

# Build a 13.5V 20A Switch- mode Power Supply...

## from junk parts!

Part One, by Phil Harman VK6APH/JA2

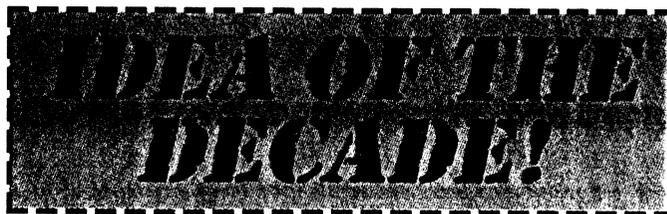
**Need a 13.5V 20A Power Supply to power that new rig? Here's a genuinely brilliant idea — a low-cost method of building a lusty 20A shack supply from a junked IBM PC... and the result is RF squeaky clean, cheap and reliable!**

Many mid-range transceivers available today require an external 13.5V 20A power supply to power them. Whilst commercial power supplies are available, these generally tend to be rather expensive.

Home-made units are a common alternative, although since these almost universally use conventional linear regulator circuitry, they often turn out both substantially larger and heavier than the radio they are powering.

Switch-mode power supplies, used universally in the PC industry, are now small, lightweight and cheap enough to replace rather than repair. Some amateurs I have spoken to are reluctant to use a switching power supply to power their radios, despite being quite happy to accept all the unit's benefits in their equally complex and expensive PC.

This is primarily due to the fact that, in the past, such supplies have had an unfortunate reputation of being unreliable. However, with simply millions of such power supplies in use in PCs daily, there is no longer any logical rea-



son why we should not realise all the benefits of using them to power amateur radio equipment. Indeed, many of the top-of-the-range HF/VHF transceivers have such power supplies built in already.

Whilst commercial switch-mode power supplies are available that will provide the necessary 13.5V at 20A required by modern 100w transceivers, these are sometimes substantially more expensive than their linear counterparts, although the Emtron EPS-20ST we reviewed recently is a refreshing departure from the norm. (We so liked that supply that we bought it. It hasn't missed a beat and is in daily use. No noises whatever; a high recommendation if you don't want to build this project! Ed.)

The design of a 250w switch-mode power supply, from scratch, is viewed by some as a 'black art' and is not for the inexperienced or faint hearted!

Most PC power supplies are designed to provide between 200 to 300 watts in the form of separate +5V, +12V, -5V and -12V supplies. This total power provision is similar to the 250w required to power a standard 100w transceiver.

Unfortunately, if we try to draw this much current from just the 12v output of a standard PC power supply, we end up overloading the unit, causing it to either shut down or the output voltage to drop alarmingly at full load.

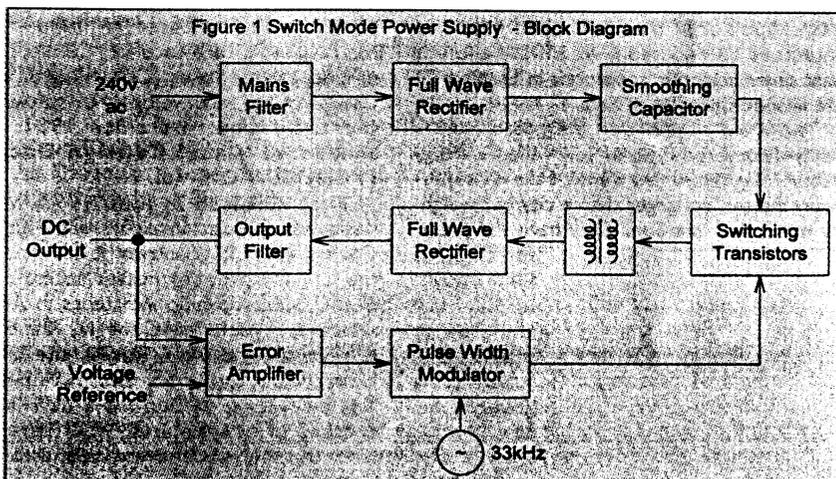
An article in the RSGB's *Radio Communications* magazine<sup>1</sup> outlined the process of converting a standard PC switch-mode power supply into one with a single 13.5V output suitable for powering a 100w radio. Using an existing, fully functional, PC power supply as a starting point for one for a HF/VHF transceiver greatly simplifies the construction and eliminates much of the 'black art' mystique.

Whilst the RSGB article was suitable for experienced constructors, I felt that more detail — particularly in regard to testing — was needed for the average constructor to tackle such a conversion, hence this article.

### How do they work?

Before we look at the details of how to modify a PC power supply, it's useful to have an understanding of how these little beasts actually work. Figure 1 shows a block diagram of the type of power supply we will be modifying.

The circuit operates as follows: The incoming mains is rectified in a full-wave bridge and applied to a smoothing



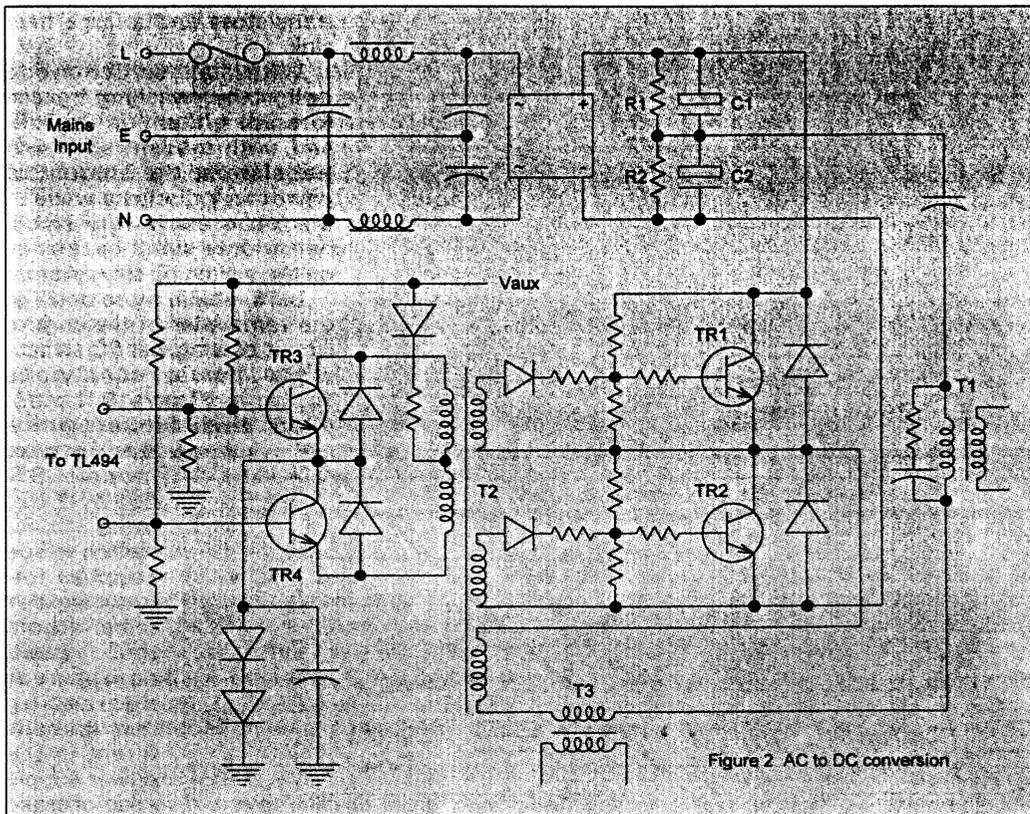


Figure 2 AC to DC conversion

kHz of switch-mode power supplies, ferrite material is generally used. The use of ferrite also enables fewer turns to be used in the transformer windings — more on this very useful feature later.

Let's look at how we convert the 340V DC into 33kHz AC — a typical circuit is shown in **Figure 2**. This circuit may look a little daunting at first, so let's simplify it as per **Figure 3** overleaf, by replacing the output transistors with switches.

In **Figure 3a**, the top switch is closed and current flows through the primary of the transformer in the direction shown. In **Figure 3b**, the top switch is opened and the bottom switch closed and current now flows in the opposite direction.

The speed at which we alternatively close the switches determines the frequency of the AC we produce. This technique goes back many years, to the

days when mechanical switches, known as 'vibrators', were used to provide the HT supply for valve car radios from the 12V car battery.

Today, rather than using switches, we use transistors — TR1 and TR2 in **Figure 2**. The other components in this circuit simply provide the necessary drive voltages and waveforms to switch these transistors in the correct sequence.

I'll leave it to your imagination to work out what might happen if both transistors were accidentally to be turned on together! Unfortunately, this could occur in some early switch-mode power supply designs, and gave switch-mode power supplies the reputation as being 'only one microsecond away from disaster'. Modern PC switch-mode power supplies are carefully designed to ensure that this unfortunate event rarely, if ever, occurs.

The above analogy of the transistors acting as switches can also help to explain how we can control the output voltage of the power supply. Although the input voltage to the transformer is fixed by the level of the AC mains voltage we apply, there is not much we can do about that.

capacitor. This results in a DC voltage equal to the peak of the 240v AC mains, ie  $240 \times 1.414 = 340V$ .

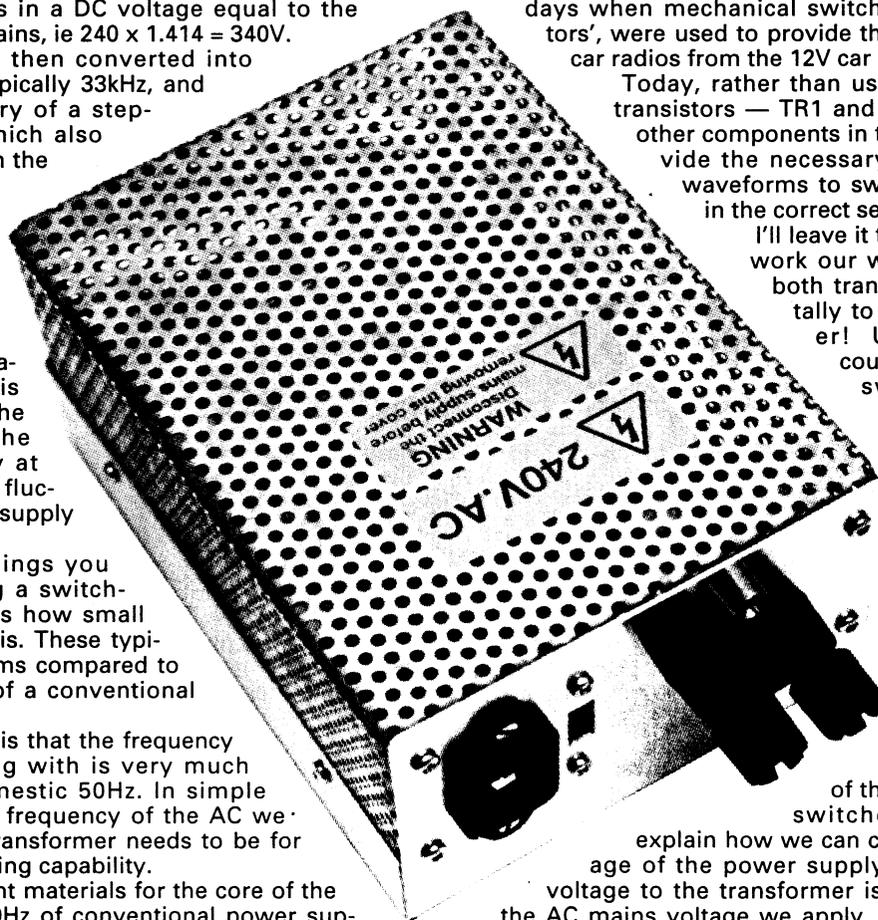
This DC voltage is then converted into high frequency AC, typically 33kHz, and applied to the primary of a step-down transformer which also provides isolation from the 240v mains. This lower voltage AC is then rectified and filtered in a conventional manner, so it provides our DC output voltage.

Like its linear regulator cousin, feedback is applied to maintain the output voltage the switch-mode supply at 13.5V, irrespective of fluctuations in the mains supply or load current.

One of the first things you notice when opening a switch-mode power supply is how small the main transformer is. These typically weigh a few grams compared to the many kilograms of a conventional linear power supply.

The reason for this is that the frequency of AC we are working with is very much greater than the domestic 50Hz. In simple terms, the higher the frequency of the AC we use, the smaller the transformer needs to be for the same power-handling capability.

We also use different materials for the core of the transformer. At the 50Hz of conventional power supplies steel laminations are used, whilst at the tens of



However, we can vary the amount of *time* that each switch remains closed. Referring to **Figure 4a**, we see that both switches are closed for the majority of each AC cycle — with a small period, called the 'dead zone', where neither are on — to prevent the catastrophe described above.

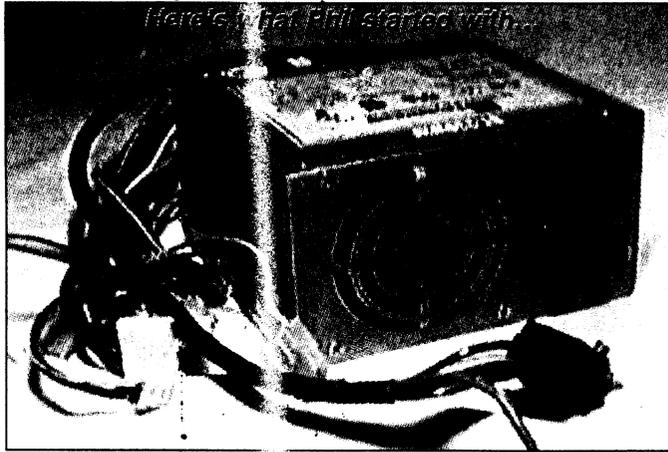
Since we are applying this waveform to the primary of a transformer, a similar signal will appear on the secondary to be subsequently rectified and smoothed to produce our 13.5V DC. The actual value of DC voltage we produce is dependent upon the turns ratio of the transformer, just like a conventional 50Hz power supply, and on the period during each AC cycle that the switches are closed.

If we therefore vary the time that each transistor is turned on, we can vary the level of the DC voltage we produce after rectification and filtering. So in **Figure 4b** we have reduced the time that both switches are on, which will reduce the DC output level.

If we continuously measure the DC output voltage against a desired reference, and use the difference as an 'error' signal to control the width of the pulses feeding the switching transistors, then we can regulate the DC output voltage. This technique is called 'pulse width modulation' and is the function provided by the remainder of the components in **Figure 5** we have not discussed yet.

One other advantage of the use of 33kHz AC rather than 50Hz is we can use much lower value, and physically smaller, smoothing capacitors. In this case, 8800µF is used in the switch-mode power supply as compared to typically 47,000µF for a linear design.

Another reason that switch-mode power supplies are small and light in weight is that, unlike conventional linear regulator supplies, we have very little heat to dispose of. With a linear supply, any excess power between what is provided by the transformer and rectifier, and the 100w of power we require has to be disposed of in the pass transistors, in the form of heat. In a conventional linear supply capable of 20A, this situation requires a number of power

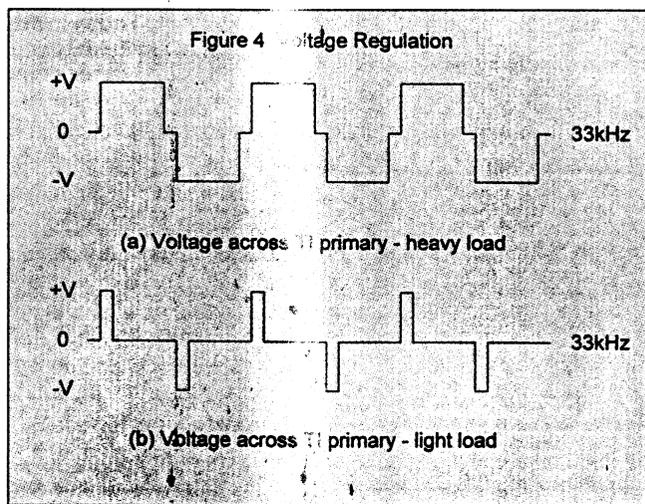
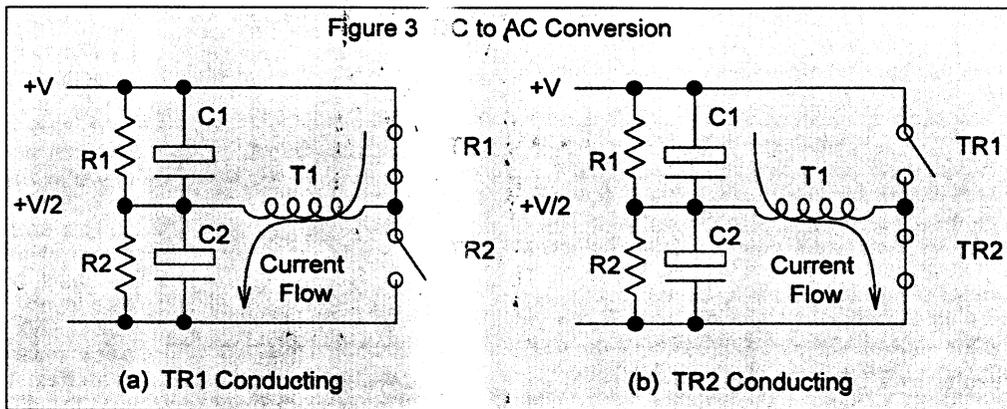


transistors and a large heat sink.

With a switch-mode design the switching transistors are either 'on' or 'off' and, with modern switching transistors, the amount of power they dissipate when in the 'on' state is very small, hence only small heat sinks on the switching transistors.

Let's look in more detail at the remainder of the control circuit of a typical PC switch-mode power supply, as shown in **Figure 5**. I modelled this circuit on a

*Seventeam model ST-230WHT* but most PC switch-mode supplies follow similar lines — note the exact component numbering may be different in the power supply you choose to modify from those in **Figure 5**.



The 'heart' of the switch-mode supply's control circuit is usually based upon a Texas Instruments TL494 integrated circuit. This provides the waveforms for the switching transistors, the 33kHz oscillator and voltage reference.

Pin 15 provides a regulated 5V supply that is used to power the remainder of the circuitry and is used as a voltage reference against which the output voltage is constantly compared. Pin 4 enables the power supply to be shut down in the event of an over-voltage/current situation and 'soft start', via C23 and R44, which cause the output voltage to rise slowly at switch on.

The regulation circuit works by varying the pulse widths at pins 8 and 11 to try to maintain the DC voltage at pin 1 equal to that at pin 2. The voltage at pin 2 is our reference voltage which is derived from the regulated 5V line. Since R38 and R42 are equal, then our reference will be 2.5V. This is compared with the voltage on pin 1, which is derived from the 13.5V output via R41, R2 and R3.

If the 13.5v output voltage should tend to rise, then the voltage at pin 1 will increase above 2.5v and the pulse width at pins 8 and 11 narrows, reducing the output voltage. Similarly, should the output voltage fall, due to an increase in load current, then the pulses will be widened, resulting in an increase in output.

This method of output voltage regulation is very efficient and results in a variation of only a few millivolts in the nom-

inal 13.5V output level when moving from zero to full 20A load.

Since R3 is variable, it is used to set the output voltage to the required value, a nominal 13.5V. When fault-finding these power supplies, checking for 5V on pin 15 and 2.5V on pins 1 and 2 is a good starting point.

The actual supply voltage for the TL494 is provided on pin 12 and comes from the secondary of transformer T1. It's usually in the range 15 to 20v and, again, checking for its presence is a good place to start fault finding. This voltage is also used to provide power for transistors TR3 and TR4 that drive the final switching transistors.

The remainder of the circuit is concerned with over-voltage/current protection, which is the job of the LM339, is a 'quad comparator'. Simply put, when the + input is at a higher voltage than the - input, then the open collector output transistor within the quad-comparator IC no longer conducts.

### Over-voltage protection

Let's look at the over-voltage protection circuit first. Pin 6 of the LM339 is held at 2.5V by the potential divider formed by R32 and R33. The non-inverting input at Pin 7 is connected to the 13.5v output via a potential divider formed by R23, R5 and R4. By suitable adjustment of variable resistor R4, we can set the output voltage at which pin 1 goes 'high' — say 14V — our 'over-voltage' threshold.

Pin 1 going high, via D16, causes TR5 to conduct, which

in turn causes TR6 to conduct, causing TR5 to conduct some more... and so on until both transistors are 'latched' on. The positive voltage at the collector of TR6, via D17, places a positive voltage on pin 4 of the TL494 which shuts the power supply down.

Even if the momentary over-voltage is removed, these transistor remain 'latched' and the output voltage stays at 0v. The only way to 'unlatch' these transistors is to turn the power supply off for a few seconds and then back on again.

You may be wondering, if the over-voltage latch has operated and there is no longer any output, then where the voltage comes from to keep the latch transistors conducting? In this case, TR1 and TR2 have sufficient feedback applied to them, via a winding on T2, that they oscillate for a short burst every few seconds.

This provides a small maintaining current, just enough to keep the latched transistors conducting, but not enough to provide a level of output voltage that would damage any equipment connected to the output.

Whilst in this 'latched' state, many switch-mode power supplies give an audible 'hiccup' every few seconds — very useful when fault finding!

The next thing to consider is over-current protection, and we'll come to that next month. But first, *find your supply!*

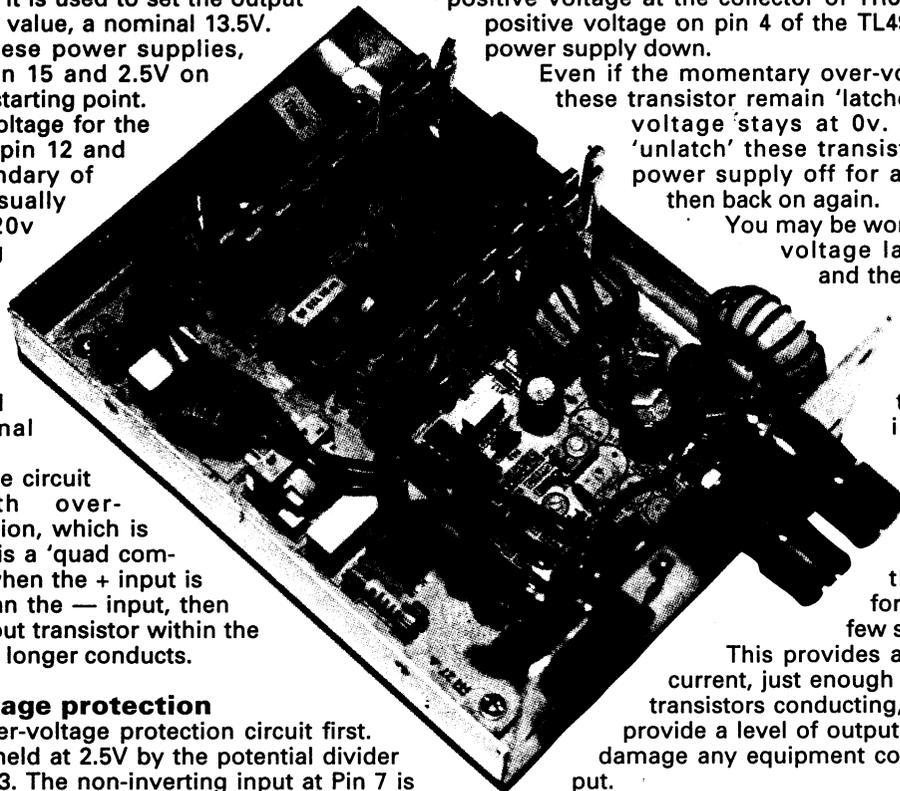
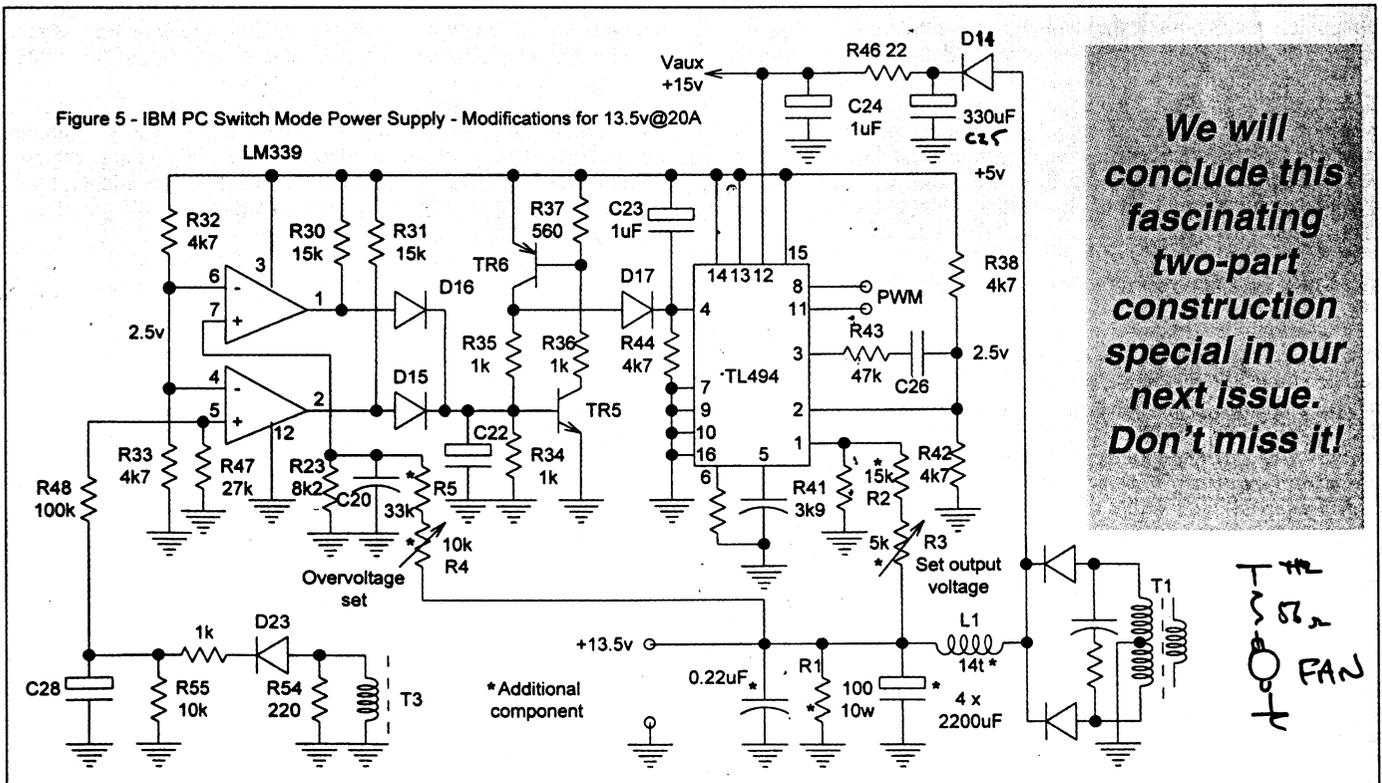


Figure 5 - IBM PC Switch Mode Power Supply - Modifications for 13.5v@20A



*We will conclude this fascinating two-part construction special in our next issue. Don't miss it!*

# Build a 13.5V 20A Switch Mode Power Supply...

## from junk parts!

Part Two, by Phil Harman VK6APH

**Need a 13.5V 20A Power Supply to power that new rig? Here's a genuinely brilliant idea — a low-cost method of building a lusty 20A shack supply from a junked IBM PC... and the result is RF squeaky clean, cheap and reliable!**

### Over-current protection

The over-current protection operates in a similar manner. Current flowing in the primary winding of the switching transformer T1 also flows through the primary of current transformer T3. The primary of this transformer is usually just a single turn, which helps to identify it on the PCB. This current causes a voltage to be developed across R54 that is proportional to the current flowing in the primary winding of T3. This voltage is rectified by D23 and smoothed by C28, resulting in a DC voltage that is also dependent upon the current flowing in the primary of the main switching transformer.

Via R48 and R47 this voltage is applied to the non-inverting input, pin 5, of the LM339. Should the primary current exceed the designed value, then the voltage at pin 5 will increase above 2.5V and, in a similar manner to the over-voltage protection, shut the power supply down.

The exact current at which the shut down occurs depends upon when the voltage at pin 1 reaches 2.5v. Increasing R48 will increase this value whilst reducing it will lower it. Whilst you could alter the value of R48, I left it at its original design value which would protect the power supply should more than 230W be drawn from the secondary. This will cause the

## IDEA OF THE DECADE!

supply to shut down if you drive your transceiver to more than 100w output. It's up to you — if you think the difference between 100 and 110w output is significant, then by all means adjust it.

### Finding a suitable supply...

The first step, of course, is to select your power supply. Whilst you could purchase a new or second hand PC power supply to convert, there's a cheaper and more 'amateur tradition' method.

As I mentioned earlier, PC power supplies are now considered to be 'replace rather than repair' items. The economics are such that it's simply not cost-effective for PC supplier's service departments to repair these units today.

Despite their reliability, switch-mode power supplies *do* fail — often caused by mains spikes, which can be reduced by fitting an external spike arrester, or temporary mains 'brown-outs' (short term reductions in voltage). Operator error is also some times encountered — setting the input voltage selector to 110v and then connecting to 240v causes a spectacular fireworks display! (Hey, it was late at night, I'd been using the PC in the USA for weeks and I was jetlagged, okay?!)

Rather than purchase a new switch-mode power supply, I found that the local PC repairman would give me an arm full of faulty units for the asking. You need to be really cheeky, know him personally, bribe him with a slab of tinnies, or actually buy something as well, since you need to select units with the following characteristics:

- Output power between 230 to 300w (the lower power ones are good for spare parts to fix the faulty units but don't have enough 'guts' to run a 100w transceiver);
- Use conventional PCB construction rather than surface mount technology; and
- Use TL494 and LM339 ICs for control.

I managed to scrounge five 230w 'Seventeam' model ST-230WHF power supplies. These had the following faults:

—One had a faulty mains on/off switch — replacing this resulted in a fully functional power supply!

—Two had faulty switching transistors. Actually, that's something of an understatement, they had literally exploded and all that remained was a charred mess!

—One had the Metal Oxide Varistor (MOV) across the mains which had gone 'short circuit'; replacing this and the blown fuse had the unit working in short time.

—One had the MOV surge suppressor across the smoothing capacitors blown to pieces, as well as the input bridge diodes. Since the mains input selector was set at 110v, no guesses as to what caused these to blow up! (*That wasn't one of yours, was it Phil?! Ed.*)

Most of these faults were very simple to fix, some being obvious after a thorough visual inspection. I chose the unit in the worst condition as a 'sacrificial lamb' to fix the remainder of the units. More complex faults can be repaired by applying the simple technique I'll describe a little later.

Having selected your power supply, and ensured it works correctly, you need to obtain the circuit diagram. If you're really lucky, your friendly neighbourhood PC repair man will provide you with one, otherwise you will need to trace this yourself.

The circuit of the 'Seventeam' unit I modified is shown in **Figure 5**, (presented with last month's first part) and most

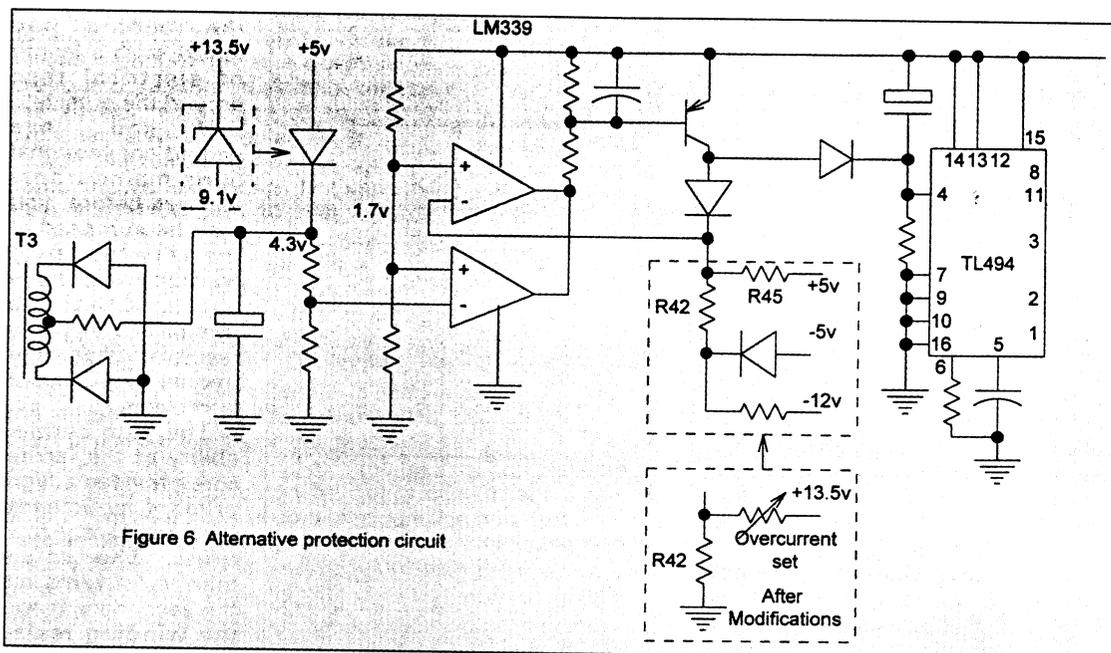


Figure 6 Alternative protection circuit

Strip all the multiple windings from the choke L1 and rewind it with 14 turns of 16SWG enamel copper wire — space the winding evenly around the core. This becomes L1 in Figure 5.

We need to either rewind or replace T1. As a guide, I've done it both ways. I now much prefer the replacement method, but I'll describe both ways so you can decide which you prefer.

#### Rewind method.

We need to carefully take T1 apart. These transformers are usually held together with electrical tape

and varnish. Try leaving the transformer soaking in a jar of mineral turps for a few days.

With luck, this will soften the varnish enough so that the two ferrite cores can be separated from the bobbin that carries the windings. Unless you have a scrap spare transformer, take some care and patience in getting it apart — placing it in the jaws of a vice is a guaranteed method of shattering the ferrite core into a thousand pieces! If you do break it, do not be tempted to glue it back together, either start again with a fresh transformer, or give up and use the replacement method below.

Once you have separated the core from the bobbin, strip all the windings off the secondary. These are usually on the outside of the bobbin and use heavy gauge wire. You will now be left with just the primary winding, remove this also but count the number of turns and measure the wire gauge used.

It's only necessary to trace the circuitry around the TL494 and LM339, since we don't need to make any modifications to the primary of the power supply, or to the switching transistor drive circuitry.

The best way I have found to trace such circuits is to hold the PCB over a bright light. This allows you to see both the component side and PCB side tracks simultaneously. If you have never done this before, it can be quite tedious and I recommend no more than 15 minutes at a time. Over a week you will be able to determine all the elements of the circuit that you need. You will also appreciate why it's desirable to obtain a number of power supplies of exactly the same model — unless you really enjoy tracing circuits!

**Replacement method.** If you broke the core using the rewind method, or if you prefer a much quicker approach, then you can make a replacement transformer from scratch. You will need a pair of ferrite cores and bobbin — I used

### Starting construction

Before we start stripping unnecessary components off the PCB it is essential that the power supply you are going to modify actually works — expecting to fix a faulty power supply after you have modified it is for the foolish or very experienced constructor!

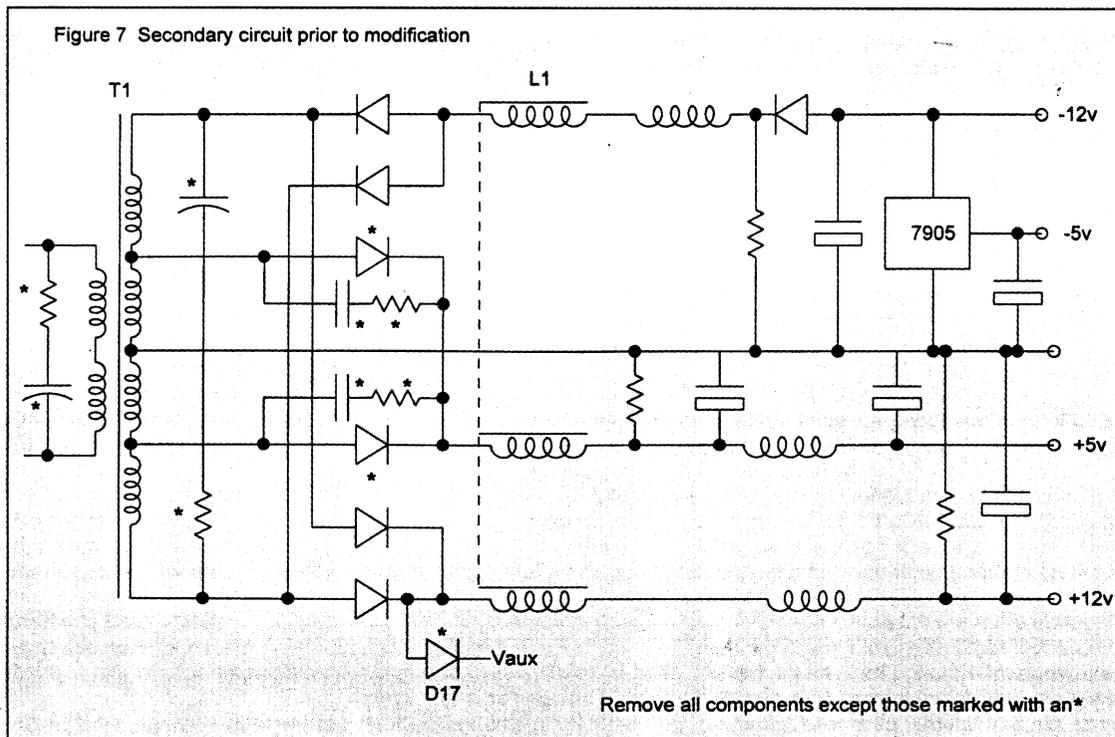
If your selected power supply is faulty, then use the test procedure I have explained for the modified power supply later in the article. Don't be afraid of tackling the repair of a faulty unit — you can usually obtain these for free and it's a great way to learn about how they work and gain some confidence before testing your modified unit.

### The construction

Start construction by removing all the components associated with the +5, +12, -5 and -12V supplies (see Figure 7, overleaf). Also remove transformer T1, but leave the 5V full wave rectifier and its heat sink in place.



Figure 7 Secondary circuit prior to modification



components from Siemens<sup>2</sup>. In general, most ferrite cores designed for 250W, 33kHz switch-mode power supply transformers should be suitable, although since finding the Siemens ones worked perfectly I have not bothered to look for a local source.

Break the ferrite cores from the existing transformer, count the number of turns on the primary, and identify the wire gauge used, as for the rewind method.

We now wind a new primary using the same number of turns and wire gauge as the original. If you use the Siemens cores, then 40 turns of 0.63mm diameter enamel copper wire will be fine. Wind these in two 20-turn layers, one on top of the other, with a layer of PTFE plumbers tape between layers.

After completing the primary, cover it with two layers of vinyl electrical tape. The secondary is wound using two lengths of 1.25mm diameter enamel copper wire, wound in parallel. The reason for using two lengths is to reduce the winding resistance, and hence voltage drop on full load, and ensure that the winding is 'flat' so that it will fit on the bobbin.

The number of turns need will depend upon the number of turns on the original winding. Use one fifth the number of turns on the secondary as was on the primary. For example, using the Siemens cores and a 40-turn primary, the secondary would need eight turns, centre tapped.

This is wound as four turns, then bringing out the centre tap, usually in the form of a 'pig tail' where the four wires are twisted together. Cover the winding with a layer of PTFE plumbers tape and then continue the winding **in the same direction** for a further four turns. Keep the two wires side by side to ensure a flat profile to the winding. A completed replacement transformer is shown in the photograph nearby.

Cover the completed winding with a couple of layers of vinyl electrical tape. Temporarily place the ferrite cores into

the bobbin and secure with a length of electrical tape around the outside.

If you have wound conventional 50Hz mains transformers before, you may be surprised at the very few turns on both the primary and secondary in this case. This is a result of using high frequency AC and a ferrite core.

The high permeability of the ferrite core provides a high primary inductance with relatively few turns. The small number of turns on the secondary keeps the winding resistance down and the voltage drop within the winding at high currents is minimised.

If have access to an audio sine wave signal generator and oscilloscope you can test the transformer before putting it back onto the PCB. Set the generator to 33kHz, maximum voltage output, and connect it to the primary of the transformer.

Using the 'scope, measure the peak-to-peak voltage across the primary. Now measure the peak-to-peak voltage across the total secondary. This should be approximately 1/5th of the primary voltage. No voltage across the secondary usually means that you forgot to keep winding in the same direction when completing the secondary winding. You can also check that the centre-tapped secondary is correct and both halves of the winding provide equal voltage outputs.

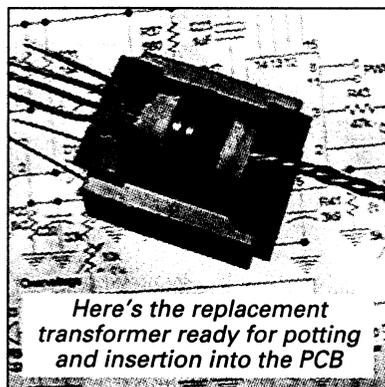
Testing with a 'scope is usually a luxury and, if you are careful with the transformer winding, can be eliminated. In the early days of perfecting the winding technique, I did find one transformer where I had inadvertently wound each half of the secondary in opposite directions. This didn't help it at all...

Once you have completed construction of the transformer it needs to be sealed. This is not necessarily to improve the electrical insulation but rather to stop the ferrite cores from vibrating during the cyclic nature of the load current swing produced by SSB operating. Without some form of sealing, the cores have a habit of 'singing' as the load current is altered.

The simplest way to do this is to 'dunk' the completed transformer in a tin of clear polyurethane varnish. Wait until all the air bubbles have disappeared and then let it dangle over the tin until all the drips stop. The best way to 'cure' the varnish is to put in an oven set to 100°C for a few hours — wait until the XYL is out of the house first, though!

### Completing Construction

Once dry, you can assemble the transformer back on the original PCB. Mount four new 2200µF (25V) working electrolytic capacitors as the main smoothing com-



Here's the replacement transformer ready for potting and insertion into the PCB

ponents. Don't be tempted to use a single capacitor for this purpose — the four capacitors in parallel reduce the series resistance of the total capacitance when used at 33kHz.

Add the remainder of the components shown last month in Figure 5. Note that a 100 ohm 10 watt resistor is permanently connected across the output of the supply. This is to provide a minimum load — switch-mode power supplies require that a small current be drawn from the secondary at all times.

Alternatively, if you decide to keep the original 12V fan that came with the PC power supply, then that will provide an alternative load and the resistor can be removed.

The power supply can be operated without a fan, but after a few hours of CW contest operation on a hot day in an outside shack, the heatsinks generally get a little too warm for my liking. If the fan noise is annoying, try putting a 33 ohm 1W resistor in series with it — this will still give a useful air flow but almost silent operation.

### Testing

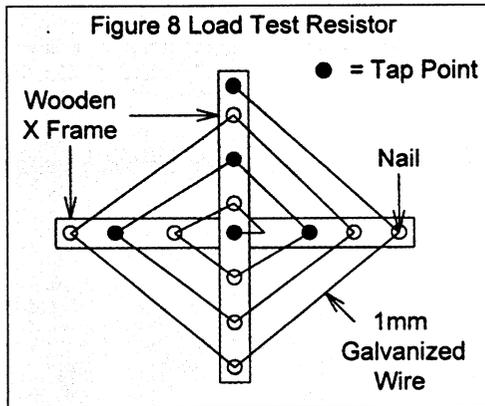
Over the past few months I have developed a simple and safe technique for testing and repairing switch-mode power supplies. The main problem with working on these supplies is the fact that a fault anywhere in the voltage control loop causes the power supply to stop. If you open the control loop, then you risk damaging the switching transistors, and with 240V mains and 340 DC on the board, mistakes can be spectacular, if not lethal. We must warn you to be very careful in any dealings you have with mains voltages.

However, there is a way around this, at least in the testing phase. The approach I have taken for testing is to use a separate 15V DC power supply to power the TL494 and associated circuitry. This voltage can allow testing to be carried out without the need for a mains supply to be connected. Thus, much of the circuitry can be tested for correct operation in complete safety.

To start testing, first set R4 to its maximum value and R3 to minimum. This sets the over-voltage cutout to maximum and the output voltage to minimum. Connect a 15V DC supply between the output negative rail and pin 12 of the TL494. Note that placing the 15V at this point in the circuit means that no voltage is available at the output of the power supply since D14 is reverse-biased.

Check that there is approximately 5V DC available at pin 15 of the TL494 and 2.5V at pin 2. If possible, use an oscilloscope on pins 8 and 11 and check that 33kHz square waves are present there. If you don't have access to an oscilloscope, then checking with a multi-meter that approximately 1.5V DC is present is a healthy indication that all is well on these pins. Also check for 2.5V DC on pins 4 and 6 of the LM339.

The next step is to set the output voltage and test the over-voltage cut-out. Transfer the 15V



power supply to the cathode of D14 and place a digital voltmeter across the output of the switch-mode power supply.

Reduce the 15V power supply until the voltmeter reads 13.5V. Transfer the voltmeter or oscilloscope probe to pin 8 of the TL494 and very slowly adjust R3 until pulses are no longer visible on the 'scope or 2.5V is registered on the voltmeter. At this point we have adjusted the feedback loop to provide 13.5V output.

To set the over-voltage cut-out, increase the power supply until the output voltage of the power supply

reads 14V (or whatever voltage you decide that you want it to trip at). Connect the voltmeter to pin 4 of the TL494 and very slowly adjust R4 until the meter indicates 5V.

At this stage, the 'latch' will have operated, and reducing the variable power supply slightly will cause 5V to remain on pin 4. Removing the power supply for a few seconds and then reapplying it again — set at 13.5V this time — will reset the latch.

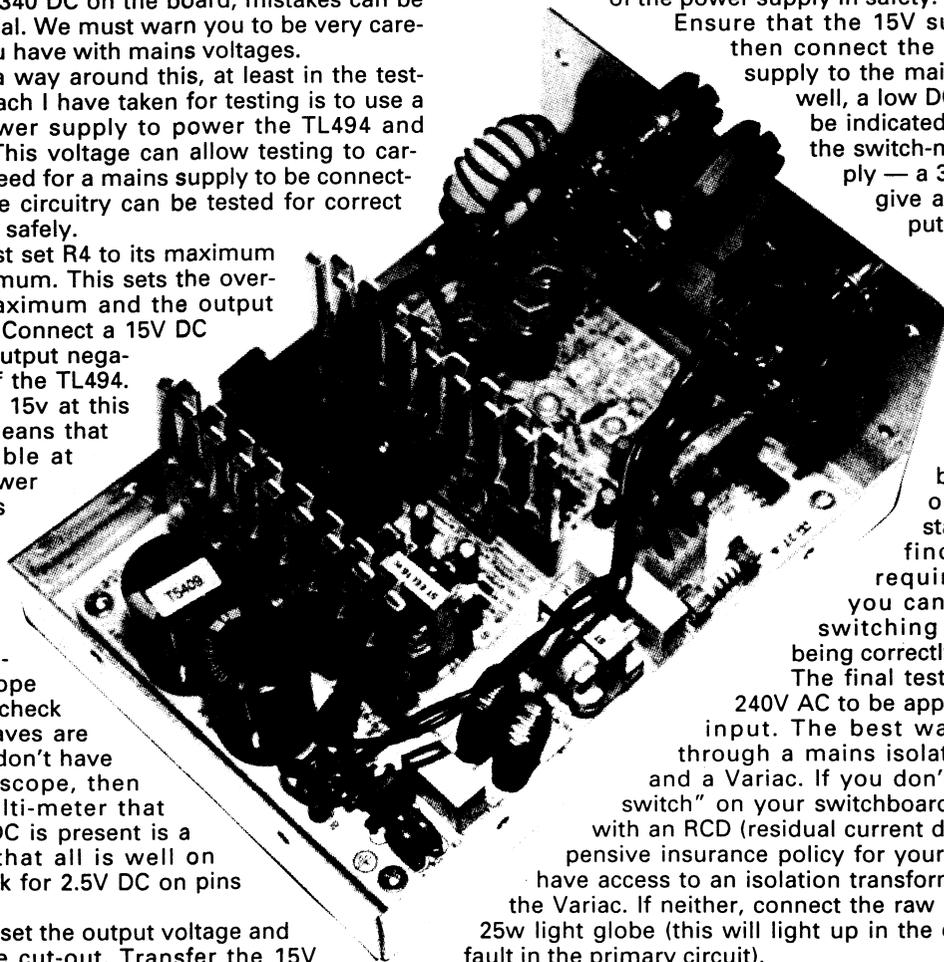
We now have the output level set and over-voltage trip operating. Next, we test the switching transistors. Reconnect the variable power supply to pin 12 of the TL494 and set it to 15V. Connect the mains input of the power supply to the secondary of a low voltage output mains transformer; an output somewhere between 30 and 60 volts AC is fine. This enables us to test the primary circuit of the power supply in safety.

Ensure that the 15V supply is on and then connect the low voltage AC supply to the mains input. If all is well, a low DC voltage should be indicated at the output of the switch-mode power supply — a 30V AC input will give about 1V DC output.

If you get no output, then check for a DC voltage across the mains smoothing capacitors C1 and C2 and also the mains bridge rectifier output. At this stage, further fault finding really

requires a 'scope so you can check that the switching transistors are being correctly driven.

The final testing requires full 240V AC to be applied to the mains input. The best way to do this is through a mains isolation transformer and a Variac. If you don't have a "safety switch" on your switchboard, a power board with an RCD (residual current device) is an inexpensive insurance policy for your life. If you don't have access to an isolation transformer then use just the Variac. If neither, connect the raw 240V mains via a 25w light globe (this will light up in the case of a serious fault in the primary circuit).



**Remember that the voltages at the input to the power supply can kill — it's not worth attempting to save a few dollars by building this power supply to get electrocuted.**

Leave the 15V DC supply connected and, using the Variac, slowly increase the mains input voltage. If all is well, the output of the switch-mode power supply will slowly climb to 13.5V and stay there. If everything looks fine, disconnect the mains and remove the 15V power supply.

This time reconnect the mains directly to the power supply and apply the full 240v at switch on. Do **NOT** bring the supply up slowly using the Variac — the sudden switch-on voltage is needed to cause TR1 and TR2 to oscillate, which provides enough volts to power the TL494. The circuit will then commence operation.

Prospective constructors may like to note that I do not have access to a Variac. The five power supplies I have modified to date have all been finally tested using the 240V AC 'cold turkey' method, with no mishaps. *The secret is to thoroughly test the circuit with the 15v DC supply and low voltage AC before finally testing it on 240V mains.*

At this stage, you should have a fully functional 13.5V 20A power supply. Before making any more adjustments or measurements, either place the completed power supply in its original case or in a smaller custom cabinet. I prefer to use an enclosure made of perforated zinc-plated steel, since it provides for better air circulation than the original PC power supply case. If you do use the original case then the use of a fan is essential. In any case, a fully-screened enclosure is essential to prevent RFI both to and from the power supply.

### Final Construction

The final stage is to determine if the completed power supply is adequately screened — if not, the 33kHz and fast switching transients of switch-mode power supplies can wreak havoc with sensitive HF receivers.

In most cases, any harmful interference will be radiated via the mains electricity supply and an additional, commercial, mains filter fitted inside the case will cure any remnants of this. One of the PC power supplies I considered converting did not have *any* mains filters fitted — the holes were there for the components but all had been replaced with wire links! With standards like this it's no wonder that the average suburban HF noise level has risen in the last few years!

I have not had any problems with 33kHz ripple on the DC output of any switch-mode supplies I have converted. If this problem is experienced, a ferrite core, perhaps from a junk power supply, should remove any trace of this ripple.

### Final Tests

Before connecting the completed modified switch-mode power supply to your expensive transceiver it's wise to check the output voltage at various current loadings. High power, low resistance resistors are not easy to come by and don't be tempted to use car headlight bulbs — these have

such a low cold resistance that the power supply will trip as soon as you switch it on.

A suitable high power test load can be made from a length of 1mm galvanised wire. Measure a length of wire so that it has a resistance of 2.7 ohms, which will give a starting load of 5A.

Make a cross out of two pieces of wood and bang a few nails into each of the cross arms. Wind the galvanised wire spiral fashion onto the resulting frame. See **Figure 8**. Place a nut and bolt and solder tag at 1.35 ohm, 0.9 ohm and 0.675 ohm points which will give currents of 10, 15 and 20A respectively.

If you don't have a meter that can read accurately a few ohms, then with a suitable ammeter, and either an existing 13.5V supply or a car battery, find the correct tapping points on the spiral resistor.

Check that the output voltage does not vary more than a few tens of millivolts at each of the different load settings. An oscilloscope is ideal to check that the output voltage is stable at all current settings. Since we are dealing with a closed loop control system it is possible, just like a conventional linear power supply, that instability could occur at certain current levels.

When connecting your power supply to your rig, use the shortest length of large diameter wire possible. Using thin gauge wire will result in a significant voltage drop between the power supply and the rig. If you don't have access to suitable large diameter wire, then use two or more wires in parallel. (And yes, this applies to *any* power supply, not just this one!)

### Conclusions

With a little time and effort, a very cheap, small, lightweight and reliable 13.5V 20A power supply can be constructed from a conventional PC switch-mode power supply. Much of the mystery of switch-mode power supplies, and the fear that they will fail and damage the equipment they are powering, can be overcome once you have some basic understanding of how they operate.

In reality, switch-mode power supplies are no more likely to fail than the pass transistors of conventional linear supplies. A short circuit in a pass transistor can do just as much damage to the equipment connected to it as a faulty switching supply. In my experience, switch-mode power supplies tend to do more damage to themselves, rather than the equipment they are powering, in the rare event that a failure does occur.

In closing, remember that the final stages of testing the supply will require raw 240V AC to be applied to the PCB. Take *great care* at this stage... we have

enough 'silent keys' already.

<sup>1</sup>RadCom, RSGB, July 1992.

<sup>2</sup>Seimens part numbers: **Core** B66363-G-X167 (2 required)

**Bobbin:** B66364-A1016-T1 (1 required)

One source of these is from Distrelec in Switzerland (tel 01 944 9911 fax 01 944 9988), part numbers from their catalogue is Cores — 33 39 60, Bobbin — 33 40 00.

