SGD	
1	F1	3 Amp, GMA	5mm x 20mm Fuse	504-GMA-3	
1	P1	3x18AWG Cord set	NEMA 5-15P	562-311007-01	
1	Q1	IRF520	Power FET	844-IRF520PBF	
1	Q2	2N3771	NPN Pwr	511-2N3771	
1	R1	0.02Ω, 3 W, 5%	Metal Film Power	66-LOB3R020JLF	
1	S1	250 V, 6 Amp	SPST Rocker Switch	642-FMC12A220	
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	T1	16 VAC 130 VA	115 VAC Power Transformer	RL-2260-130-16 Renco www.rencousa.com	
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
1	XF1	5mm x 20mm Fuse Holder	Panel mount	441-R3-12-GRX	
1		Heat Sink	ΔT_{SA} = 40 °C at 45 W	567-423K Wakefield	

Material List - PS15D201 Rectifier Assembly for PS-15D-2

Qty	Designator	Value/Type	Description	Part Number*	Supplier
1	BR101	GBPC3510W	1000 V, 35 A Bridge Rectifier	512-GBPC3510W	
1	C101	22,000 µF, 25VDC	Al electrolytic	598-SLPX223M025E7P3	
1	F101	7.5 Amp ATC	Blade Auto fuse	576-025707.5PXPV	
1	R101	1 kΩ, 0.25 W, 5%		291-1K-RC	
1	R102	2.2Ω, 0.25 W, 5%		291-2.2-RC	
1	XF1	ATC Fuse clip	PWB Mtg	534-3522	

Material List - PS15D300 Chassis Assembly for PS-15D-3

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	C1, C2	0.001 µF, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
1	D1	LED	Green	604-WP7113SGD	
1	F1	5 Amp, GMA	5mm x 20mm Fuse	504-GMA-5	
1	M1	100 CFM 119mm Sq x 38 mm	115 VAC Muffin Fan	433-4E-115S	
1	P1	3x18AWG Cord set	NEMA 5-15P	562-311007-01	
1	Q1	IRF520	Power FET	844-IRF520PBF	
2	Q2, Q3	2N3771	NPN Pwr	511-2N3771	
2	R1,R2	0.02Ω, 3 W, 5%	Metal Film Power	66-LOB3R020JLF	
1	S1	250 V, 6 Amp	SPST Rocker Switch	642-FMC12A220	
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	S3	49 °C, N.O.	Thermal Switch	802-STC-120	
1	T1	16 VAC 400VA	115 VAC Power Transformer	406-3800	MFJ
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
1	XF1	5mm x 20mm Fuse Holder	Panel mount	441-R3-12-GRX	
1		Heat Sink	θ_{sa} = °C/W @ ΔT_{SA} = 40 °C	TBD	

Material List - PS15D301 Rectifier Assembly for PS-15D-3

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	BR101, BR102	GBPC3510W	1000 V, 35 A Bridge Rectifier	512-GBPC3510W	
3	C101, C102, C103	22,000 µF, 25VDC	Al electrolytic	598-SLPX223M025E7P3	
1	F101	15 Amp ATC	Blade Auto fuse	576-0257015.PXPV	
1	R101	1 kΩ, 0.25 W, 5%		291-1K-RC	
1	R102	2.2Ω, 0.25 W, 5%		291-2.2-RC	
1	XF1	ATC Fuse clip	PWB Mtg	534-3522	
1	XBR	Rect Heat sink	θ_{sa} = 0.86°C/W @ ΔT_{SA} = 30 °C	TBD	

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Material List - PS15D400 Chassis Assembly for PS-15D-4

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	C1, C2	0.001 µF, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
1	D1	LED	Green	604-WP7113SGD	
1	F1	6 Amp, GMA	5mm x 20mm Fuse	504-GMA-6	
1	M1	100 CFM 119mm Sq x 38 mm	115 VAC Muffin Fan	433-4E-115S	
1	P1	3x18AWG Cord set	NEMA 5-15P	562-311007-01	
1	Q1	IRF520	Power FET	844-IRF520PBF	
3	R1, R2, R3	0.02Ω, 3 W, 5%	Metal Film Power	66-LOB3R020JLF	
3	Q2, Q3, Q4	2N3771	NPN Pwr	511-2N3771	
3	R5	2.5/0.09 Ω, 8A	NTC Surge Current Limiter	527-CL30	
1	S1	250 V, 6 Amp	SPST Rocker Switch	642-FMC12A220	
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	S3	49 °C, N.O.	Thermal Switch	802-STC-120	
1	T1	16 VAC 540VA	115 VAC Power Transformer	406-3800	MFJ
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
1	XF1	5mm x 20mm Fuse Holder	Panel mount	441-R3-12-GRX	
1		Heat Sink	θ_{sa} = °C/W @ ΔT_{SA} = 40 °C	TBD	

Material List - PS15D401 Rectifier Assembly for PS-15D-4

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	BR101, BR102	GBPC3510W	1000 V, 35 A Bridge Rectifier	512-GBPC3510W	
4	C101, C102, C103, C104	22,000 µF, 25VDC	Al electrolytic	598-SLPX223M025E7P3	
1	F101	20 Amp ATC	Blade Auto fuse	576-0257020.PXPV	
1	R101	1 kΩ, 0.25 W, 5%		291-1K-RC	
1	R102	2.2Ω, 0.25 W, 5%		291-2.2-RC	
1	XF1	ATC Fuse holder	Pig tail	534-3522	
1	XBR	Rect Heat sink	θ_{sa} = 0.61°C/W @ ΔT_{SA} = 20 °C	TBD	

Material List - PS15D500 Chassis Assembly for PS-15D-5

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	C1, C2	0.001 µF, 1KV	Ceramic disk (power line rated)	81-DEBB33A102KA2B	
1	D1	LED	Green	604-WP7113SGD	
1	F1	8 Amp, GMA	5mm x 20mm Fuse	504-GMA-8	
1	M1	100 CFM 119mm Sq x 38 mm	115 VAC Muffin Fan	433-4E-115S	
1	P1	3x18AWG Cord set	NEMA 5-15P	562-311007-01	
1	Q1	IRF520	Power FET	844-IRF520PBF	
4	Q2, Q3, Q4, Q5	2N5886	NPN Pwr	863-2N5886G	
1	R5	2.5/0.09 Ω, 8A	NTC Surge Current Limiter	527-CL30	
4	R1, R2, R3, R4	0.02Ω, 3 W, 5%	Metal Film Power	66-LOB3R020JLF	
1	S1	250 V, 6 Amp	SPST Rocker Switch	642-FMC12A220	
1	S2	71° C, N.C.	Thermal Switch	802-STO-170	
1	S3	49 °C, N.O.	Thermal Switch	802-STC-120	
1	T1	16 VAC	115 VAC Power Transformer	8233 (35A) or 8401 (50A)**	Astron
1	Z1	130 VAC	MOV	650-ROV07H201K-S	
1	XF1	5mm x 20mm Fuse Holder	Panel mount	441-R3-12-GRX	
1		Heat Sink	θ_{sa} = °C/W @ ΔT_{SA} = 40 °C	TBD	

** Astron 8233 is used in the RS-35M rated 25 ADC CCS and 35 ADC ICAS and is marginal for the PS-15D-5. The 8401 is used in the RS-50M and should be sufficient for the PS-15D-5.

Material List - PS15D501 Rectifier Assembly for PS-15D-5

Qty	Designator	Value/Type	Description	Part Number*	Supplier
2	D101, D102	70HF120	1000 V, DO-5 Rectifier	844-70HF120	
5	C101,102,103,104,105	22,000 µF, 25VDC	Al electrolytic	598-SLPX223M025E7P3	
1	F101	30 Amp ATC	Blade Auto fuse	576-0257030.PXPV	
1	R101	1 kΩ, 0.25 W, 5%		291-1K-RC	
1	R102	2.2Ω, 0.25 W, 5%		291-2.2-RC	
1	XF1	ATC Fuse clip	PWB Mtg	534-3522	
1	XD101, 102	Rectifier heat sink (per diode)	θ_{sa} = °C/W @ ΔT_{SA} = 35 °C	TBD	

Power Capability Warning

The specified components, with proper heat sinks will provide 100% duty cycle (CCS).

Even so, the temperature rise may exceed 50°C in areas around the transformer and heat sinks. It is strongly recommend forced air cooling be employed to both

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Current limit calculations

Figure 17. equations calculate the PS-15D-( ) current limit and fold-back. They can be used for custom designs or to adjust the described versions. The current limit is sensitive to D201 and Q202 BE forward voltage drop, so variations of ± 15% can be expected and precise settings will require some selection of components. R206, R207 and R208 primarily effect the initial current limit whereas R209 and R210 primarily effect the fold-back ratio. However, all of the resistors interact to effect both settings. Table 4. lists R208 values for currents of 3 to 30 ADC.

Strap S201

Strap S201 is connected from A to B when R208 is mounted on the PS15D122 PWB. S201 is not used when R208 is mounted external to the PWB, but rather S201-A and B are connected as shown in Figure 18, with the high current connection to point B actually close to or on, E202 - the positive output terminal.

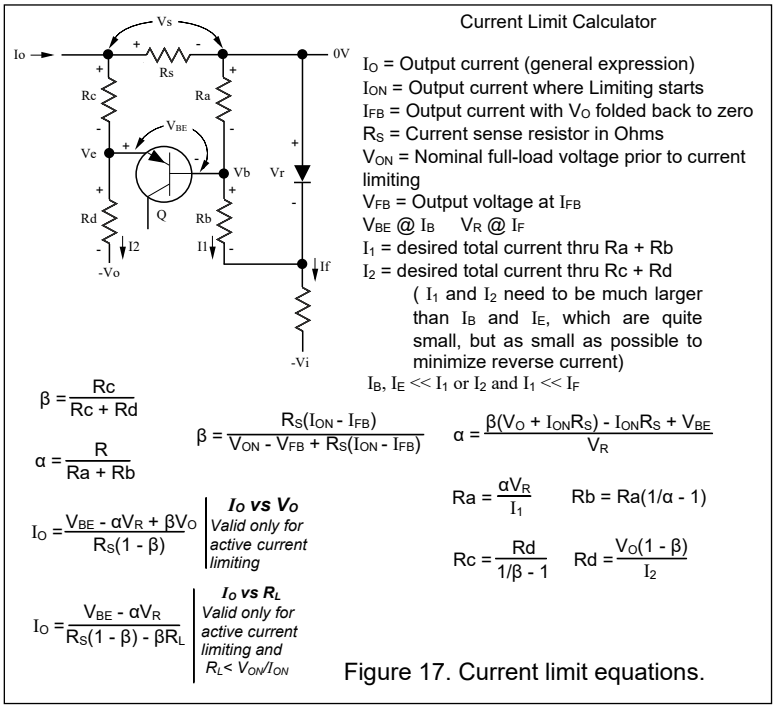

Figure 17. Current limit equations.

Table 4. R208 values.

PS-15D-( )	Current Limit (ADC)	R208			
		Value	Wattage	Part Number	
-1	3.6	0.10Ω	3 W	66-LOB3R100JLF	
-2	7.2	0.05Ω	5 W	66-LOB5R050JLF	
-3	18	0.02Ω	10 W	66-LOB5R040JLF	2 ea 0.04Ω, 5W paralleled
-4	24	0.015	10W	66-LOB5R030JLF	2 ea 0.03Ω, 5W paralleled
-5	36	0.01Ω	25 W	71RH250.01	

Part numbers listed above are Mouser Electronics www.mouser.com

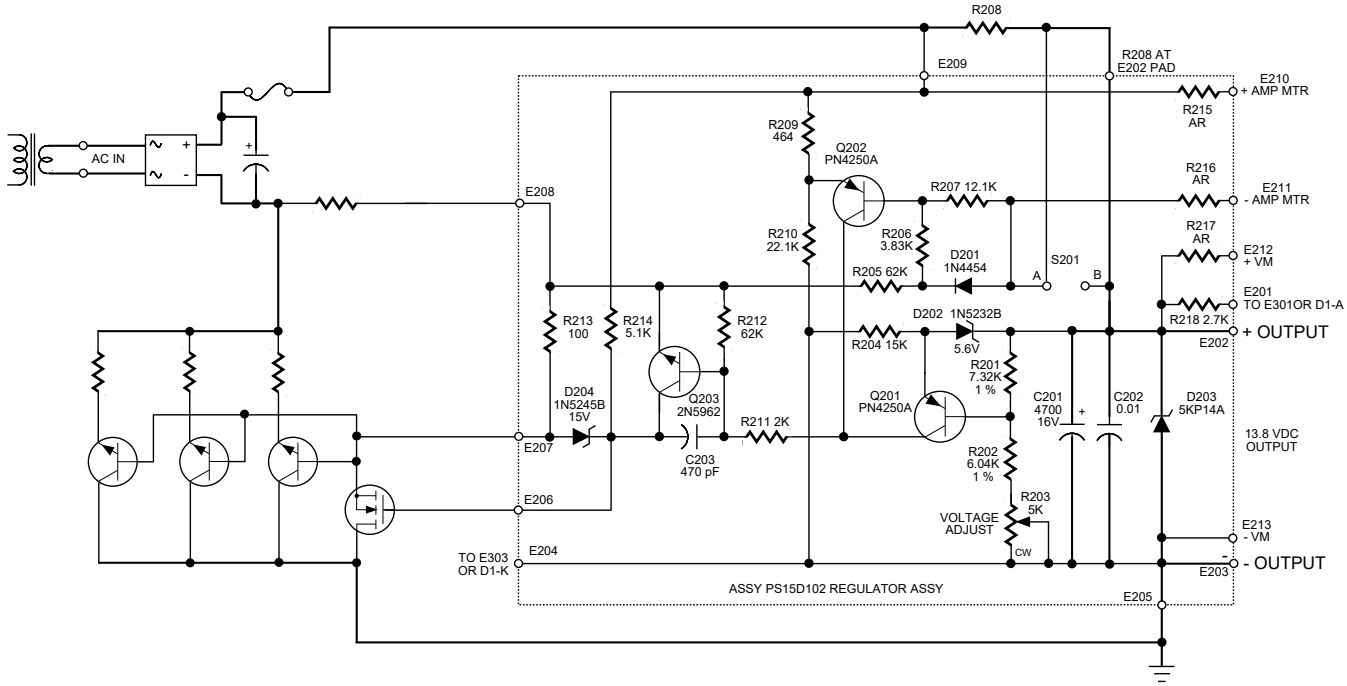

Figure 18. Externally mounted R208 wiring using a Kelvin connection to minimize errors. Darker lines indicate high current connections.

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Typical construction of the PS-15D-( ) power supplies as new and refurbished.

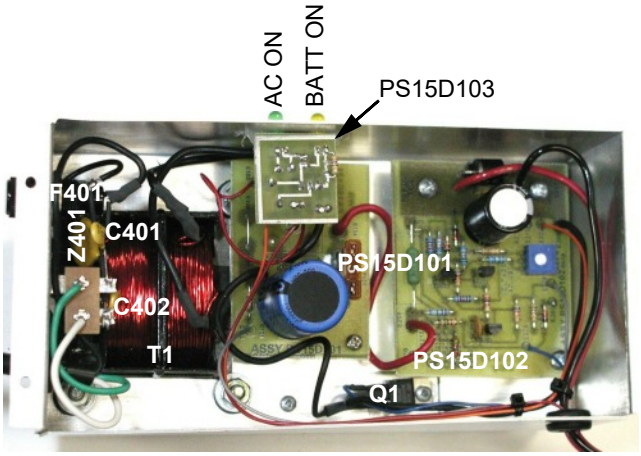

Figure 19. PS-15D-1 view inside chassis. Chassis formed from 0.040 5052-H32 sheet aluminum on shop brake. Bud or other manufacturer's chassis can be substituted.

Figure 20. PS-15D-1 top view . Heat sink mounts on chassis which has a cut-out for Q1 to mount directly on the heat sink.

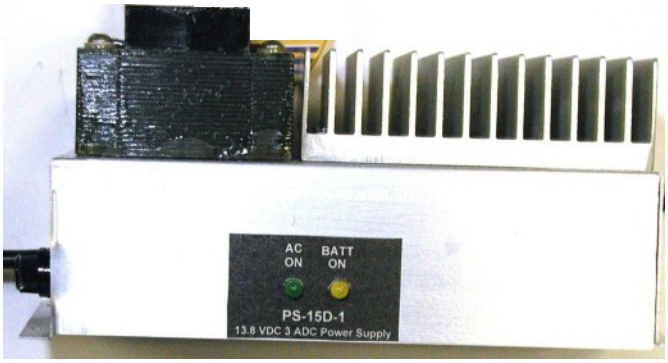

Figure 21. PS-15D-1side view showing the Buss Status LEDs. This particular power supply provides float charge and regulation for an entry gate where the Buss Status is adapted to provide local and remote status as well as to control the enclosure's ventilation fan.

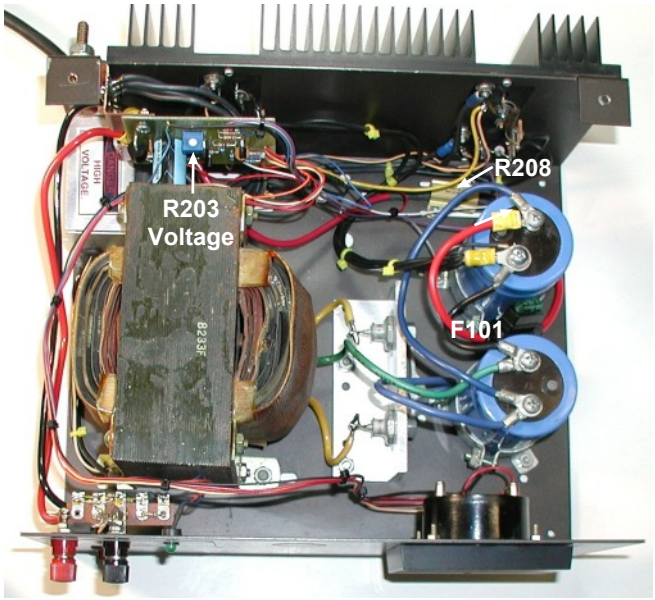

Figure 22. Inside view of PS-15D-5 reworked into an Astron RS-35M power supply. Transformer, rectifiers, filter capacitors and heat sink were re-used with the PS15D102 regulator assembly.

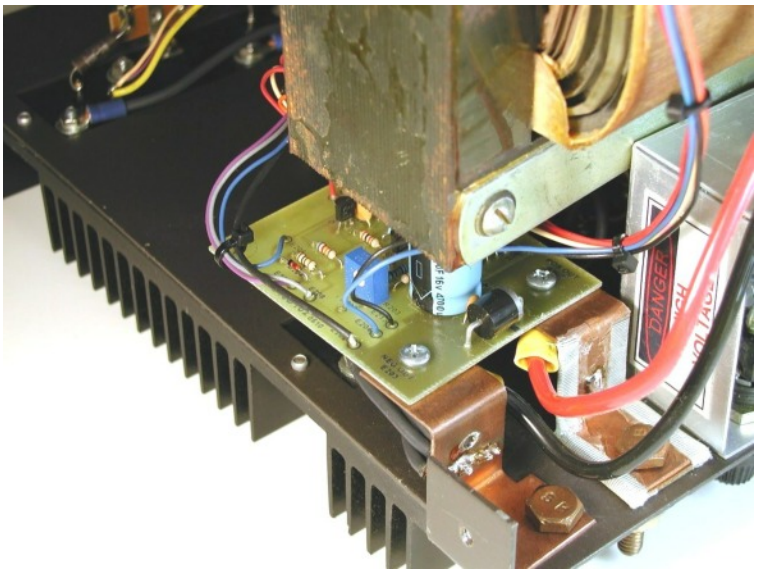

Figure 23. Close-up view of PS15D102 mounted on copper brackets to the output terminals of the RS-35M refurbished into a PS-15D-5.

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FAQ and user experience

As of September 2017, a few hundred PS15D102 regulator boards have been built and installed. Of these I have only had a few request for help (which I am glad to provide).

In all cases, difficulties have been traced to wiring errors, with the exception of D203, which can fail if a prolonged over voltage is present at the output (which has occurred due to wiring errors). This TVS is present to provide reverse voltage protection, protect the load and regulator from high voltage inductive spikes resulting from switching an inductive load and induced EM transients (such as near-by lightning).

The original implementation indicated the TVS would open F101 for an extended over-voltage, but for different sizes and types of fuses, this can not be expected. For extended over-voltage protection, the MC-20A-1 DC Buss Monitor and Control or an SCR crowbar , see Figure 24., is recommended.

Figure 25. is the schematic of one Astron RS-35M I reworked for a friend. I have received comments this helps understand the board implementation when reworking Astron power supplies. Note however, Astron power supply models differ one from another depending upon when they were manufactured and so may not be represented by this particular refurbish.

Also notice the 2.2Ω, R102 is no longer recommended. Its purpose was to protect the circuit board, but if it opens the regulator looses control which is a bigger problem.

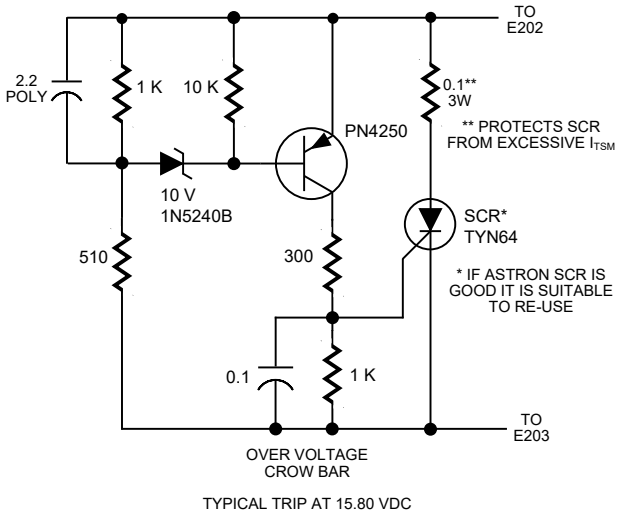

Figure 24. SCR over-voltage crowbar.

FAQ

1. The regulator has NO minimum load requirement.
2. Q1-S connects to the negative side of the rectifier/filter when it is the only pass element in use (no NPN pass transistors).
3. Q1-S connects to E207 when external NPN pass transistors are used.
4. S201 is wired from S201-A to S201-B if R208 is mounted on the PCB.

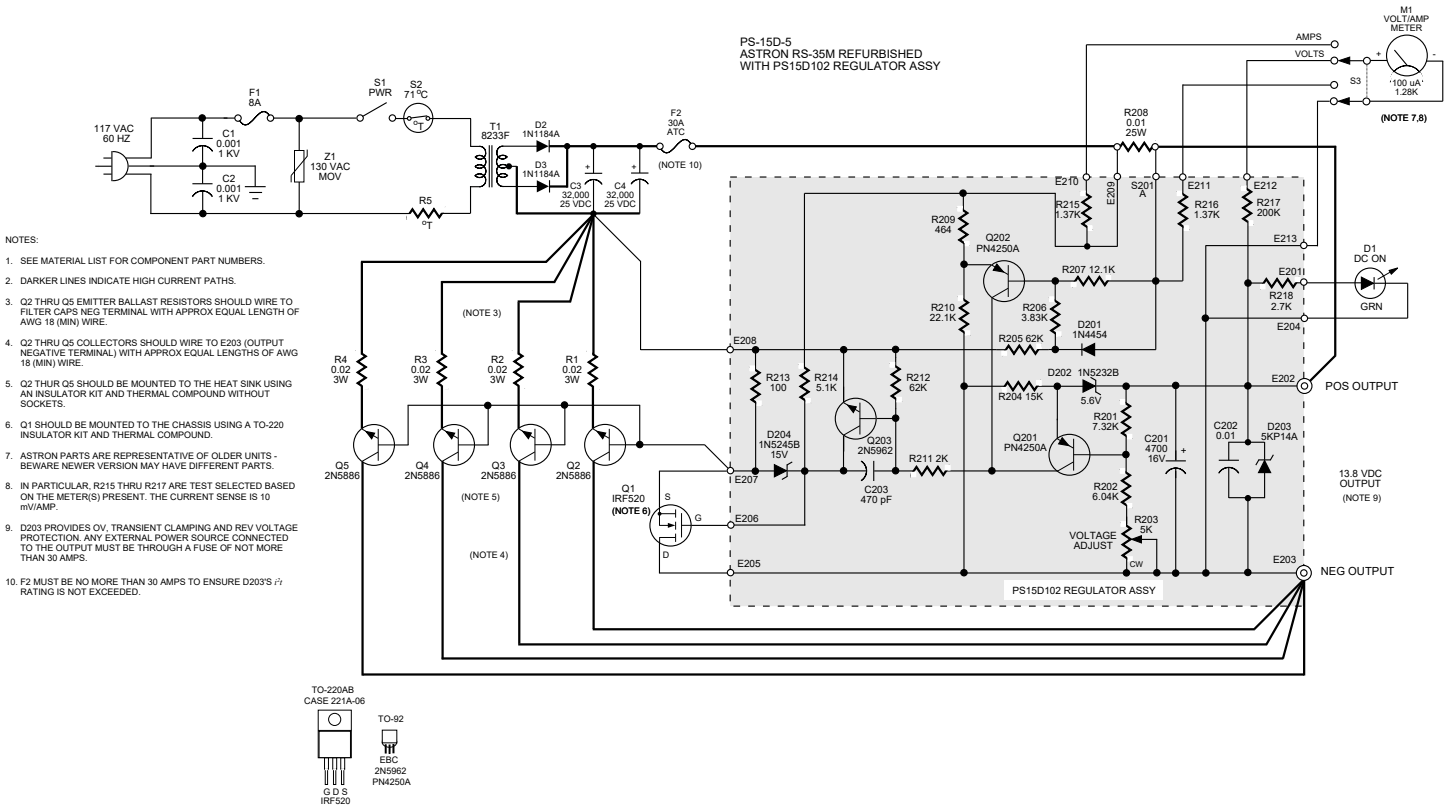

Figure 25. Schematic of an Astron power supply refurbished with the PS15D102.

FAQ (continued)

5. S201-A is wired to the output terminal side of R208 when an external resistor is used. S201-B is left unused.

6. The PS15D102 is NOT a drop in replacement for Astron boards.

7. The PS15D102 is for refurbishing Astron power supplies - meaning it is not a drop-in replacement. For instance, the pass transistors are emitter followers in most Astron circuits but are common emitter configuration in the refurbish.

8. The PS15D102 is a very robust circuit. Most wiring errors do not damage the regulator itself. However, Q1 and D203 can be damaged by miswiring.

9. The PS15D102 regulator assembly does not have to be mounted on the output terminals. Best transient response and regulation are achieved by doing so, but for powering most electronic equipment, such as HF transceivers, it is of less importance.

10. Basic electronics training, soldering skills and ability to read schematics are required to refurbish a power supply.

11. For instructional purposes, the PS15D102 can be used to build the PS-15D-1 (basic 3A power supply). Even so, it is strongly recommended you have an instructor or mentor on hand.

12. I can provide tech support but I am not capable of providing correspondence electronic technician training.

13. This document contains a lot of information and deserves careful study if you have problems, and I likely will refer you to it when you request tech support. Even so, fell free to ask for help if you get stumped.

14. Component changes; D203 is now 1.5KE18 and Q201, Q202 are 2N5087 (still can use PN4250A if you can find them). Even 2N3906 can be used with slight loss of performance.