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12V computer power supplies

Are they suitable for amateur radio use?

INTRODUCTION. With the advent of the personal computer came and ever increasing need for processing horsepower – and the associated increase in DC power to drive these animals. The amateur radio community has sometimes eyed these units as a possible source of low cost motive power for radios. Attempts at re-use have had varying degrees of success. This article provides some background into some of these issues and introduces a new class of low cost power supply that is almost directly fit-for-purpose for VHF FM applications.

This is not intended as a constructional article, more of an investigation and discussion into the types and classes of various power supplies that are available. The article describes some test methods and concludes with specific measurements made to two low cost, high current power supplies able to supply 12V at 26A and 77A respectively. The smaller units are often seen on eBay UK for under £10 including postage; the larger ones are typically £40 or so.

Two things struck me at the start of this project. (1) I know about PSUs, this should be easy. (2) This should be reasonably quick set of tests. In practice, I scored a very solid, not-to-be-argued-with 0 out of 10 on both points. But I learned a lot, which I'm sharing with you now.

POWER SUPPLY REQUIREMENTS. A significant amount of radio equipment is designed to be operated in a mobile environment from the ubiquitous 12V lead-acid battery. In practice, this supply voltage wanders all over the place, depending on driving conditions.

Daylight motorway driving provides the opportunity for minimal load on the electrical system, while plenty of charge current may be available from the alternator.

PHOTO 1: I thought testing PSUs would be simple. I was wrong.

Battery voltage can rise past 14.5V under such conditions.

Night time driving in the rain while stopped at a traffic light means low engine revs, with extra loads from the windscreen wipers and (obviously) the headlights. Battery voltage may be at a minimum during these situations. A nominal low rail of 11V is sometimes taken for this situation.

So, let's take 11.0 to 14.5V as a reasonable supply range for a mobile radio. The exact limits are usually specified in the radio handbook.

LINEAR VS SWITCH MODE. There are two main techniques to create a regulated low voltage supply from mains power, each with their own pros and cons.

By far the oldest approach to the problem is the linear power supply. Mains power at 50 or 60Hz is fed through an appropriate transformer with a secondary typically in the order of 14V or so AC. This is then rectified, smoothed and passed through series pass element – usually one or more bipolar transistors or, more recently, power MOSFET(s). This technique is called secondary side regulation.

This is not the most efficient sort of power supply, since the design has to take a lot of things into consideration. First is low or high mains voltage – an allowance of ±10% on nominal is usual. The power supply must work OK on an input that's 10% low so, as a consequence, with a 10% high mains voltage

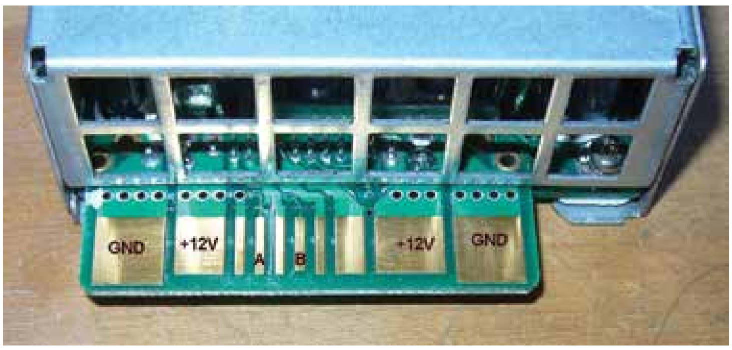

PHOTO 3: HP ESP128 pins A and B need to be connected to ground (GND) before the PSU will function.

PHOTO 2: A HP ESP128 switch mode power supply – 12V at 26A for about £10.

there is 20% more DC voltage for the secondary side to regulate (read 'drop', ie to dissipate as heat). Further sources of loss include copper wire resistance (heating in the primary and secondary windings), magnetising current, rectifier drop (0.7V or 1.4V, depending on rectifier/transformer topology), voltage drop of the series pass element, current sense resistor and PCB track resistance. The list just goes on…

Full load efficiency may be around 50% for this type of regulator. If you plan to run high RF powers from a linear power supply, it is sure to keep you warm. But on the upside, linear power supplies tend to be electrically very quiet, as the circuits are quite low bandwidth and no high frequencies are involved. The large reservoir capacitors mean that transient responses can be quite good.

So, while the good old linear PSU is not the most efficient, the technique can result in a supply that is quiet and can respond to load changes very rapidly.

One way of significantly improving efficiency and reducing weight for a power supply is to use a (significantly) higher frequency for the transformer current. This allows the use of a very much smaller and

PHOTO 4: A Dell 7000245 switch mode power supply – 12V at 77A for about £40.

PHOTO 5: The pins in the white box must be shorted together to make the Dell 7000245 PSU operate.

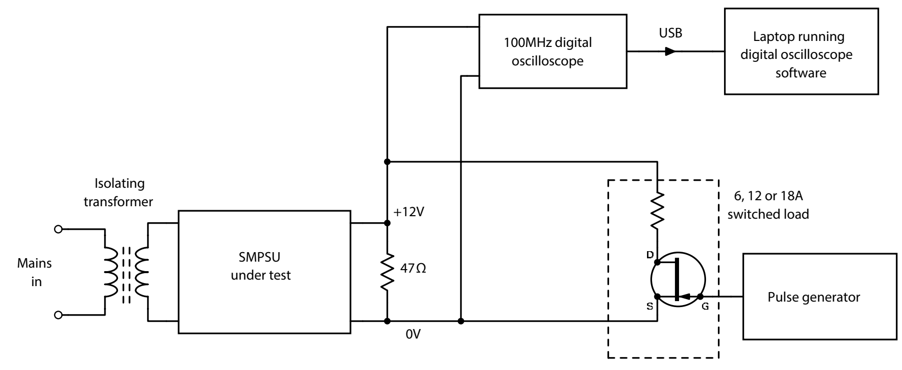

FIGURE 1: General test setup.

lighter transformer core, typically made of a ceramic-ferrite compound. Another mechanism to improve efficiency is to regulate the mark-space ratio of the current passing through the transformer. This primary side regulation technique delivers power to the primary as demanded from the secondary (load) side. Load information is usually passed through an optocoupler to provide electrical isolation between primary (live) and secondary (grounded) side of the system. This architecture is known as a switch mode power supply (SMPSU) and the factors that need to be taken into consideration include:

- Rectifying and smoothing the mains to around 400V DC (230V countries) or 200V DC (117V countries), whilst managing the power factor (to keep the power company happy)
- Using a pulse width modulator (PWM) to generate a switching waveform (often running at >100kHz) and a suitable high speed switching device to chop the high voltage DC
- Passing this chopped DC through a ferrite transformer into a rectifier and smoothing circuit
- Regulating the secondary (output) voltage by feeding back a demand request to primary side PWM.

While the efficiency of latest-generation SMPSUs can be in the high 90s of percent, the downside of these techniques can be the generation of RF noise since fast moving, harmonic rich square waves are used in the power transfer process.

As the output capacitors of the units have a finite effective series resistance (ESR), associated circulating currents will therefore create noise voltage on the output. Careful design along with careful selection of output capacitors can manage these noise currents; appropriate screening can significantly reduce noise voltage on the output of a SMPSU. It is unlikely however, that the techniques will ever be as quiet as a linear power supply. Also, SMPSU regulators tend to be (reasonably) slow in responding to load changes. This is often because they are designed to power relatively static loads.

The bulk of the lower cost integrated, multi voltage SMPSUs have only a single regulated secondary supply. In the case of units designed for the PC market, it is normally the low voltage, high current rail that is regulated. All of the other auxiliary rails (±12V etc) tend to 'go along for the ride'. One of the consequences of this is that if significant current is drawn from the main rail, the primary side regulation mechanism increases the primary side switching current to keep the low voltage rail regulated, but the auxiliary rails may also rise in the process.

STACK-O-BOXES. Given that only the main rail (maybe 5V) is regulated, if you need high current in the order of 15V, why not wire several power supplies in series? Actually, it's a Really Bad Idea.

The ground rail of the PSU is often connected to the chassis, so this would need to be isolated if this approach is to be considered – there can be some serious safety implications of such actions. Also be aware that you would have three different frequency switching components being mixed in the output rail. There is also the issue of having three sets of fans running, which can be quite (acoustically) noisy.

In my opinion, this approach should be avoided at all costs.

(RE)WIND YOUR OWN SECONDARY. I know of at least one published article where the author took apart and rewound the secondary of a SMPSU to allow operation at 12V. This approach is best described as being hazardous and cannot be recommended.

POWER SUPPLIES SUMMARY. As a broad generalisation, linear power supplies are more appropriate for use on the lower frequency bands, while linear or switched mode supplies may be used on the VHF bands and above. One caveat to this statement is the point at which a power supply is just so noisy that supply injected noise starts to affect transmit performance (eg creating unwanted sidebands) and receive performance (local oscillator noise – not to mention received 'hash').

If you want to learn more about SMPSU design, see the excellent book *Demystifying Switching Power Supplies* by Raymond A Mack, ISBN 9780750674454.

NEXT GENERATION COMPUTER POWER DISTRIBUTION. In older PCs and servers, a single point of regulation has traditionally been used for power distribution. It is generally located within the main power supply. One of the consequences of this is that low voltages at high current have to be carried around. This entails the use of bundles of cable, as well as very thick copper tracks on the main motherboard (PCB).

Some newer servers have been designed to produce an intermediate voltage DC rail (typically 12V) which is connected to the motherboard. Secondary regulators, physically close to the main CPUs, regulate this down to the required core voltages, which can be less than 2V and at very high currents. These newer 12V power supplies are the focus of this article.

PREREQUISITES AND PERFORMANCE

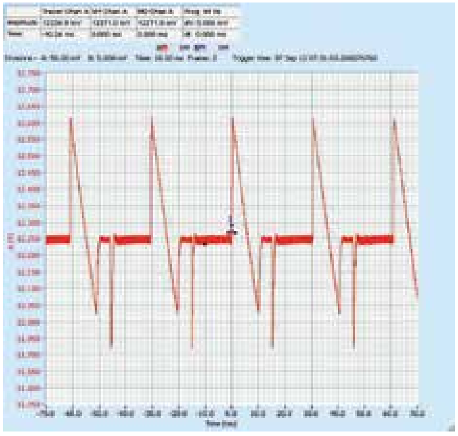

FIGURE 2: HP ESP128 undergoing the truly evil test of a 260mA fixed load plus an 18A load switched at 33Hz.

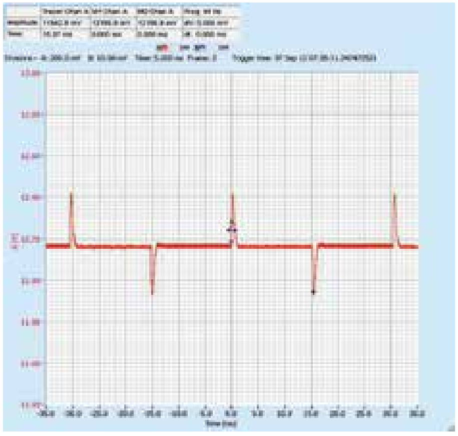

FIGURE 3: HP ESP128 with a 6A fixed load plus a 12A load switched at 33Hz.

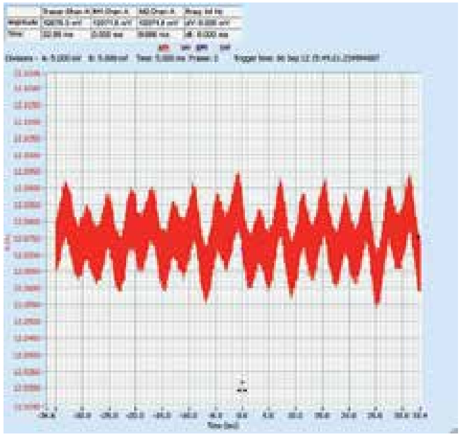

FIGURE 4: Dell 7000245 with 260mA fixed load.

TESTS. Since these power supply units are going to be used somewhat outside their original design brief, some testing is called for. And given the currents involved with these tests, I feel some precautions are called for. My standard set of prerequisites include: (1) a fire extinguisher, (2) rubber gloves and (3) a change of underwear.

I also armed myself with some test equipment, detailed in Table 1. The basic test setup is shown in Figure 1 and Photo 1. Where appropriate, all units are in calibration, or have been tested against in-cal units.

BASIC TESTS. *Fixed load (260mA):* The 47Ω resistor shown in Figure 1 was always in circuit; this is to simulate current being drawn by a transceiver in receive mode.

Switching load (260mA to 18A): Computer power supplies tend to expect reasonably static load currents. This parameter is evaluated by using a 33Hz switched 18A load test (with a constant 260mA drain from a 47Ω resistor) controlled by the pulse generator. Peak-to-peak and RMS noise are of interest, along with waveforms. This is to simulate a medium power SSB transceiver on transmit with aggressive speech peaks.

Switching load performance (6.26A to 18A): Same as above, but with one of the 6A (2Ω) loads always in circuit. This test is to see if SMPSU regulation performance improves with a higher residual current.

Fixed load (18.26A): Six 4Ω resistors in parallel, along with the 47Ω resistor. This simulates a medium power FM transceiver on transmit.

RF susceptibility: Any power supply that is intended to be used in an environment with possibly high RF field needs to be tested to confirm that the regulation mechanism is not upset by such conditions. This can be estimated by waving a 4W 144MHz FM hand held around the test setup while pushing the PTT. This has been a remarkably useful and successful way of causing havoc with prototype equipment in the past.

Real world Tx: connecting the SMPSU to a real transmitter: This is only a reality check to see how a real-world product behaves with a noisy supply. I used a FT857D, set to 144.000MHz, with the output set to +45dBm (~31W). The resulting spectrum was checked for unwanted sidebands.

Real world Rx: FT857D to SSB RX at 144.001MHz, listening for a barely detectable signal 1kHz high (I would have done a SINAD test if time permitted).

Correct grounding for these types of tests is critical. To have any hope of being able to understand and measure circulating currents within the test setup, the system must only have a single ground point. Incorrect grounding for these tests can end up with load current passing through test equipment ground test leads causing (huge) errors.

This suite of testing is far from exhaustive, but will hopefully be useful at supplying some kind of information about first-order performance of the various power supplies.

HP ESP128 SMPSU TEST. This 325W power supply is used inside the HP Proliant DL360 G3 server. They are often available used on eBay for around £10 including postage. The main regulated output of this unit is 12V at 26A. AC input is on a standard IEC-60320 C14 chassis male, which mates with the common-or-garden PC power lead. This unit does not have an internal fan, so it must be placed in the path of some free flowing air if it is intended to draw anything like full power for extended periods. **Photo 2** shows my example.

Two edge connector pins need to be grounded to enable the unit. This is easily done by soldering a small piece of tinned copper wire between ground and pins A and B in **Photo 3**.

Various loads were applied to the PSU and the results observed on the oscilloscope.

The output was shorted out several times; the unit gracefully closed down and recovered.

With a 260mA fixed load, there was about 20mV pk-pk of noise (4.8mV RMS). At a steady load of 18A there was about 25mV pk-pk noise (7mV RMS).

260mA fixed load, with 18A load switched at 33Hz. This is the truly evil test and represents an about-as-bad-as-it-can-get condition. The power supply is well behaved with the 18A load, but takes some time to readjust to a light load of 260mA. I observed 700mV pk-pk noise (112mV RMS) – see **Figure 2**.

6.27A fixed load, with 12A load switched at 33Hz. The fixed 6A load clearly improves loop stability with the unit. Noise is just under 500mV pk-pk (39mV RMS) – see **Figure 3**.

With a constant 18A load applied, waving a 144MHz 4W handheld around the test setup and keying the transmitter at about 1Hz caused the output to change by about 500mV. I thought this was quite a significant change.

Real world Tx: No unwanted sidebands noticeable with FM transmitter set to 144.000MHz at +45dBm, over 200kHz span, with 1kHz resolution bandwidth over 80dB dynamic range.

Real world Rx: With SSB RX set to 144.000MHz, able to detect signal at 144.001MHz at -137dBm (this is as low as can easily be generated using my signal generator).

DELL 7000245 SMPSU TEST. This power supply is used inside the Dell Poweredge PE 6650 server. It is rated at 900W and has been seen on eBay for under £40 including postage. The main regulated output of this unit is 12V at 77A. AC input is an IEC-60320 C20 chassis male, which mates with the IEC-60320 C19 female. This unit is fitted with a pair of 65mm

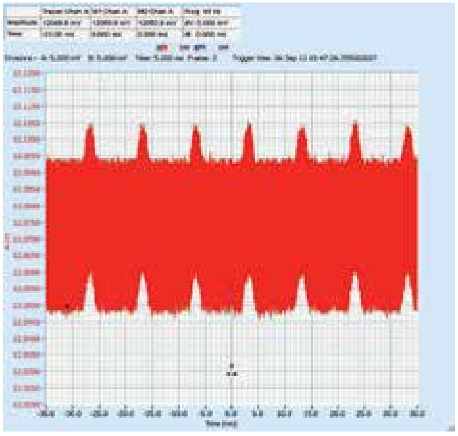

FIGURE 5: Dell 7000245 with 18A fixed load.

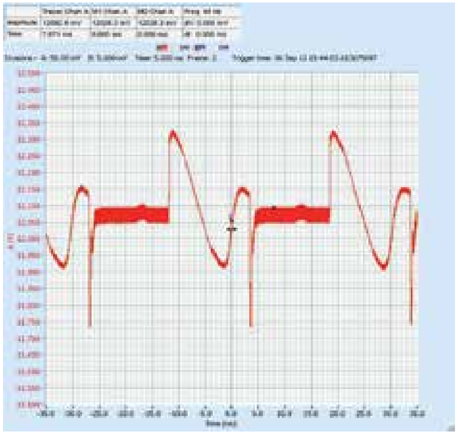

FIGURE 6: Dell 7000245 undergoing the truly evil test of a 260mA fixed load plus an 18A load switched at 33Hz.

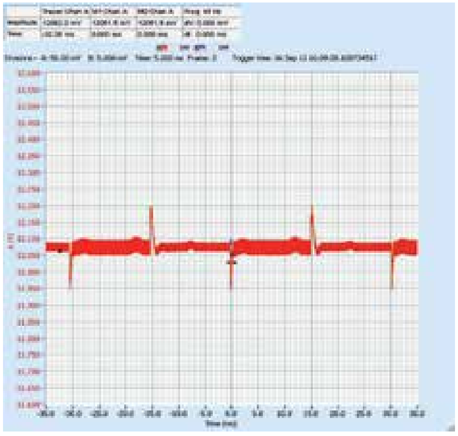

FIGURE 7: Dell 7000245 with a 6A fixed load plus a 12A load switched at 33Hz.

fans, which are reasonably quiet during normal operation. **Photo 4** shows a typical example.

In order to make the PSU operate, three pins need to be joined together. These are shown in the white box in **Photo 5** and this connection may be accomplished with a 3 pin 0.1" in line female connector with all pins shorted. Photo 5 also indicates the main output connections.

Nominal power up voltage was set to 12.087V. The supply appears to have a switching frequency around 130kHz. The output was shorted out several times and the unit gracefully closed down and recovered without any sparks or explosions.

With a 260mA fixed load, there was about 30mV pk-pk noise (7mV RMS), comprising 15mV pk-pk switching noise and 15mV pk-pk low frequency ripple. The unit appears slightly unstable with such a small load – see **Figure 4**.

With an 18A fixed load there was about 60mV pk-pk noise (16mV RMS), comprising 52mV pk-pk switching noise and 8mV pk-pk mains ripple – see **Figure 5**.

The PSU was quite well behaved with the truly evil test of a 260mA fixed load with 18A load switched at 33Hz. It settles quickly with the 18A load, but takes some time to re-adjust to a light load of 260mA, showing 600mV pk-pk noise (97mV RMS) – see **Figure 6**.

6.27A fixed, with 12A load switched at 33Hz. The fixed 6A load clearly improves loop stability with the unit (**Figure 7**). Noise is just under 250mV pk-pk (19mV RMS).

With a constant 18A load applied, waving a 144MHz 4W handheld around the test setup and keying the transmitter at about 1Hz caused the output to change by about 8mV. This is much better than the HP supply.

Real world Tx: no unwanted sidebands were noticeable with the FM transmitter set to 144.000MHz at +45dBm, over 200kHz span, with 1kHz resolution bandwidth over 80dB dynamic range.

Real world Rx: With SSB RX set to 144.000MHz, I was able to detect a signal at 144.001MHz at -137dBm.

NOTES, FINAL THOUGHTS AND FURTHER WORK. I learned much, much more during these experiments than I would have credited at the start of the project. It proved the old adage, 'the more you learn, the less you realize that you know'.

In SMPSU-land, bigger is not necessarily better. Some units require quite a significant amount of idle current (minimum load) before they can gracefully switch between small and large loads, eg from receive to transmit. Both of these units are adjustable to at least 13.0V with the addition of a resistor. There is lots of data available on the internet covering these and several other units.

It is likely that any high power SMPSU you find will require some form of cooling, either by way of a heatsink or, more likely, a fan. Having said that, beware of small fans, they can deliver quite an annoying whistle. The 2 x 57mm fans used in the Dell unit produced broad acoustic noise, which was acceptable.

I only tested these PSUs for interference at a spot frequency on 2m. It would be prudent to check them out on the lower bands as well – some SMPSUs can emit quite a lot of hash on HF.

A test that I have contemplated is to generate a 1.5kHz test tone, amplitude modulated at 1kHz and fed into the mic input on SSB. This would case a continuing and rapid change of supply current. Supply voltage and RF spectrum could then be checked to see how the SMPSU performed.

Unless specifically designed for the purpose, SMPSUs do not generally fare well with very high speed load changes. However, by its very nature, SSB transmissions (and therefore current demands) are pretty much slew rate limited to the highest frequency passing through the microphone. This results in much slower current demand and release, so these tests really can be considered rather aggressive.

Don't underestimate the havoc that RF injection can cause to you power supply. In the 1980s there was one 20A CB power supply that gave a perfect 13.8V until it saw a sniff of RF, whereupon its output went to 30V. Few transceivers survived. Careful inclusion of ferrite filters may mitigate these problems, but take great care. You may want to do more testing than just waving a 2m handheld around before connecting your expensive amateur radio gear to a PSU designed for a computer.

TEST EQUIPMENT USED

Agilent 34401A
6½ digit multimeter, DC and AC volts

Agilent 8935A
spectrum analyser (up to +50dBm) with signal generator (down to -137dBm)

HP 8013B
pulse generator

CleverScope CS328A
100MHz oscilloscope with 4M sample buffer

Load bank
comprising 3 x 4Ω // 4Ω metal clad resistors on heatsink, 300W peak rating

Load switcher
made from 3 x IRFZ22 power FETs

Receiver simulator
1 x 47Ω metal clad resistor, always in circuit, drawing ~260mA to simulate a receiver

Yaesu FT857D HF-70cm
medium power all mode radio

Icom V-85 144MHz
FM radio, used as a portable RF source to inject noise