University of Brighton
School of Engineering

Power Supply Unit (PSU)
EO108 – Engineering Applications A

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Abstract

This project is to build and fully test a regulated variable DC power supply unit (PSU).

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1. Introduction & Background of the project

This is a Year 1 introduction project, so that new students can get used to the lab and equipment. The project is based on a variable DC PSU, with supplied pre-prepared materials (i.e. pre-drilled PSU box, pre-drilled & printed circuit-board). The project includes testing of modules and a full written report.
As this PSU is a tried and tested design, there are previous students' PSUs to refer to, if the directions in the booklet are not clear.

2. The Transformer, Rectifier & Input Filter

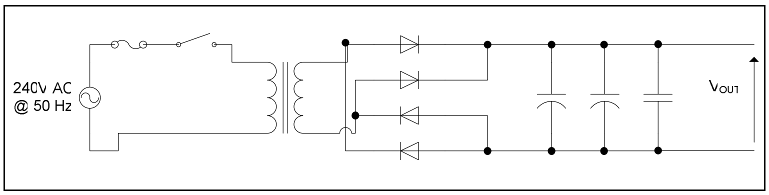


Figure 1 - Transformer, Rectifier & Smoothing diodes

2.1. Discussion of Transformer Modelling & Losses

The ideal transformer, for AC signals will change the voltage across the primary winding side to the secondary side, in a ratio directly proportional to the ratio of windings on either side.

I.E. $\frac{\hat{V}_{Primary}}{\hat{V}_{Secondary}} = \frac{\text{No. Turns Primary}}{\text{No. Turns Secondary}}$

However, in practice, there will be losses due to heat dissipation (copper losses) and magnetic (iron losses).

The stage after the transformer is the bridge rectifier (or full wave rectifier), which inverts the negative part of the sine wave. The smoothing capacitors then turn the rectified sine wave into a rippled DC waveform.

2.2. D.C. & A.C. Signals

A direct current signal (DC) is such that for any given moment in time, the voltage produced is unidirectional. Theoretical components will produce a perfect smooth DC output (i.e. with 0V ripple) but in practice, as a load is applied (current drawn), the DC voltage will fluctuate, due to internal resistance.

Conversely, an alternating current (AC) signal is one that changes direction, in the context of mains power-supplies it would be typically sinusoidal.

2.3. Test Procedure

a) Plug in Mains
b) Connect Digital Multimeter (DMM) to V_{OUT}
c) Switch on Mains (at plug then at PSU switch)
d) Measure V_{OUT} (should be almost 20V DC)
e) Connect Cathode-Ray Oscilloscope (CRO) to V_{OUT}
f) Measure Ripple Voltage (CRO on AC setting)

2.4. Test Results

d) Voltage at V_{OUT} ➔ 20.7V (DC)

f) V_{RIP} at V_{OUT} ➔ 15mV (peak-to-peak)

Note: Ripple voltage hard to measure due to small size and CRO not being able to lock on properly.

3. *The Voltage Regulator Circuit Board*

3.1. Specification & Principal Operation

The principal operation of the voltage regulation part of the circuit is to ensure a variable smooth DC voltage is produced across the output terminals. The amplitude of the DC output is varied by a variable resistor in the feedback loop, allowing the voltage difference across the terminals to be varied from 5-15 volts.

3.2. Construction

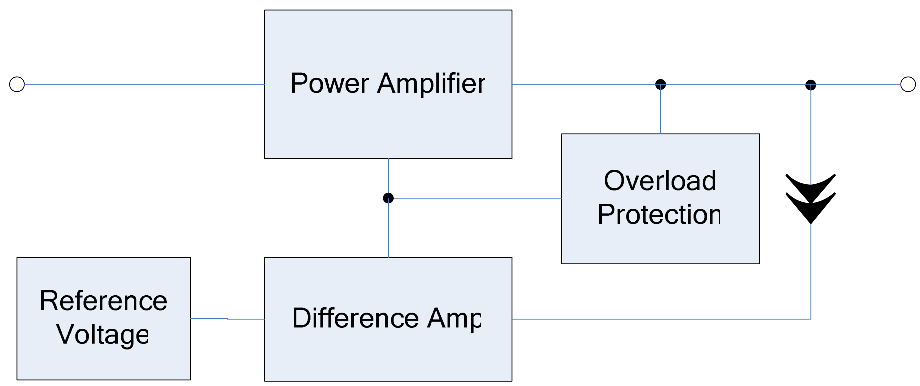


Figure 2 - Block Diagram of Regulator

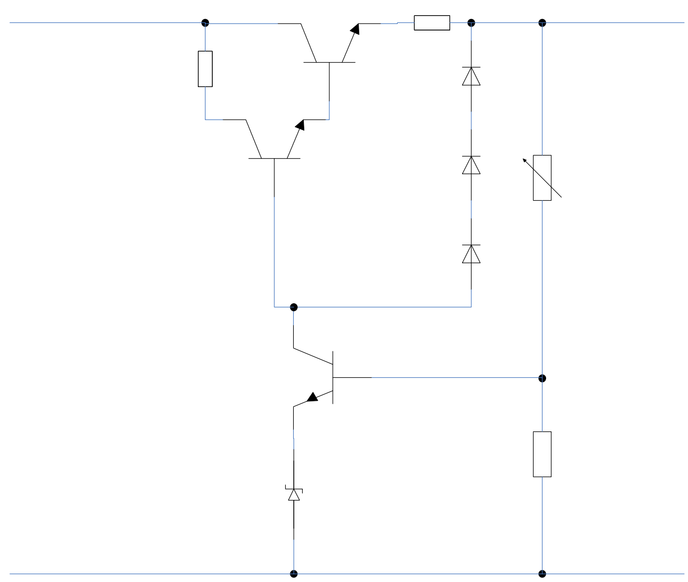


Figure 3 - Circuit Diagram of Regulator

3.3. Test Procedures

3.3.1. D.C. Tests

a) Firstly, the transformer must be disconnected from the PCB and a DC bench power supply connected in place of the secondary winding. The rectifier at the beginning of the PCB, can be ignored for this test. (There will be a fixed 1.4V drop but this will be made up for in the bench PSU.)
b) By plotting input against output voltage (starting at 0 and going up to 20V) it should show a graph that levels off at a different voltage, according to the setting of the variable resistor. This shows the regulation working.
c) These tests should be repeated with the variable resistor in
   i. Lowest Position
   ii. Middle Position
   iii. Highest Position
d) After each test, the Capacitors must be discharged

3.3.2. A.C. Tests

By inverting the DC voltage across the input terminals, this simulates the negative cycle of the AC waveform and will show that it will work for both parts of the AC input.

3.4. Results

3.4.1. D.C. Tests

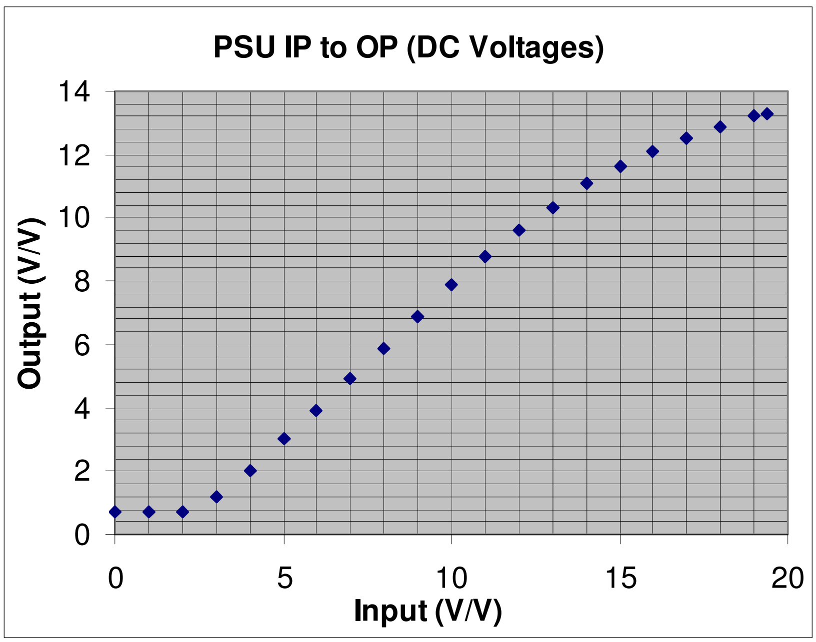


Figure 4 – Graph of IP to OP Voltage (Variable Resistor set to mid-way)

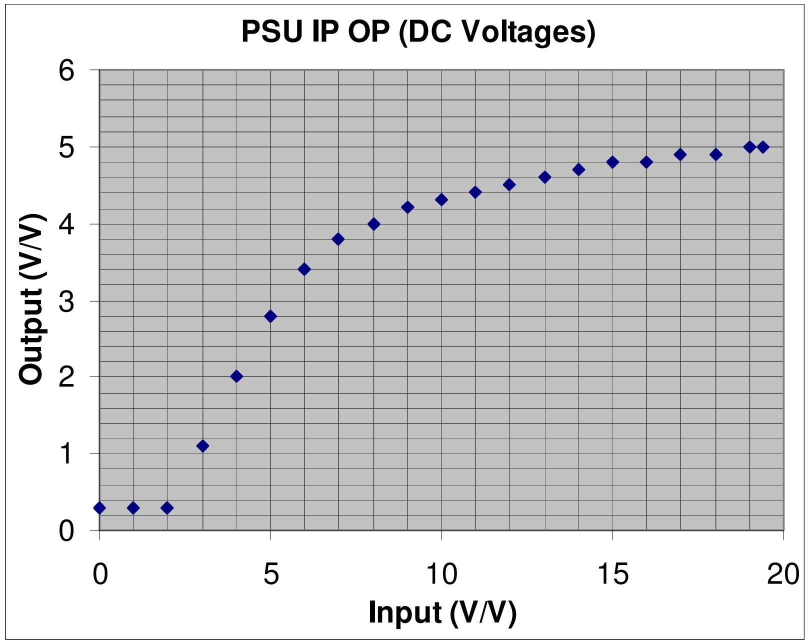


Figure 5 - Graph of IP to OP Voltage (Variable Resistor set to minimum)

As these graphs show, the voltage regulator begins to control the output, when there is sufficient voltage supplied and it levels out at the position the variable potentiometer is set to. (See *Appendix B* for details of results)

3.4.2. A.C. Tests

The same as DC tests (give or take accuracy of measuring instruments) For Example:

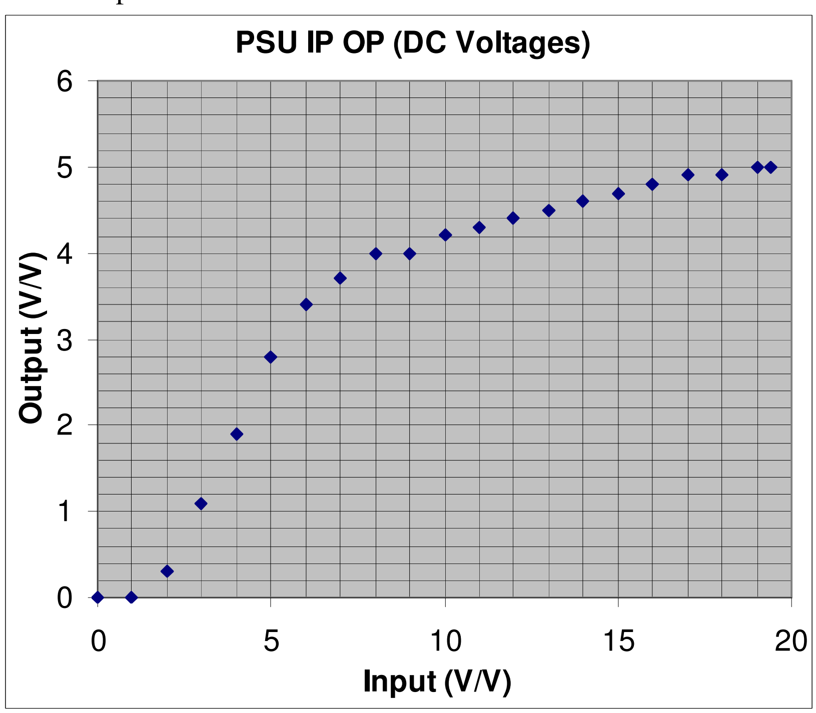


Figure 6 - Graph of IP to OP Voltage (Variable Resistor set to minimum, input terminals reversed)

4. The Completed PSU

4.1. Construction

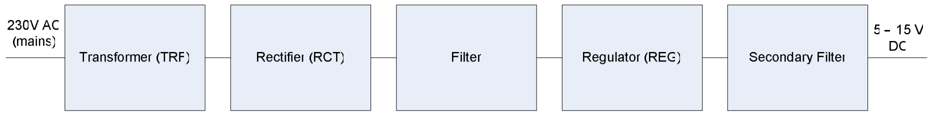
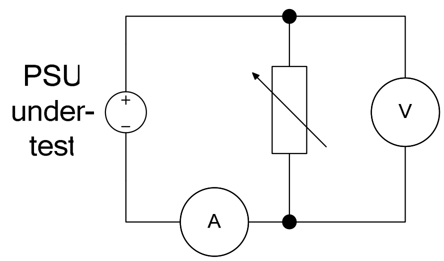


Figure 7 - Block Diagram of Complete PSU

Also see Appendix A for completed PSU circuit diagram

4.2. Test Procedures

All the final tests, are loading tests. This involves connecting up a circuit like follows:



As this is a variable DC PSU, there will need to be several runs, with the DC voltage amplitude dial set to different levels. For the purposes of testing, these levels shall be *lowest*, *mid-way* and *highest*. This should show the complete range of the PSU, identifying obvious trends etc.

The results will be recorded in a table of output-current to output-voltage, which can be plotted on a graph. The full range of currents the PSU can supply can be obtained by using a variable resistor (or rheostat) with at least a 1 amp current rating. This resistor can then be varied from 0Ω (effective short circuit) to at the most 200Ω, to give it a range of almost 100mA to 1A.

The specification of this PSU's design states that it should be able to supply a current of 500mA, therefore meaning that a flat line should appear on the graph to at least the 500mA point. After this point, the voltage is expected to break down as the overload protection kicks in, to protect the components from overheating.

4.2.1. Regulation

<u>Definition</u>:

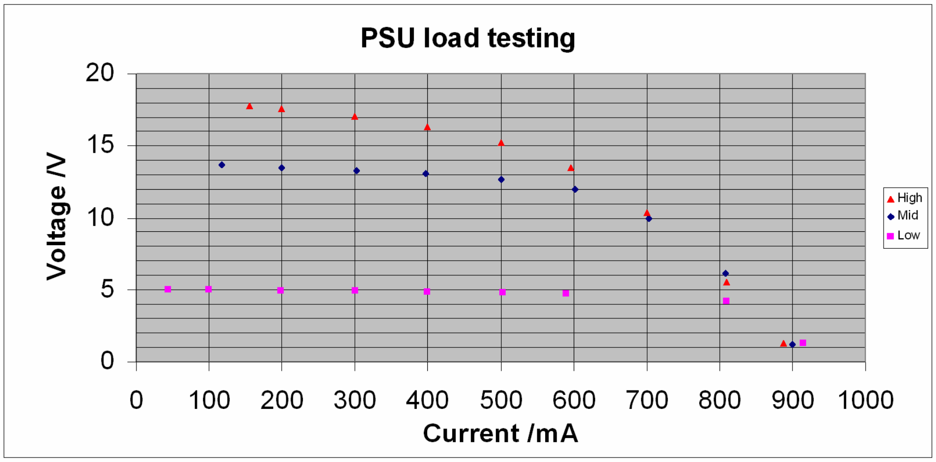
$$\text{Regulation} = \frac{(\text{Off - load voltage}) - (\text{On - load voltage})}{\text{Off - load voltage}} \times 100\%$$

The nominal specified rating is 500mA, so this is the point where the regulation will be calculated

4.2.2. Ripple

<u>Definition</u>: *The peak to peak ripple level superimposed on a DC output.* [EAA04-5]. The ripple voltage is best measured with an oscilloscope using AC coupling. This allows the ripple to be amplified by excluding the DC component of the waveform.

4.3. Results



4.3.1. Regulation

Lowest Voltage Setting (at 500mA)

$$\frac{4.99-4.81}{4.99}\times 100\% = 3.6\% \text{ Regulation}$$

Mid-Way Voltage Setting (at 500mA)

$$\frac{13.69-12.66}{13.69}\times 100\% = 7.5\% \text{ Regulation}$$

Highest Voltage Setting (at 500mA)

$$\frac{17.76-15.24}{17.76}\times 100\% = 14.2\% \text{ Regulation *}$$

* The highest voltage setting had already started breaking down before 500mA.

4.3.2. Ripple

Lowest Voltage Setting < 3mV peak-peak ripple
Mid-Range Voltage Setting ~3-17mV peak-peak ripple
Highest Voltage Setting > 71mV peak-peak ripple (140mA load)

4.4. Discussion of Results

See Appendix C for load testing data (using AVO as ammeter, using Crotech 4049 as ammeter and oscilloscope traces).

The most useful analysis representation for this PSU is the load testing graph. This clearly shows that as the voltage amplitude dial setting is increased, the amount of current that can be drawn before the voltage starts dropping goes down.

5. Conclusions

Doing this project has been a very worthwhile experience, allowing students such as myself to use the lab instruments, and develop such skills as soldering. Apart from discovering that the first oscilloscope I was using had a fault, the project construction and testing went without any drawbacks. All the results from the tests completed show the PSU is working in a manner that the specifications dictate, hence it would be a fair assumption that the components have been soldered in the correct places, with correct polarisation etc.

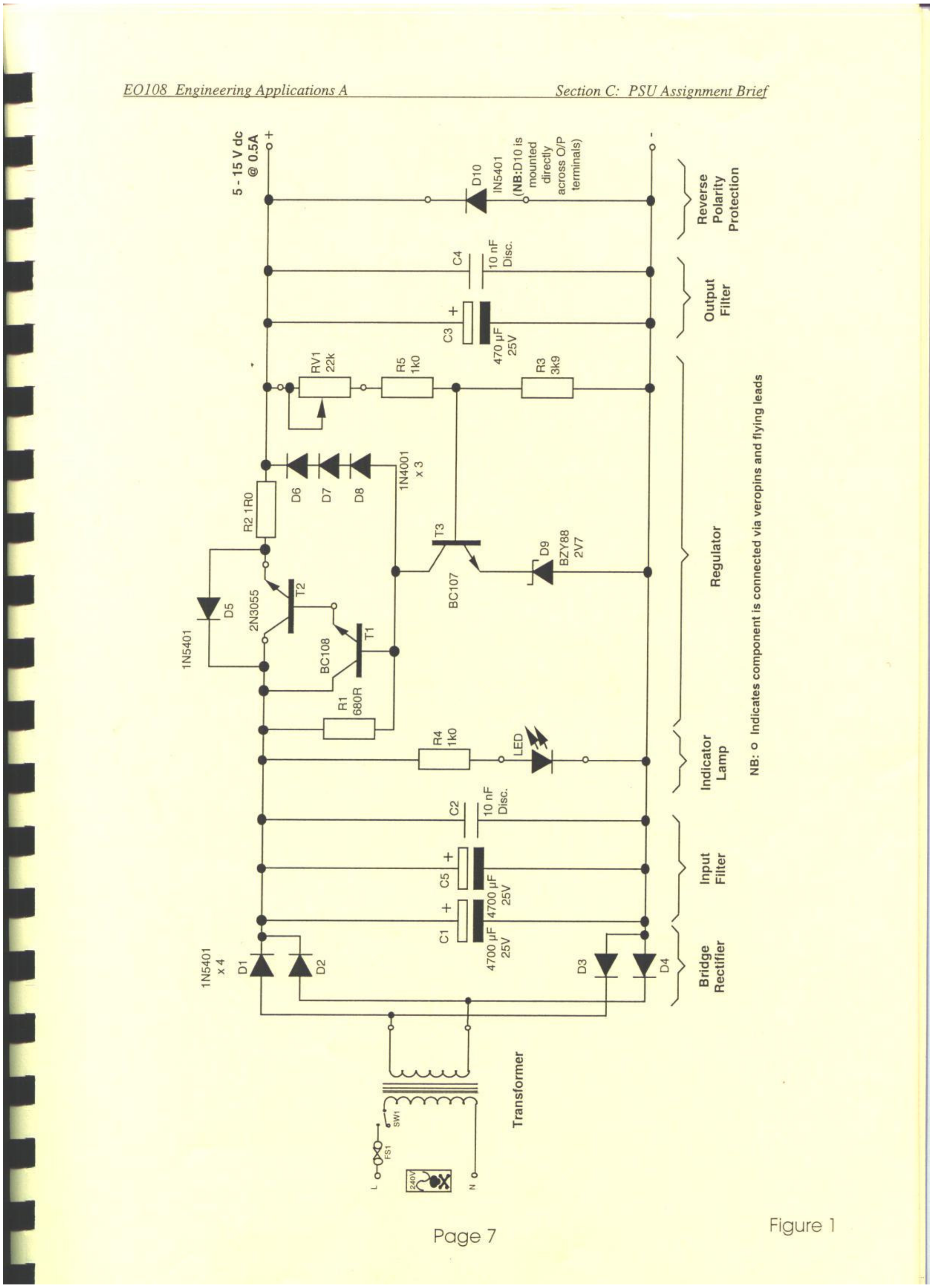
The lowest resistor setting gives a lower output voltage. It regulates at about 5V and can supply up to 800mA with good regulation.
The mid-way resistor setting gives a mid-range output voltage, It regulated, in this instant, at 13V, supplying up to 600mA with reasonable regulation.
The highest resistor gives the highest output voltage. Off-load it can supply about 18V, although the voltage drops quickly due to internal resistance taking a larger effect on the output. Due to this voltage drop as more current gets drawn, the regulation figures worsen, but this is expected.

Due to the fact that this project has been almost following instructions, using pre-designed components, there is not anything can be discussed about the final product meeting original specifications, apart from the points that have already been stated.

6. References

[EAA04-5] refers to the EO108 Engineering Applications A booklet, for 2004-2005

7. Appendices



Appendix A – Complete PSU circuit diagram, from [EAA04-5]

Variable Resistor set to mid-way

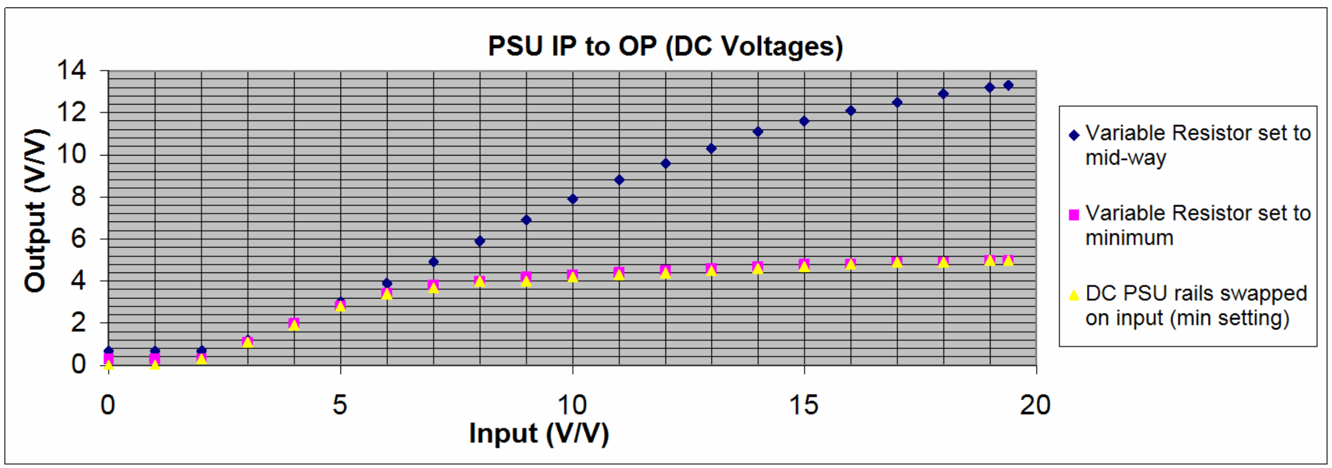
I/P V	O/P V	
0	0.7 \	
1	0.7 >	Caps not fully discharged
2	0.7 /	
3	1.2	
4	2	
5	3	
6	3.9	
7	4.9	
8	5.9	
9	6.9	
10	7.9	
11	8.8	
12	9.6	
13	10.3	
14	11.1	
15	11.6	
16	12.1	
17	12.5	
18	12.9	
19	13.2	
19.4	13.3	

Variable Resistor set to minimum

I/P V	O/P V	
0	0.3 \	
1	0.3 >	Caps not fully discharged
2	0.3 /	
3	1.1	
4	2	
5	2.8	
6	3.4	
7	3.8	
8	4	
9	4.2	
10	4.3	
11	4.4	
12	4.5	
13	4.6	
14	4.7	
15	4.8	
16	4.8	
17	4.9	
18	4.9	
19	5	
19.4	5	

DC PSU rails swapped on input (min setting)

I/P V	O/P V
0	0
1	0
2	0.3
3	1.1
4	1.9
5	2.8
6	3.4
7	3.7
8	4
9	4
10	4.2
11	4.3
12	4.4
13	4.5
14	4.6
15	4.7
16	4.8
17	4.9
18	4.9
19	5
19.4	5



Appendix B – Rectifier Tests

PSU load.xls

Dial set mid-range

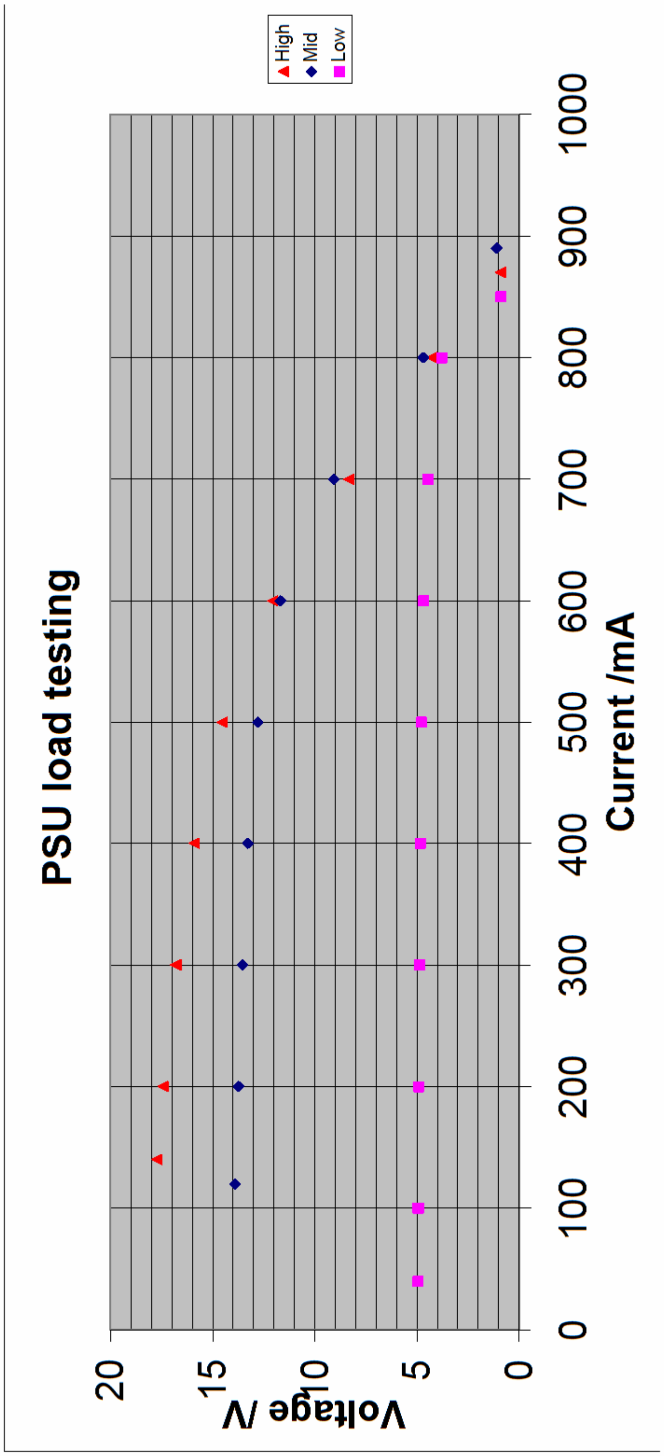
Vout /V	Iout /mA	
13.9	120	3 (2ms/div, xV/div)
13.73	200	
13.56	300	
13.28	400	
12.8	500	
11.69	600	
9.07	700	
4.69	800	
1.1	890	

Dial set lowest

Vout /V	Iout /mA	
4.95	40	4 (5ms/div, 5mV/div)
4.94	100	
4.9	200	
4.87	300	
4.83	400	
4.77	500	
4.68	600	5 (2ms/div, 5mV/div)
4.46	700	
3.79	800	
0.88	850	

Dial set highest

Vout /V	Iout /mA	
17.73	140	6 (2ms/div, 10mV/div)
17.43	200	
16.81	300	7 (2ms/div, 20mV/div)
15.91	400	
14.54	500	
12.07	600	
8.34	700	
4.26	800	
0.9	870	



Prepared by Michael Curry 15/11/2004

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Appendix C.1 – PSU load testing, with AVO model 8 to measure current

Dial set mid-range

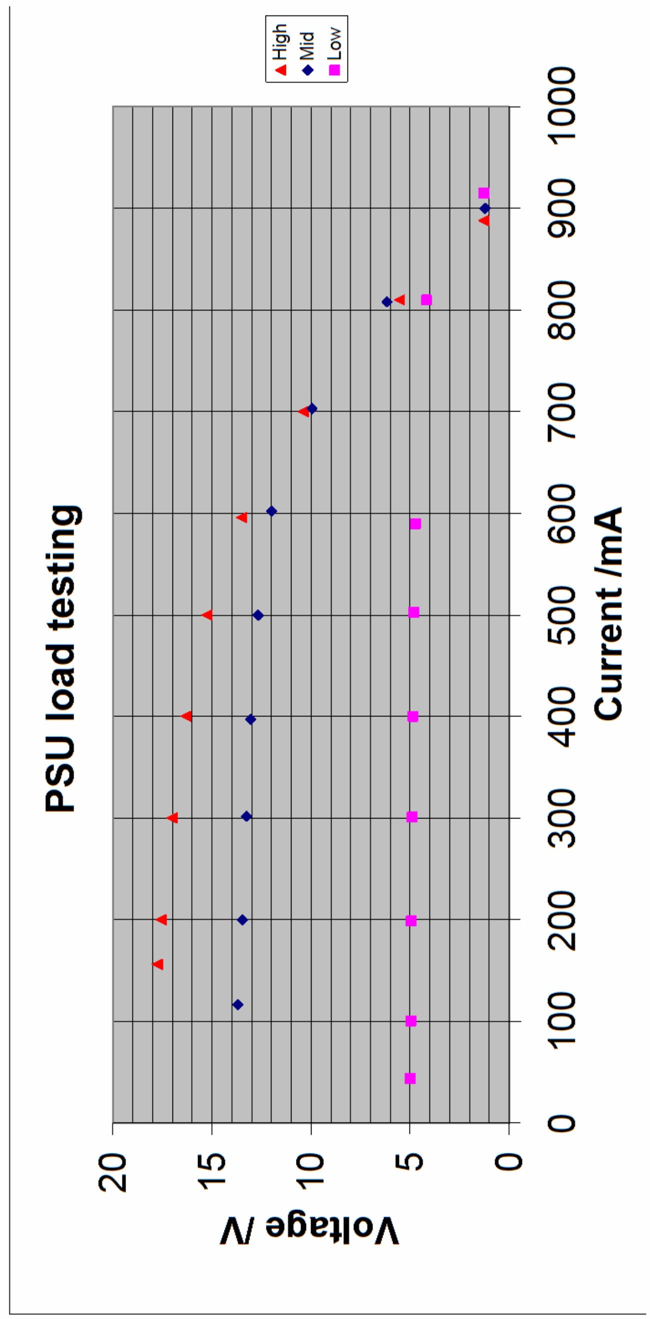
Vout /V	Iout /mA
13.69	116.6
13.46	200
13.25	302
13.05	397
12.66	500
11.99	602
9.95	703
6.16	808
1.23	900

Dial set lowest

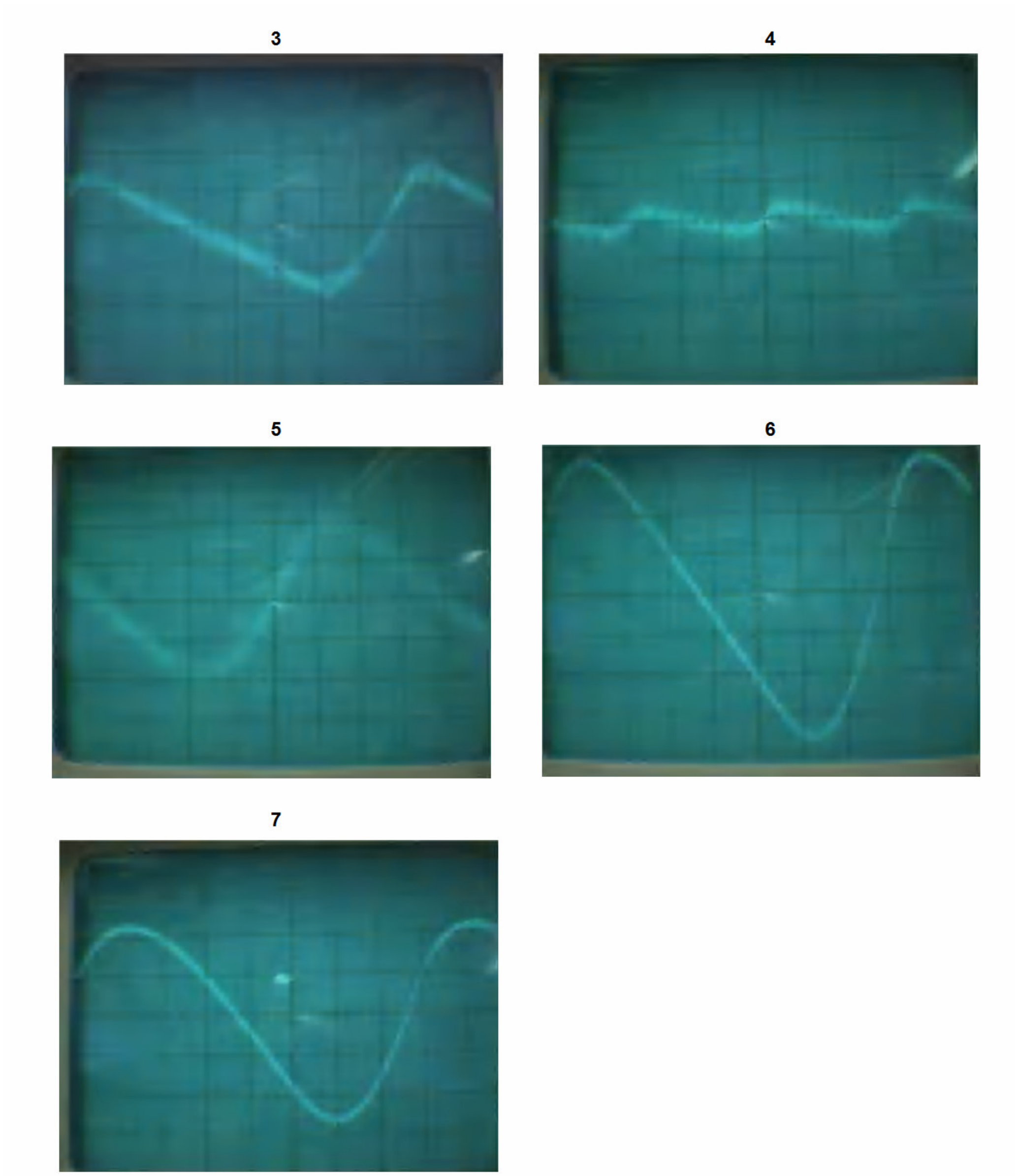
Vout /V	Iout /mA
4.99	44
4.97	100.5
4.94	199
4.9	301
4.86	400
4.81	503
4.74	590
4.18	810
1.26	915

Dial set highest

Vout /V	Iout /mA
17.76	156.1
17.56	200
17.01	300
16.3	400
15.24	500
13.5	596
10.4	700
5.54	810
1.3	888



Appendix C.2 – PSU load testing, using Crotech 4049 to measure current



Appendix C.3 – PSU load testing – Oscilloscope traces

These traces are in reference to the AVO load testing readings in Appendix C.1

<u>*Key*</u>
3 – 2ms/div, 1mV/div
4 – 5ms/div, 5mV/div
5 – 2ms/div, 5mV/div
6 – 2ms/div, 10mV/div
7 – 2ms/div, 20mV/div