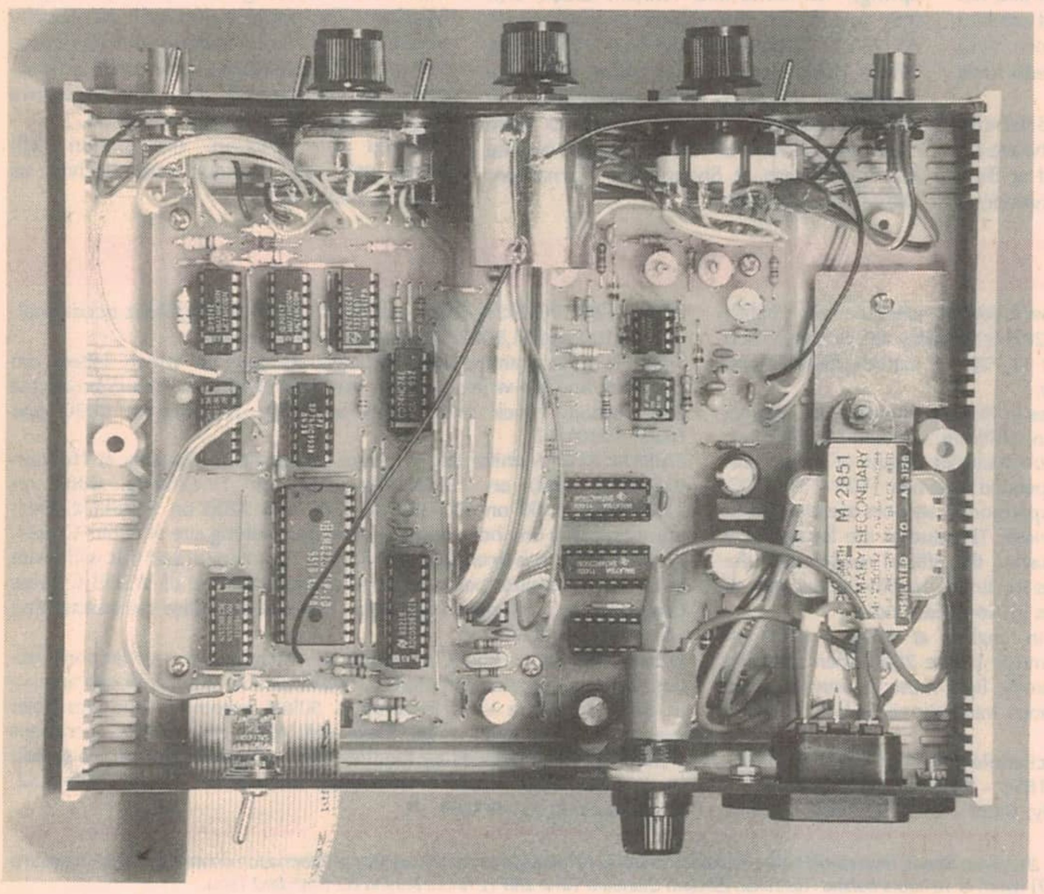
AN IMPROVED DSO ADAPTOR FOR PC'S - 2

As promised, here are the full construction details for our new PC-based DSO adaptor Mark 2. Also described are its testing and adjustment, including calibration and frequency compensation of the vertical amplifier. Using the adaptor in conjunction with the new and enhanced 'Version 3.0' software package from David Jones will be discussed in the third and final article.

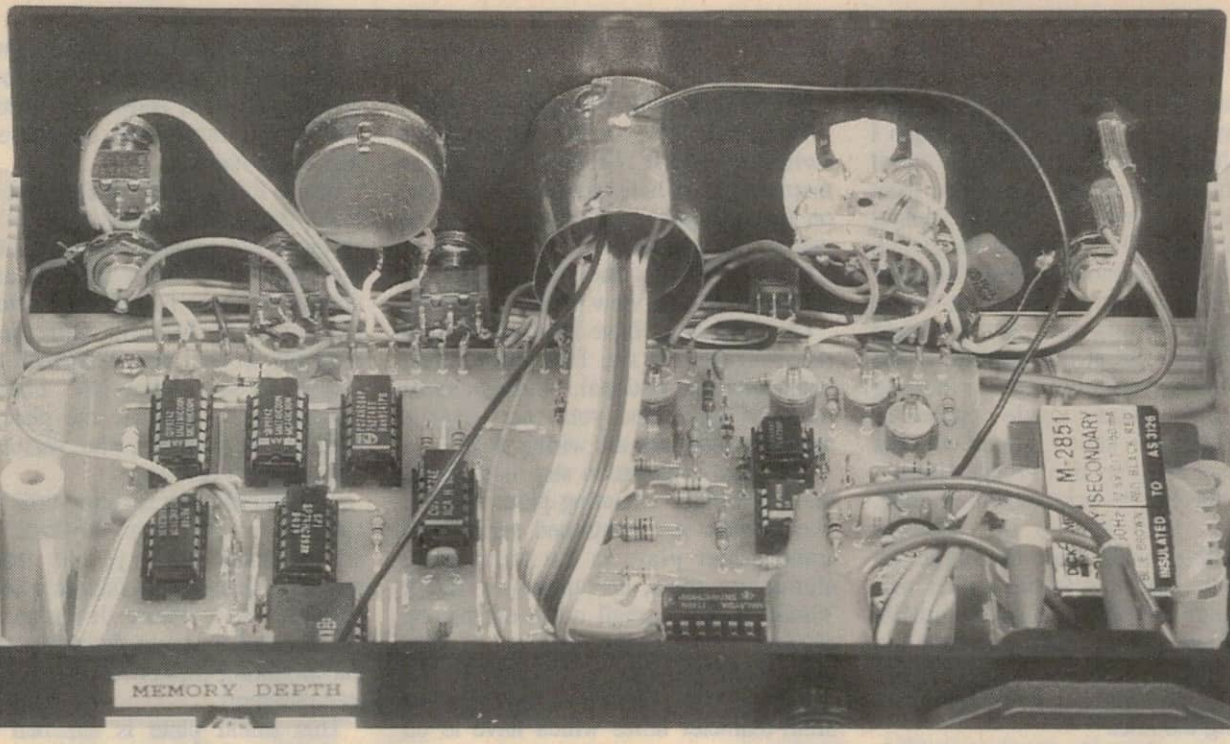
by JIM ROWE

As you're no doubt aware from the photographs, the new DSO Adaptor is housed in a low cost standard plastic instrument case, measuring 200 x 160 x 70mm (or 65mm). To simplify the construction most of the circuit components are mounted on a single PC board, measuring 143 x 123mm and coded 94dso5. The only parts not on the board are the input connectors and controls (all mounted on the front panel); the vertical input coupling capacitor C1; a couple of the input attenuator compensation capacitors (C32 and C33); power transformer T1, which mounts on a small earthed aluminium plate beside the PCB; the IEC mains input connector and mains fuseholder, which both mount on the rear panel; and the optional switches for manual read/write mode switching (S9) and effective memory depth — which also mount on the rear panel, if they're used. A memory depth switch is actually shown on the prototype's rear panel.

Because of the high input impedance of the vertical input circuitry, it tends to pick up noise and hum from both outside the adaptor's plastic case, and from the digital circuitry inside it. To minimise this pickup, a shielding plate made from an 80 x 45mm rectangle of unetched PCB laminate is fitted immediately underneath this area of the main PCB — a very successful technique pioneered by Rob Evans in his Noise and Distortion Meter design. Holes are drilled and reamed in the shield board so that it clears the mounting pillars for the main



Most of the components in the new DSO Adaptor are mounted on a single horizontal PC board, as you can see from this view looking directly into the case with the lid removed. The compact 2VA power transformer used mounts alongside the board on a small plate cut from one millimetre aluminium sheet. The ribbon cable which connects the adaptor to the parallel printer port of a PC enters via a slot in the rear panel, and plugs into connector J2 via 26-way IDC connector.



This view looking inside the case at the rear of the front panel should help you in wiring up your adaptor. Note the cylindrical tinplate shield around the time/sample switch S8, in the centre of the panel. The shield is connected via a length of insulated hookup wire to the PCB earth pin near C15, on the right hand side in this photo.

PCB, and the copper of the shield board is connected to the main PCB earth line.

A small cylindrical shield is also fitted around the body of the rotary timebase selector switch S8, to minimise coupling from the 5V p-p timebase signals present there. This shield is cut and formed from a 100 x 35mm strip of thin tinplate, and is again connected to the main PCB earth line.

The combination of the two shields reduces the noise induced into the vertical amplifier to a very low level.

Construction

As usual, the best way to start construction is to assemble all of the small components on the PC board. This should be fairly straightforward if you use the overlay diagram and the photos as a guide, and follow the steps I'll now give.

Assuming your board is drilled, and that you've checked it to make sure there are no faults in the etching, I suggest that you start by fitting all of the PCB terminal pins. There are 47 of these, most of them around the outside of the board — apart from the 11 located between ICs U3/U4/U7 and U6, which handle the timebase clock signals — plus up to five further optional pins between U13 and U14, if you wish to fit the optional EOB switching to adjust effective memory depth.

With the PCB pins fitted, the next step is to fit the links which run on the top of the board (one of the small prices we pay for using a single-sided PCB). There are 35 of these, plus an additional link for the EOB connection if you elect *not* to fit the optional memory depth switching. All of these links are straight and run either 'North-South' or 'East-West'. I suggest you use single-core insulated hookup wire to make the links, stretching it slightly so that they lie straight.

After the links, it's a good idea to fit the DIL connector strip J2 and the IC sockets. I recommend that you use sockets for all of the DIL devices, as apart from the two op-amps U5 and U8, the others are all CMOS devices and sockets allow you to leave fitting the actual chips until the end. If you *really* want to save money, you could skip the sockets for the lower cost chips, but at the very least you should fit sockets for the two expensive chips U12 (the A/D converter) and U16 (the SRAM).

Don't fit the two voltage regulator chips (U1, U2) or the reference device U11 at this stage. Instead, fit the passive components — first the resistors, next the small ceramic and monolithic capacitors, then the diodes and trimmer capacitors, and finally the tantalum and aluminium electrolytics, the calibration trimpot VR1 and the 2MHz crystal X1. Take special care not to overheat the relatively fragile monolithic caps during soldering, and also to place the polarised parts the correct way around. Watch also that you fit the 10-60pF trimcaps (brown plastic) in positions CV2 and CV3, and the 2-20pF trimcaps (green) in the other three positions.

If you now fit the two voltage regulator chips U1 and U2, and the reference chip U11, your PCB assembly will be complete apart from the DIL devices.

Note that if your reference chip is an LM4040CIZ-2.5V, you won't need to fit resistors R36 and R37 (both 10k). These resistors are only required if you use the alternative LM336Z-2.5 or LM4041CIZ-ADJ devices. It's perhaps also worth reminding you at this stage that if you have elected to use the cheaper but slower ADC8020 chip for U12, you should also have used a 680 ohm resistor for R21 instead of the 150 ohms needed for the faster ADC08061 chip.

Just before you continue, now is a good time to fit the small insulated link which goes *under* the PCB, from pin 10 of U6c to pin 15 of connector J2.

Front, rear panels

The next construction step is to prepare the front panel, by drilling and reaming the holes for the various controls and connectors. I suggest you use an accurate 100% photocopy of the front panel artwork as a template to mark the hole locations, so that everything lines up correctly, and also that you use the various controls and connectors themselves as 'gauges' when you ream the holes to size. This avoids ending up with holes that are too large...

If you are using the same plastic-body

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rotary switches as used in the prototype, you may care to follow the technique I use, which involves drilling a small 'blind' hole in the rear of the plastic front panel, to mate with the locating spigot on each switch. This prevents the switch from rotating, without having to tighten the attachment nut to the point where you risk stripping the plastic thread moulded into the switch ferrule. I also like to drill a similar but smaller locating hole for the miniature toggle switches, to mate with their keyed spigot washers and ensure that *they* don't rotate either.

With the single-hole mounting BNC sockets, I even like to file these to shape with a small round file, to get an elongated 'flat sided' hole which will just accept the socket ferrule with its milled flats. This again prevents the sockets from working loose and rotating in use — without the need for overtightening the nuts.

When mounting the indicator LEDs, you have a choice. You can of course use the moulded clip-together ferrules for these, if you like them. Personally I find them a bit ugly, and I prefer to simply drill and ream the panel holes very carefully, until the LEDs just fit in them snugly from the rear. Then when the rest of the holes have been finalised, and the stick-on Dynamark metal dress panel applied carefully to the front, I push the LEDs through the holes from the rear, as far as they'll go comfortably, and apply a small fillet of plastic adhesive around them at the rear. The panel is then put aside for 24 hours, for the adhesive to set. Note that the green LED is used for the lower 'Sampling' indicator, and the red one for the 'A/D OVF' indicator.

Before finally mounting the rotary switches and pots, I like to cut their shafts to a suitable length (say 10mm) to mount the knobs, and if necessary also file flats on them carefully to locate the knob attachment screws. This again makes it unnecessary to overtighten the screws.

The final stage of assembling the front panel is to fit all of the controls and connectors, and fit the knobs. It should then be ready for the wiring, a little later.

The rear panel is somewhat simpler than the front panel, and therefore a little easier to prepare. The main tasks are to cut the mounting holes for the IEC mains connector and fuseholder, and also the rectangular slot in the lower edge, near the far end, to clear the ribbon cable when it exits from J2. The location and dimensions of these holes are shown in the small diagram.

If you wish to fit the optional manual Write/Read mode switch S9, and/or a switch to adjust the DSO's effective memory depth, holes for mounting these on the rear panel will also need to be made. The logical position for them is above the slot for the ribbon cable, as shown in the rear view photo last month.

Once the holes have been prepared in the rear panel, the IEC connector, fuseholder and optional switches can be mounted on it, and your rear panel is now also ready for the wiring stage.

The final preparation step is to make the transformer mounting plate, and the two shields. As mentioned earlier, the transformer plate is cut from 1mm aluminium sheet, and measures 100 x 30mm. It has a small notch cut in one side, as shown in the diagram, to clear the assembly spigot at the end of the case lower half. Otherwise there are five 3mm-diameter holes which have to be drilled: two to mount the transformer on the plate, to more to mount the plate in the case, and the final one to attach a solder lug for plate/transformer earthing.

The two transformer mounting holes (marked 'T') and the earthing screw hole ('E') are countersunk on the underside of the plate, to allow countersink-head screws to be used to mount both the transformer and the earthing to the plate. This leaves the lower surface of the plate flush, so that the plate can easily be mounted into the lower half of the case after the screws are fitted.

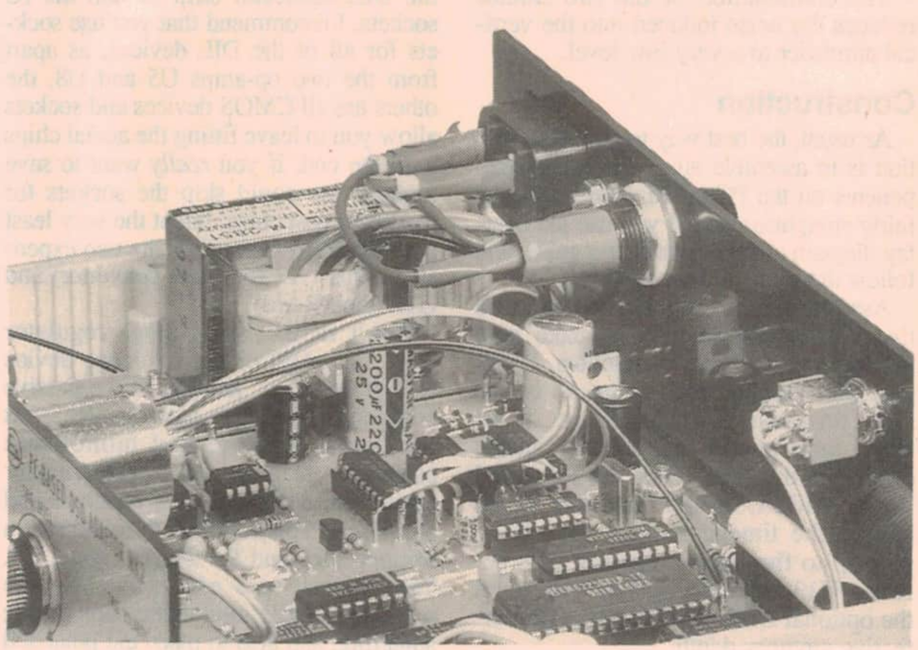
Note that 'star' lockwashers should be used under the nuts of each of these countersink-head screws, to ensure that neither the transformer nor the earthing lug works loose.

Since things are a little tight on the plate, the assembly procedure is to first fit the T and E screws to the plate, with the solder lug under the nut and star washer of screw E. All three screws are then well tightened, and the plate mounted in the case using self-tapping screws through holes 'M'. Finally the transformer is fitted to the plate, using further flat washers, star washers and nuts on the T screws.

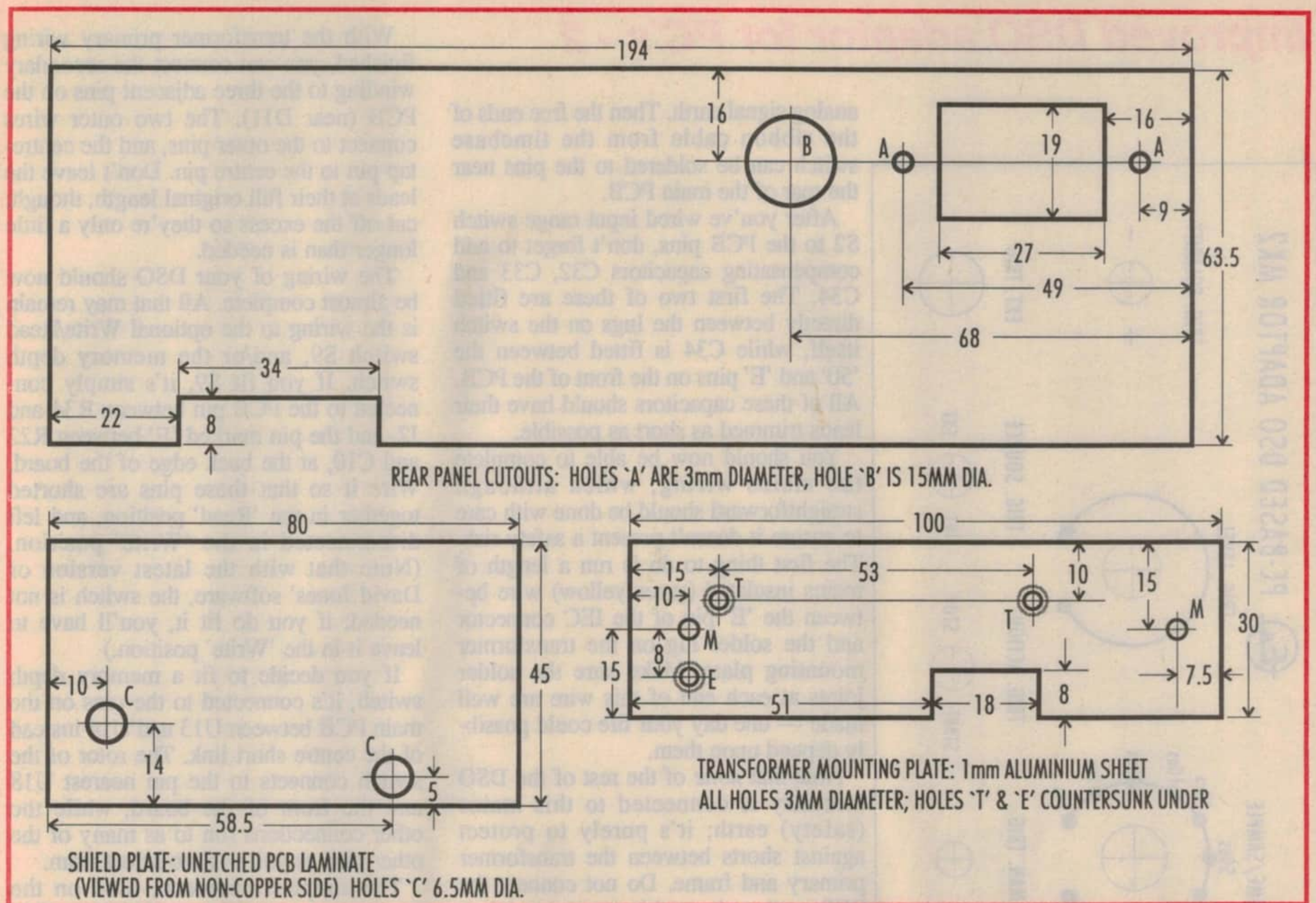
The shield plate for the vertical input circuitry at the front left-hand corner of the main PCB is cut from unetched PCB laminate (single sided), and measures 80 x 45mm. It has two holes 'C' about 6.5mm in diameter, to clear the mounting pillars for the main PCB (see diagram).

This shield plate is attached to the underside of the main PCB, as close as the solder joints of the latter will allow, but with its own copper side facing away from it (so it doesn't cause shorts!). The easiest way to attach it is by soldering three short lengths of tinned copper wire (i.e., component pigtail offcuts) to the earthy outer copper track of the main PCB — just near the corner, about 38mm up the side (near C7) and about 75mm along the front. These all face outwards, at roughly 90° to the board edges.

The shield plate can then be offered up



Another view inside the DSO Adaptor case, this time looking towards the rear and the mains input circuitry. Note the sleeving around the mains fuseholder and IEC input connector, to prevent accidental shocks.



This diagram gives the dimensions for the holes to be cut out of the rear panel (top), plus the dimensions and hole details for the shield plate which goes under the vertical amplifier section of the main PCB (lower left!), and the transformer mounting plate (lower right).

underneath, and the three wires bent around and soldered to the exposed copper. The three wires not only hold the shield in place, but also ensure that it's properly connected to board earth.

(**Note, however**: The main earth track along the front of the main PCB has a deliberate 'gap', to minimise interference to the analog front end circuitry from circulating currents associated with the digital circuitry.

When you fit the third shield wire to the main PCB, near this gap, make sure that you solder it to the 'analog' side of the gap — i.e., the side nearer R8 and D5, NOT the side near R28. Otherwise, the shield plate will 'bridge' the gap and you may get noise in your vertical amplifier.)

Once the shield plate is attached to the main board, the two are ready to be mounted into the lower half of the case alongside the transformer plate, again using small self-tapping screws. However you will almost certainly have to clip off some of the unused mounting pillars moulded into the case, to clear both the shield plate and the solder joints on the underside of the main PCB, before they'll lie flat for mounting. Just make sure that you don't clip off any of the six pillars which *are* used for mounting! (Use the 3mm holes in the main PCB to locate these first, and perhaps mark them with a felt pen to prevent mistakes.)

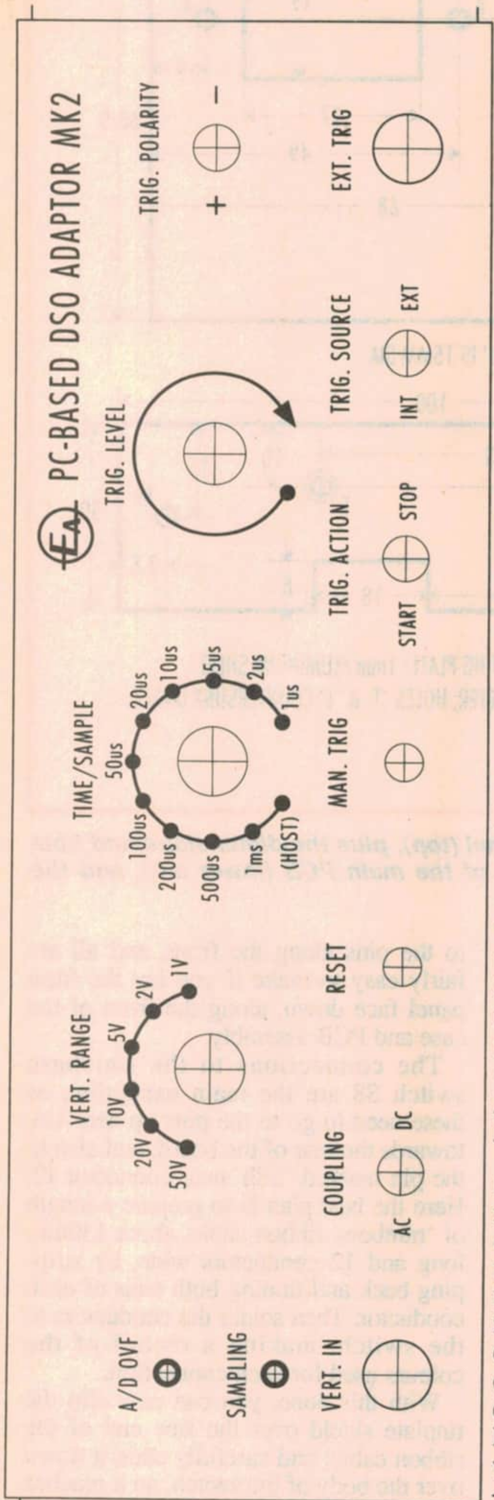
You can leave fitting the timebase switch with its small cylindrical shield for a while, at this stage — it's best left until you've soldered the leads to its lugs. However now would be the time to prepare the shield, from a 100 x 35mm strip of clean tinplate (which can be quite thin). Carefully roll it up around a piece of broomstick or a similar makeshift mandrel, until it becomes a neat springy cylinder about 24 - 25mm in diameter and 35mm long. Then it can be put aside briefly.

You're now ready to connect up the front panel controls and connectors, to both each other and the main PCB. Note that input coupling capacitor C1 mounts on the rear of AC/DC coupling switch S1, as part of these connections. Most of the connections to the main PCB connect to the pins along the front, and all are fairly easy to make if you lay the front panel face down, along the front of the case and PCB assembly.

The connections to the timebase switch S8 are the main exception, as these need to go to the pins up near U6, towards the rear of the board, and also to the pin marked 'S8h' near connector J2. Here the best plan is to prepare a length of 'rainbow' ribbon cable, about 130mm long and 12 conductors wide, by stripping back and tinning both ends of each conductor. Then solder the conductors to the switch, making a record of the colours used for each connection.

With this done, you can now slip the tinplate shield over the free end of the ribbon cable, and carefully slide it down over the body of the switch, so it reaches the rear of the front panel. A couple of 'tacking' solder joints can then be applied to the exposed overlap join, to hold it in place.

Once the shield is fitted, you can then run a length of insulated hookup wire from the earth pin on the main board, near C7 and R2, to connect the shield to



This artwork for the DSO Adaptor's front panel is reproduced here actual size, so that you can use it (or a copy) as a template for drilling the holes — and possibly as a dress panel.

analog signal earth. Then the free ends of the ribbon cable from the timebase switch can be soldered to the pins near the rear of the main PCB.

After you've wired input range switch S2 to the PCB pins, don't forget to add compensating capacitors C32, C33 and C34. The first two of these are fitted directly between the lugs on the switch itself, while C34 is fitted between the '50' and 'E' pins on the front of the PCB. All of these capacitors should have their leads trimmed as short as possible.

You should now be able to complete the mains wiring, which although straightforward should be done with care to ensure it doesn't present a safety risk. The first thing to do is run a length of mains insulated (green/yellow) wire between the 'E' pin of the IEC connector and the solder lug on the transformer mounting plate. Make sure the solder joints at each end of this wire are well made — one day your life could possibly depend upon them.

Note that *none* of the rest of the DSO circuitry is connected to this mains (safety) earth; it's purely to protect against shorts between the transformer primary and frame. Do not connect the PCB earth to it, as this can cause 'earth loop' problems when you are using the DSO Adaptor for measurements.

Next come the 'live' mains connections, and the main thing to watch here is that after soldering, each join must be fully sheathed in insulation using varnished cambric or heat-shrink plastic sleeving. So cut lengths of sleeving, and slip them over the wires before each joint is made, so they can be slid over the joint afterwards.

One primary wire from the transformer (the one with blue insulation) runs to the neutral ('N') lug of the IEC connector, while the other (brown) runs to the *side* lug of the fuseholder (NOT the end lug). Both of these wires will initially be too long, and will have to be cut to just a little longer than is needed once the rear panel is mounted in the case. With the excess cut from the brown lead, you'll probably have enough of this wire to make the remaining connection — which runs from the active ('A') lug of the IEC connector to the *end* lug of the fuseholder.

(Why have I emphasised the particular fuseholder lugs to use? Because if you wire the fuseholder the wrong way around, it's possible to get a shock from the fuseholder when the cap is unscrewed to change the fuse cartridge.)

With the transformer primary wiring finished, you can connect the secondary winding to the three adjacent pins on the PCB (near D11). The two outer wires connect to the outer pins, and the centre-tap pin to the centre pin. Don't leave the leads at their full original length, though; cut off the excess so they're only a little longer than is needed.

The wiring of your DSO should now be almost complete. All that may remain is the wiring to the optional Write/Read switch S9, and/or the memory depth switch. If you fit S9, it's simply connected to the PCB pin between R34 and J2, and the pin marked 'E' between R22 and C10, at the back edge of the board. Wire it so that these pins are shorted together in the 'Read' position, and left disconnected in the 'Write' position. (Note that with the latest version of David Jones' software, the switch is not needed; if you do fit it, you'll have to leave it in the 'Write' position.)

If you decide to fit a memory depth switch, it's connected to the pins on the main PCB between U13 and U14 instead of the centre short link. The rotor of the switch connects to the pin nearest U18 and the front of the board, while the other connections run to as many of the other pins as you wish to select from.

The simplest approach, used on the prototype, is to use an SPDT toggle switch and select between the first of the remaining pins ('32K') and the next one ('4K'), giving a choice of either 32K or 4K bytes of effective memory depth.

To essentially complete the DSO Adaptor construction, all you have to do is make up the ribbon cable which connects it to the PC's parallel printer port. This uses a 2m length of 25-way ribbon cable, with IDC connectors crimped on it at each end — a 26-way DIL header at the adaptor end, to mate with J2, and a DB-25 plug at the other. Needless to say the connectors are fitted so that pin one of each connects to the end conductor on the same side of the ribbon (so pin 26 of J2 will be left unconnected).

Checkout & adjustment

Your adaptor should now be complete, except for adding the DIL ICs. This will allow you to connect the power, and carefully check that the power supply circuitry is operating correctly before these ICs are added.

If you have a DMM handy, you should be able to measure +5V at the short link adjacent to C12 (between U3 and electrolytic C2), relative to the board earth, and -5V on the lead of diode D3 nearest to capacitor C5 (between trimcaps CV3 and CV4). You should also be able to measure +2.5V at the 'top' lug (clockwise end) of trigger level pot VR2.

If these voltages are correct, your power supply is functioning correctly and you can switch off, unplug the power lead and carefully fit all of the DIL ICs to their respective sockets — making sure you orientate them all correctly using the overlay diagram as a guide.

Hopefully you're now ready for checkout and adjustment, although you might like to apply the power again and use your DMM to check one more voltage — that at the centre lug of trimpot VR1. This should measure very close to +1.25V with respect to board earth, when the input coupling switch S1 is in the 'AC' position, and within a millivolt or two of earth when the switch is in the 'DC' position. If these voltages are reversed, you've wired the 'B' side of the switch wrongly!

The easiest way to complete the adaptor's testing and adjustment is to connect it up to the PC, and fire up David Jones' software. Then you'll be able to monitor things via the screen display.

First of all, set the DSOA's vertical range switch to the 1V position, the timebase switch to the 100us position and the trigger level pot to mid-range. Also set the input coupling switch to AC, the trigger action switch to Start, the trigger source switch to Internal and the trigger polarity switch to '+'. If possible, the memory depth should also be set for say 4K, as this will make things faster. If you have an optional Write/Read switch (S9), it should be set for Write mode. Finally, the internal calibration trimpot VR1 should be turned to its fully *anticlockwise* position.

Then connect the vertical input to an audio generator, which is set to produce a sinewave at around 50Hz and with its output level carefully set to an accurate 1V p-p. (You can check this with your DMM, set to AC volts; it should read as close as possible to 353.6mV RMS.)

Try pressing the Reset button on the DSOA front panel. The green 'Sampling' LED should light briefly (about half a second, for 4K memory depth), and then go out. The red 'A/D OVF' LED should not light. If all is well, your DSOA is probably sampling correctly.

Now run the Tronnort DSOA Version 3.0 software, and set it to look for the adaptor on the printer port you've connected it to. You should also set it to the 1V vertical range; the 100us per sample timebase range; 500 samples displayed; for Start trigger mode; for DSOA triggering (as opposed to software triggering); for Graticule On; and for the Buffer memory size (depth) your DSOA is set for.

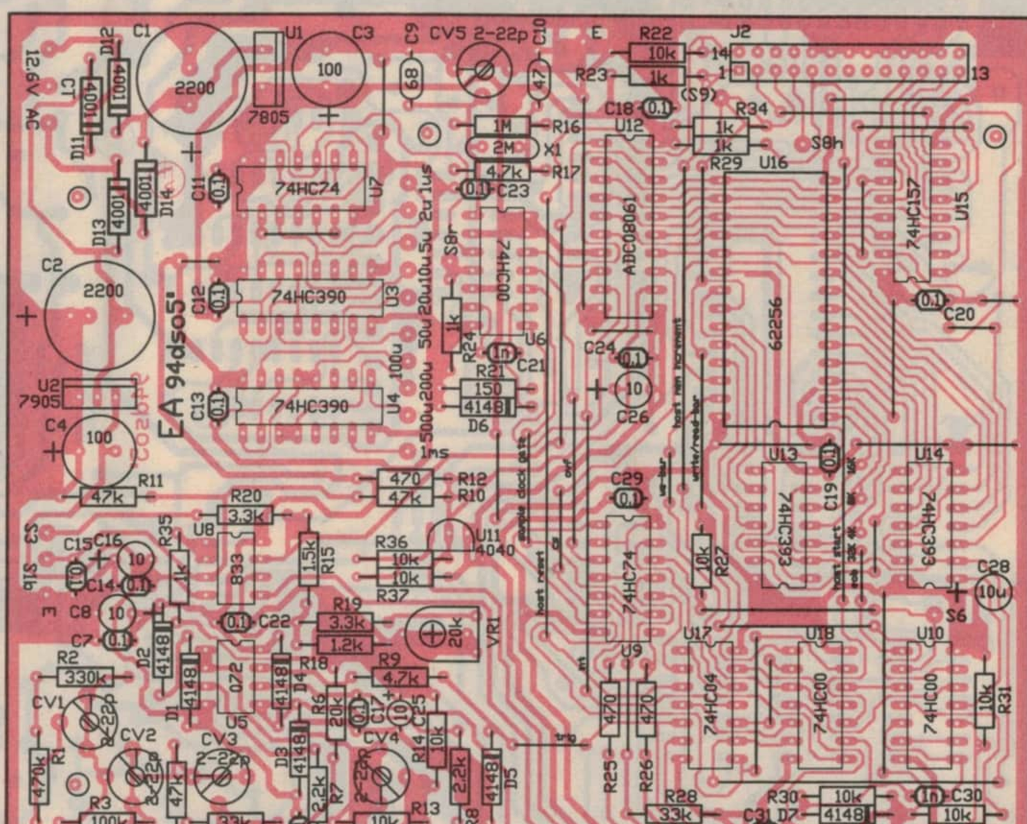
If you try pressing the <O> (one shot) key, the 'Sampling' LED on the DSOA should again glow for a short time, and then a second or two later a waveform should appear on the screen. You should see about two and a half cycles of sinewave, and its amplitude should be a little less than the full graticule height.

Vertical calibration

Assuming all is well so far, you're ready to adjust the DSOA's basic vertical calibration. By pressing the <U> key on the PC keyboard, you should get a continuous sequence of sampling sequences and updating of the screen display. This will allow you to carefully adjust the calibrate trimpot of the DSOA, with a small screwdriver, until the displayed waveform on the PC screen *almost* (but not quite) reaches the full height of the graticule.

If you turn the trimpot too far, the red 'A/D OVF' overflow LED on the DSOA front panel will start flashing along with the sampling LED, and the displayed waveform will distort due to converter overload — so back off until this stops. The correct setting of the trimpot is where the known 1V p-p waveform is as close as possible to the full graticule height, without the red LED flashing.

Use this overlay diagram as a guide, along with the internal photographs, when you're fitting the components to your own PC board. Note that there are quite a few wire links which must be fitted to the top of the board. The small vertical link between U13 and U14 marked 'EOB' is replaced by wiring to the optional memory depth switch, if used. In this case PCB pins are fitted to the holes at either end of the link as shown here, along with the holes just above marked '4K', '8K', and '16K'. A small insulated link must also be fitted under the PCB, between pin 10 of U6c and pin 15 of connector J2.



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With this done, the basic voltage calibration is completed, and you're ready to adjust the input attenuator compensation. So press the <ESC> key on the PC keyboard, to exit the continuous update mode, and prepare for this as follows.

First, change the audio generator's output frequency to 10kHz, and set it to produce a square wave of about 700mV p-p. (If you have a pulse generator with a better squarewave output, this would be preferable.) Then change the DSOA timebase switch to its fastest 1us range, and select the corresponding range on the DSOA software screen. Also set the software to display 200 samples, which will correspond to two signal cycles at 10kHz (200us).

Now press the <U> key on the PC keyboard again, and you should again see a repeatedly updated display of the waveform. Since your DSOA should still be set to the 1V range, you should see a couple of cycles of square wave, with an amplitude about 70% of the graticule height. The exact waveshape will depend largely on the output from your generator.

Now try turning the DSOA's range switch to the 2V range. The waveform will drop to half its original amplitude, and its leading edges will probably develop either overshoot (spiking) or undershoot (rounding).

By taking a small insulated alignment tool (or knitting needle filed to a screwdriver blade), you should be able to adjust trimcap **CV4** to correct this distortion, and restore the waveform to a clean square wave.

Some TL072 op-amps may introduce a small amount of ringing to the square wave, which cannot be removed using CV4. If this seems to be your situation, try adding a 10pF or 12pF capacitor from the 'S2b-2' pin of the PCB to ground (i.e., effectively across R14). This will usually remove the ringing, and allow optimising the compensation.

Now turn range switch S2 to the 5V position, and increase the square wave output from the generator until you get a display of reasonable height again. The waveform will probably again be distorted, with either overshoot or undershoot. This time, it should be correctable (or nearly so) by adjusting trimcap **CV1**.

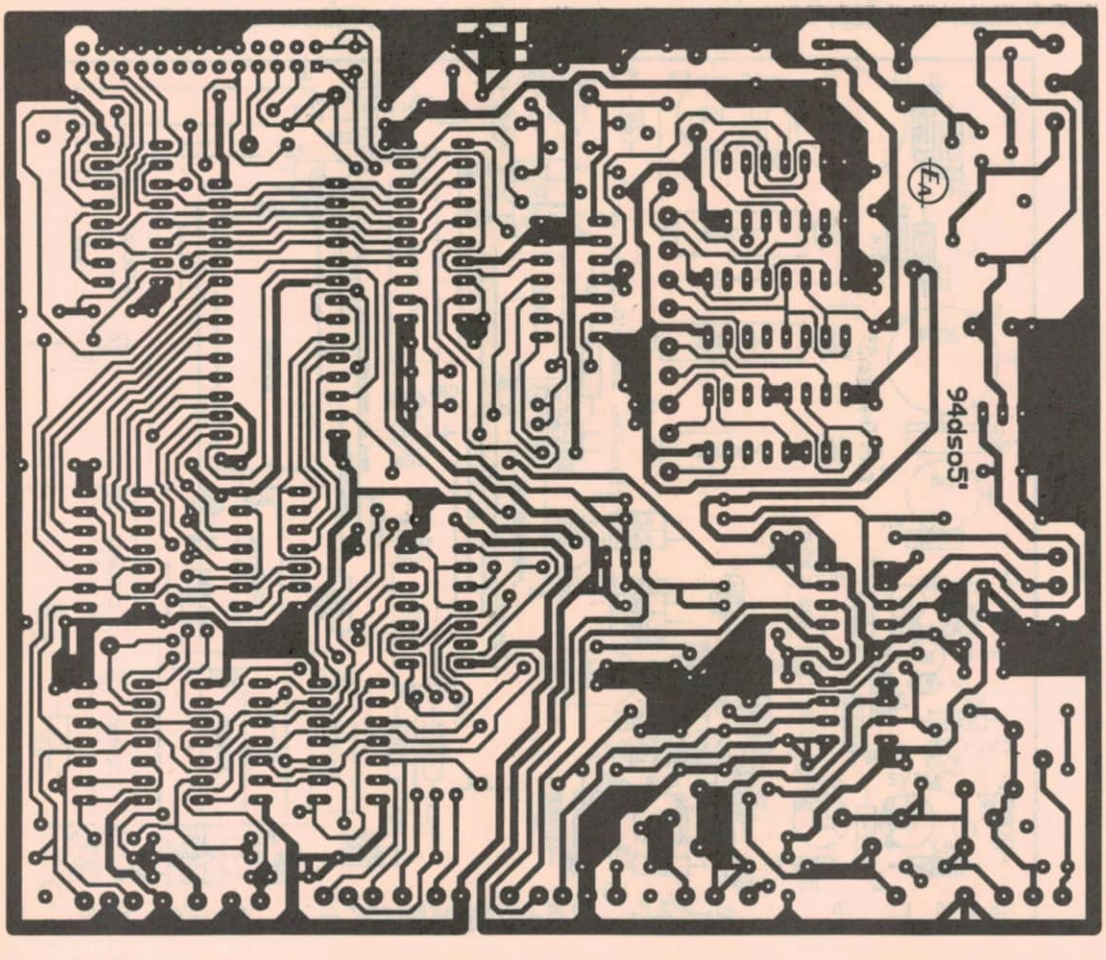
With this done, turn S2 to the 10V range, and again adjust the generator output if necessary to get a reasonable display height. To correct any distortion this time, the trimcap to adjust is **CV2**.

After this, turn S2 to the *lowest* 50V range (NOTE: not the 20V range, which has already been set along with the 2V range), and repeat the procedure again — but now using trimcap **CV3**.

Note this relationship between the various trimcaps and the ranges they are used to achieve the correct compensation for: CV4 is for the 2V and 20V ranges, CV1 for the 5V range, CV2 for the 10V range and CV3 for the 50V range. And that's also the order that these initial adjustments should be made in.

However with the exception of the CV4 setting, these trimcap adjustments are all interactive; adjusting one tends to affect the others. As a result, you actually need to run through the CV1/2/3 adjustment sequence again a couple of times, to 'fine tune' them and make sure that the overall compensation is optimised. Once this is done, though, your DSO Adaptor is effectively finished and ready for use. All that remains is to add the top half of the case, and fit the two large screws which hold it together.

In the third and final article, we'll discuss using the Adaptor in conjunction with David Jones' enhanced software. ❖



Here's the artwork for the DSO Adaptor PCB, reproduced here actual size as usual, for those who wish to etch their own board. The deliberate break in the earth track near the centre at the bottom, is to ensure that circulating currents do not inject digital noise into the vertical amplifier input circuitry.