28/6/85

EDITION 1

Assembly Manual for the

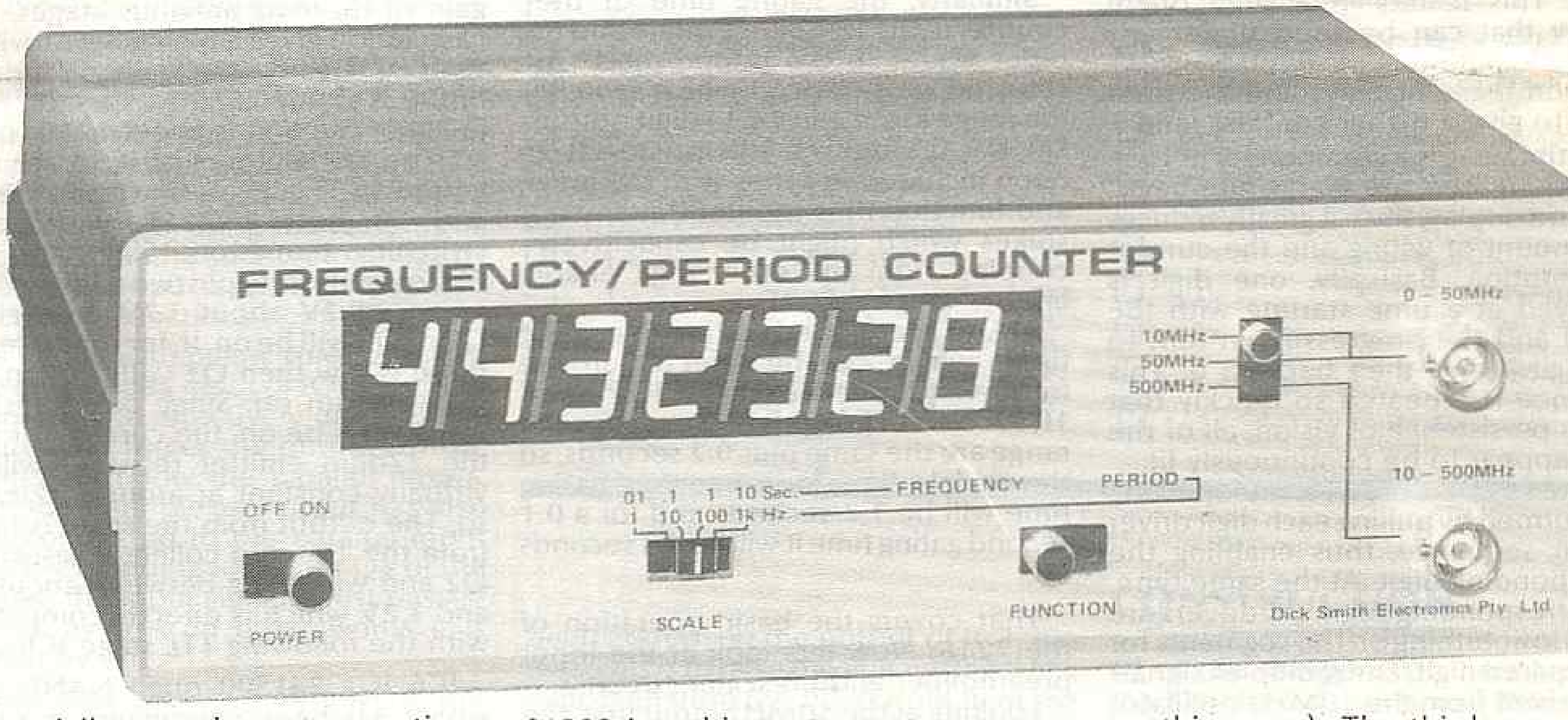
50MHz FREQUENCY/ PERIOD METER

K-3439

(May be converted to 500MHz use by the addition of the PRESCALER KIT K-3432)

Reprinted in part by arrangement with Electronics Australia from the December, 1981 edition.

This is a high performance digital counter using the latest IC technology. Measures period and high frequency to beyond 500MHz (with optional prescaler). The unit is simple to build and rivals commercial units — with considerable saving of money!



Essentially, you have two options when building this new DFM — you can either build the full 500MHz version or save money by building a 50MHz version. All you have to do is leave out the two pre-scaler ICs (IC4 and IC5) associated with the 500MHz range. More about this later on.

Gating time is selected by a four-position slide switch which selects either .01, 0.1, one or 10 seconds. The longer the gating time, the more digits displayed and the greater the resolution. Of course, the update time also increses with increasing resolution. Selectable gating makes for a more versatile DFM — you can opt for fast update times when the situation demands it, or opt for maximum resolution.

Period measurement is another quite useful feature of this DFM and is not normally found in units priced below $1000. It enables very accurate measurements of low frequency signals, ie, those below about 10kHz. In period mode, the gating time selector switch also selects the number of input cycles over which the period is to be measured — either 1, 10, 100 or 1000 input cycles — while the display reads in multiples of 0.1uS. For example, if 100 cycles was selected and the display read 8266312, then inverting this on a calculator gives 120.9729Hz — which is far more accurate than a direct frequency measurement of 120Hz.

The range selector switch has three positions: 0-10MHz, 0-50MHz and 10-500MHz. On the first range, measurements can be made up to 10MHz with 1Hz resolution (1s gating time), while the second range measures frequencies up to 50MHz with a resolution of 10Hz (the input frequency is divided by 10 on this range). The third range is for measurements from 10MHz to 500MHz and since the input frequency is now divided by 100, the resolution is 100Hz.

As noted earlier, two BNC input sockets are provided on the front panel. One of these has an input impedance of 1M shunted by about 50pF and is used for the first two frequency ranges up to 50MHz. The second has a nominal impedance of 75 ohms and is used for the third range, ie, 10-500MHz. Input sensitivity is about 10mV RMS up to about 30MHz rising to about 100mV RMS at 50MHz.

Accuracy of the frequency meter will depend on the accuracy and stability of the crystal timebase. This can be expected to be about 50 parts per million for most available crystals, which is quite adequate for this type of instrument.

Power consumption is fairly modest because of the multiplexed display. The unit is powered from the 240V AC mains and has a current drain of about 300mA from the +5V rail and about 70mA from the +12V rail. Overall power consumption is less than 7W.

HOW IT WORKS

Heart of the circuit is IC1, a 7216 counter chip. This new LSI chip is virtually a complete 10MHz frequency counter and contains a high-frequency oscillator, a decade timebase counter, an 8-decade data counter and latches, a 7-segment decoder, digit multiplexers and interface circuitry to drive 7-segment LED displays. All that has to be added to produce a working DFM is a power supply, input preamplifiers and prescalers, a 10MHz crystal and a LED display.

Referring to the circuit diagram, we can see that the 7216 directly drives a 7-digit display consisting of 7-segment LED bright amber LEDs.

This Dick Smith Kit uses the 7216B version that has slightly less display driving capability than the 7216A. Although this would normally result in a less bright display than if the A version were used, it would still be useable under normal workshop lighting conditions.

We have upgraded this display by using high efficiency 7-segment devices that have a light output level far in excess of the normal red 7-segment range. This results in a large bright display that can be used under any lighting conditions. A filter is used between these displays and the front panel to give a higher contrast ratio.

Multiplexing is a common technique used when there are a large number of digits in a display, since it greatly reduces the amount of wiring and the current consumption. Basically, one digit is displayed at a time starting with the digit 0 and the progressing in turn to the digit 7 and then back to 0. This sequence is repeated so quickly that due to persistence of vision, all of the digits appear to be continuously lit.

In the case of the 7216, multiplexing is performed by pulling each digit driver high in sequence, thus enabling the corresponding digit. At the same time, the corresponding segment drivers are pulled low, turning on the segments for the required digit. The multiplex signals are derived from the 10MHz oscillator used in the timebase and the multiplexing rate is set at 500Hz; ie, it takes 2mS to scan the display. Each of the digits however, are on for only 244us rather than 250us since the 7216 has an inter-digit blanking time of 6us to prevent ghosting between digits.

The oscillator on the 7216 is actually a high-gain CMOS inverter with pin 25 as the input and pin 26 as the output. This inverter is connected in a 'pi-network' oscillator with a 10-22M resistor connected between the input and output to provide biasing of the inverter amplifier. In most cases a 10M resistor is used and will operate properly.

The quartz crystal in the circuit operates in what is termed the parallel or antiresonant mode. The load capacitance of the crystal consists of the crystal shunt or static capacitance in parallel with the 39pF fixed and 4-20pF trimmer capacitor. The trimcap is provided to compensate for the normal frequency tolerance of the crystal, which is usually around 30ppm, and also for any stray capacitance, including the input capacitance of the 7216.

In cases where the trimmer may not be of sufficient capacity to compensate for the circuit conditions, we have made provision on the circuit board to add an extra 18pF ceramic capacitor. This is not added unless it is found neccessary in cases where the frequency will not go low enough with adjustment.

Temperature stability of a typical 10MHz crystal is better than 5ppm from −20°C to +80°C and the ageing rate is about 5ppm per year.

Apart from operating as a frequency counter, the 7216 can also measure period. This is accomplished internally by using the input signal to gate through the 10MHz clock to the counter section. The resulting count will be proportional to the input waveform and because of the 10MHz clock, the counter will display period in units of 0.1uS.

Period or frequency mode is selected using switch S4 which switches the function input, pin three, to either the D0 or D7 digit enable lines. The internal circuitry of the 7216 compares this signal against its digit multiplex information to see which digit output and hence which function has been selected.

Similarly, the gating time of the counter in the frequency mode and the input cycles in the period mode are selected via switch S3 which switches the range input, pin 14, to digit outputs D0, D1, D2 and D3. 10k resistors have been included in series with the range and function pins to filter out any fast spikes which might be capacitively coupled from the other digit enable lines.

As was mentioned earlier, the gating times which can be selected in the frequency mode are 0.01, 0.1, one and 10 seconds. The update times for each range are the same plus 0.2 seconds, so the update time for a 1 second gating time will be 1.2 seconds and for a 0.1 second gating time it will be 0.3 seconds etc.

That covers the basic operation of the 7216. Now lets look at the input preamplifier and prescaler circuits.

Looking at the 50MHz input first, the input signal is coupled in via a .047uF capacitor and a 100k resistor and 100pF in parallel. Together with two BAW62 diodes, D1 and D2, this input circuit clips the input waveform to 600mV to prevent damage to the input preamplifier. The 100pF capacitor bypasses the 100k resistor at higher frequencies to prevent attenuation due to the input capacitance of the following FET buffer stage Q1.

Q1 is a 2N5485 VHF FET arranged as a source follower with the gate connected to ground via a 1M resistor and self biased via a 1k source load resistor. This drives three cascaded ECL (emitter coupled logic) receivers IC2c, IC2b and IC2a which comprise an MC10116 triple differential line receiver IC. This basic circuit is used in many commercial designs.

Essentially, each ECL line receiver consists of an NPN differential pair with a constant current source in the 'tail' and resistor collector loads. The collector of each transistor is buffered by an emitter follower providing complemementary outputs. The emitter outputs are left open — ie, there are no internal pull-down resistors are required on each output.

ECL outputs usually swing ±0.2V about a reference voltage of around 3.7V. This reference voltage is actually provided by the 10116 on pin 11 and it has been used to bias the first line receiver IC2c via two 1k resistors. A 0.1uF capacitor and a 10uF tantalum capacitor provide decoupling of the reference voltage.

The stage following IC2b is IC2a which operates as a Schmitt trigger by virtue of the positive feedback network consisting of the 220ohm and 1k resistors. Input signals to this Schmitt trigger must exceed its two hystersis trigger levels before the output of the trigger will change, so this stage provides a good deal of noise immunity as well as squaring up the input signal.

Assuming a swing of ±0.2V at the output of IC2a, the hysteresis voltage levels are ±0.15V which is greater than the maximum output offset voltage of IC2b. so no bias adjustment of IC2c is required. The theoretical sensitivity of the amplifier may be worked out by dividing the hysteresis voltage by the gain of the two previous stages. This calculation gives a typical sensitivity of 6mV and since the gain of the FET buffer is about 0.5, the expected sensitivity of the unit is about 12mV peak.

The ECL outputs of IC2a are converted to TTL levels by transistors Q2 and Q3, both 2N4258 high speed switching transistors. Since the two ECL outputs from pin two and pin three swing ±0.2V about 3.7V then either Q2 or Q3 will be on. If, for example, pin three is low then Q2 will turn on and Q3 will turn off. Since one transistor will always be on, the current through the 27ohm emitter resistor will be virtually constant at around 32mA or so. The output from the stage is taken from the 100ohm collector resistor of Q2 and will swing between about 0.1 and 3.2V which is directly compatible with the following TTL stage IC6c.

IC6 is a 74LS00 quad NAND gate which has been connected as a two-multiplexer. One input, pin 9 on IC6c, goes to Q2 (the 50MHz preamplifier output) while the other input, pin one of IC6a, goes to the 500Mhz prescaler. One of these two inputs is selected via switch S1a and passed to the output of the multiplexer, pin 6 of IC6b.

With switch S1a set to the 10Mhz and 50Mhz positions, pin two of IC6a is pulled low disabling it and forcing its output, pin three, high. IC6d inverts the low signal from S1a setting pin ten of IC6c high. IC6c is then enabled and acts as an inverter, passing the signal from Q2 to pin 5 of IC6b. Now since the other input of IC6b is high, the output from IC6b is just the signal from Q2.

When S1a is switched to the 500MHz position, IC6d is enabled and IC6c disabled so that the signal from the 500MHz prescaler is passed to the output of the multiplexer.

THE PRESCALER

The optional 500MHz prescaler circuit is quite straightforward. Diodes D5 and D6 clip the input signal as before which is then fed to an OM350 hybrid VHF preamplifier which offers about 18dB of gain. The output of the preamplifier and the power supply are combined on pin five of the OM350.

Power is applied to the OM350 via an RF choke and the output is capacitively coupled to IC5, an 11C90 ECL decade divider. Pin 16 of this device is the clock input and pin 15 is an internal bias reference specifically intended for biasing an AC-coupled clock input.

Complementary ECL outputs are provided from the 11C90 as well as a separate TTL output which has been connected to the multiplexer IC6. A separate TTL earth is also provided on the 11C90 so that the crowbar currents of its TTL 'totem pole' output stage are not fed back to the input.

So far we have a 50MHz and a 500Mhz prescaler and a multiplexer to switch from one to the other. What is also required is a programmable divider to divide by one for signals up to 10MHz and divide by ten for signals up to 50MHz and from the 500Mhz prescaler. This could be done by simply switching a decade divider in or out but instead an electronic switching circuit that avoids taking any signals to the line switch was used.

This is accomplished by using a standard 74196 decade divider which features four outputs (Q1, Q2, Q3 and Q4) as well as four parallel inputs (D1, D2, D3 and D4) which can be loaded into the counter using the load input, pin one. To get the counter to divide by ten, the load input is switched high and the counter functions normally.

For frequencies below 10MHz, switch S1b sets the load input of IC3 (pin 1) to ground, which effectively disables the counter and forces the outputs of the counter to follow the parallel inputs. Since the multiplexer output has also been connected to the parallel input D3, corresponding to output Q3 of the counter, the input signal is just passed through as is — in other words it is divided by one.

Note that the Q3 output of the counter has been used rather than Q4 because, if the normal BCD counting sequence is examined, Q4 is low for counts zero to seven and high only for counts eight and nine. Since the 7216 has a minimum input pulse length (50ns high or low), the clock waveform must be as square as possible for it to reach its maximum specified frequency of 10MHz. The Q3 output is high for four consecutive counts and low for six, and thus has the advantage of a much squarer output.

The electronic switching used in the multiplexer and divider is slightly more complex than if the signals had been switched directly but it really simplifies construction in that wiring layout is noncritical.

One final point about the divider circuit: a 470ohm pull-up resistor has been added on the output of IC3, pin two. This is to raise the voltage level of a logic high from the TTL output to make it acceptable to the CMOS input of the 7216. According to specifications, the 7216 requires a clock signal of 2.5Vp-p centred about 2V, ie, a high is 3.25V.

The power supply consists of a 2155 transformer which is full wave rectified by diodes D3 and D4 and filtered by a 1000uF/16VW capacitor. This is then regulated down to 5V via a three 3terminal 5V regulator. The 10uF tantalum capacitors at the input and output of the regulator provide decoupling and stability.

A regulated +12V supply is also provided for the OM350 preamplifier and the FET input stage by using a voltage doubler consisting of the 470uF and 220uF capacitors plus diodes D1 and D2 to generate around 18V. This is then regulated to +12V by a 12V 3-terminal regulator.

CONSTRUCTION

Construction is simplified by having all of the components mounted on a main printed circuit board. If you carefully follow the steps involved, you should have no problems.

Note that the LED 7-segment are mounted on a separate board that butts up against the main board and is soldered to it via edge connection strips. This display board also carries all the switching facilities and so eliminates all but the mains wiring. This makes construction easier and reduces the risk of wiring mistakes. Do not mount parts on the display board as yet — it is part of the final assembly.

☐ First insert and solder all the links required on the main board. Follow the circuit overlay closely to avoid errors.

☐ Now mount the resistors and capacitors. Remember to be aware of the polarity of electrolytic and tantalum capacitors.

PARTS LIST

Resistors

☐ 1x........27 ohm
☐ 1x........100 ohm
☐ 1x........220 ohm
☐ 7x........470 ohm
☐ 2x........1k
☐ 2x........1k METALFILM
☐ 2x........10k
☐ 1x........1M
☐ 1x........10M
☐ 1x........100k

Capacitors

☐ 1x........18pF ceramic
☐ 1x........39pF ceramic
☐ 1x........100pF ceramic
☐ 1x........047uF ceramic
☐ 8x........0.1uF ceramic
☐ 1x........100uF electro
☐ 1x........220uF electro
☐ 1x........470uF electro
☐ 1x........1000uF electro
☐ 9x........10uF tantalum
☐ 1x........4-20pF trimcap

Semiconductors

☐ 1x........MPF106 or 2N5485
☐ 2x........PN4258
☐ 4x........1N4002 diode
☐ 7x........LED display
☐ 1x........74LS00 IC
☐ 1x........74196 IC
☐ 1x........MC10116 IC
☐ 1x........7216B IC
☐ 1x........7805 5V regulator IC
☐ 1x........7812 12V regulator IC
☐ 1x........Crystal, 10MHz
☐ 2x........BAW62 diode

Nuts & Bolts

☐ 1x........Regulator heatsink
☐ 1x........Screw, ⅛x¼
☐ 2x........Screw, 4BA x ½"
☐ 4x........Screw, self-tap No.4
☐ 1x........Nut, ⅛
☐ 2x........Nut, 4BA
☐ 2x........Flat washer, 4BA
☐ 1x........Solder lug, double
☐ 30x.......Molex pins

Hardware

☐ 1x........Slider, 2pol-3pos
☐ 2x........Slider, 2pol-2pos
☐ 1x........Slider, 1pol-4pos
☐ 1x........BNC socket, insulated
☐ 1x........Grommet
☐ 1x........Cable clamp, ¼
☐ 3x........Spaghetti
☐ 1x........Cable tie

Miscellaneous

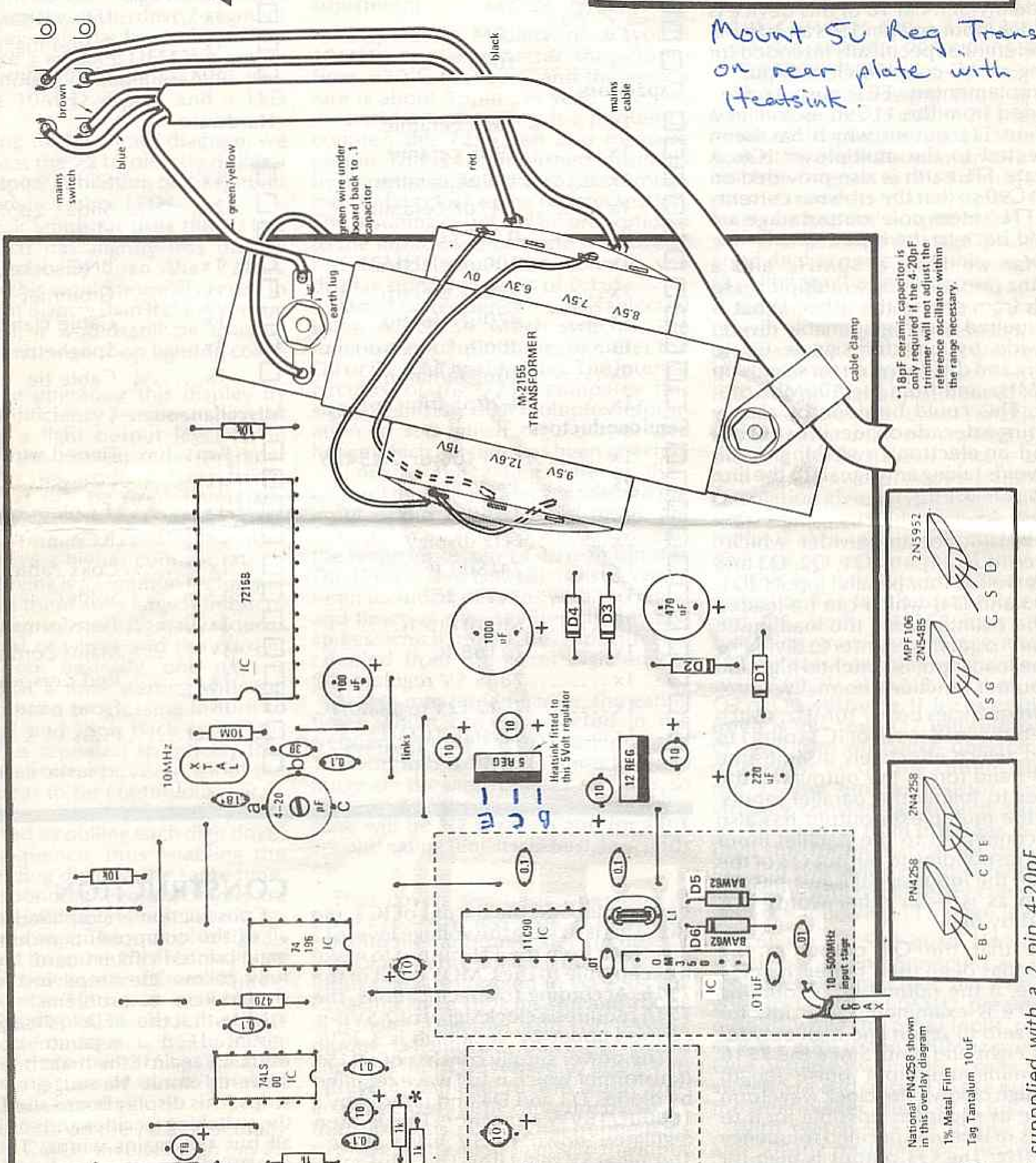
☐ ½m.......Tinned wire
☐ 4x........PCB pins
☐ 1x........3 Colour mains wire
☐ 2x........1 Colour H/U wire
☐ 1x........Coax cable, 75 ohm
☐ 1.5m......Solder
☐ 1x........Transformer, 2155
☐ 1x........Mains cord and plug
☐ 1x........Red perspex filter
☐ 1x........Front panel
☐ 1 set......PCBs (A & B)
☐ 1x........plastic case

When the mains wiring has been completed, fit the cable tie close to the mains switch wiring to prevent the spaghetti slipping back.

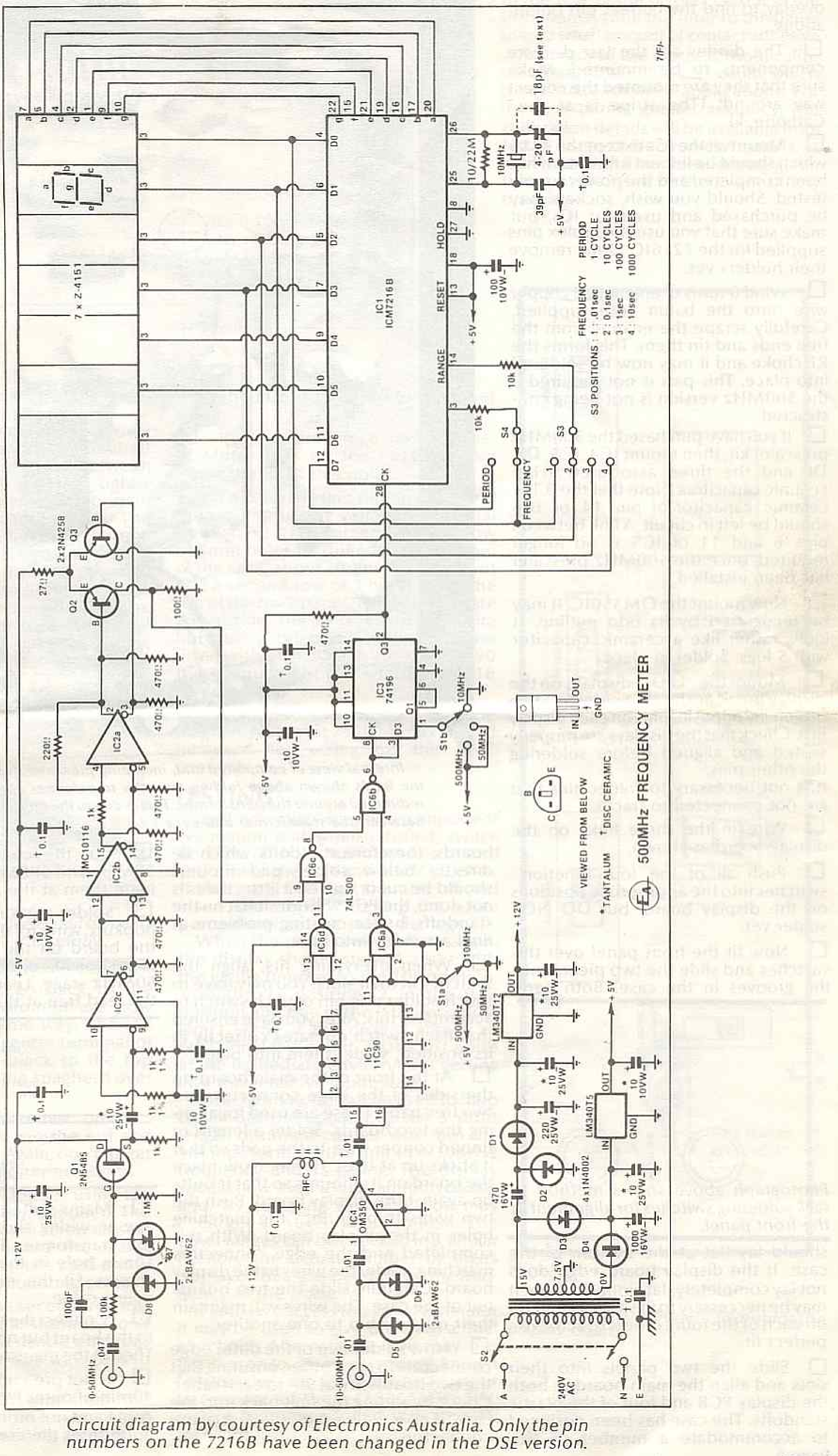
PRE-SCALER PARTS LIST
K-3432 (optional extra)

- ☐ 1x........ OM350 IC
- ☐ 1x........ 11C90 IC
- ☐ 2x........ BAW62 diode
- ☐ 3x........ 0.01uF ceramic cap
- ☐ 1x........ BNC socket, insulated
- ☐ 30cm........ Coax cable, 75 ohm
- ☐ 1x........ Balun former
- ☐ ½m........ Enamelled wire, 22#

Mount 5v Reg Trans on rear plate with Heatsink.



Note: If you have been suppplied with a 2 pin 4-20pF trimcap, insert and solder across points 'a' and 'b' only. Point 'c' will not be used. Please refer to the above component layout.



Circuit diagram by courtesy of Electronics Australia. Only the pin numbers on the 7216B have been changed in the DSE version.

☐ Now mount the two transistors and the FET. Use the drawings on the overlay to find the correct pin orientations.

☐ The diodes are the last discrete components to be mounted. Make sure that they are mounted the correct way around! (The stripe is at the Cathode, k)

☐ Mount all the ICs except the 7216 which should be left until the board has been completed and the power supply tested. Should you wish, sockets may be purchased and used for ICs, but make sure that you use the molex pins supplied for the 7216IC. Don't remove their holders yet.

☐ Wind 6 turns of enamelled copper wire onto the balun core supplied. Carefully scrape the enamel from the free ends and tin them. This forms the RF choke and it may now be soldered into place. This part is not required if the 500MHz version is not being constructed.

☐ If you have purchased the 500MHz prescaler kit, then mount IC4, IC5, D5, D6 and the three associated .01uF ceramic capacitors. Note that the 0.1uF ceramic capacitor of pin 14 of IC6 should be left in circuit. A link between pins 6 and 11 of IC5 is no longer required, once the 500MHz prescaler has been installed.

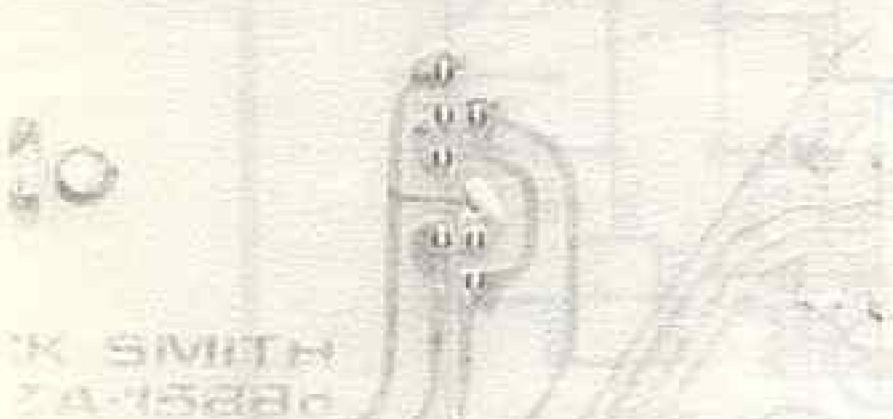
☐ Now mount the OM350IC. It may be recognised by its odd outline. It looks rather like a ceramic capacitor with 5 legs. Solder in place.

☐ Mount the LED displays on the display board as shown. Solder just two diagonally opposite pins on each display first. Check that the displays are properly seated and aligned before soldering the other pins.
It is not necessary to solder pins that are not connected to tracks.

☐ Wire in the three links on the display board as shown.

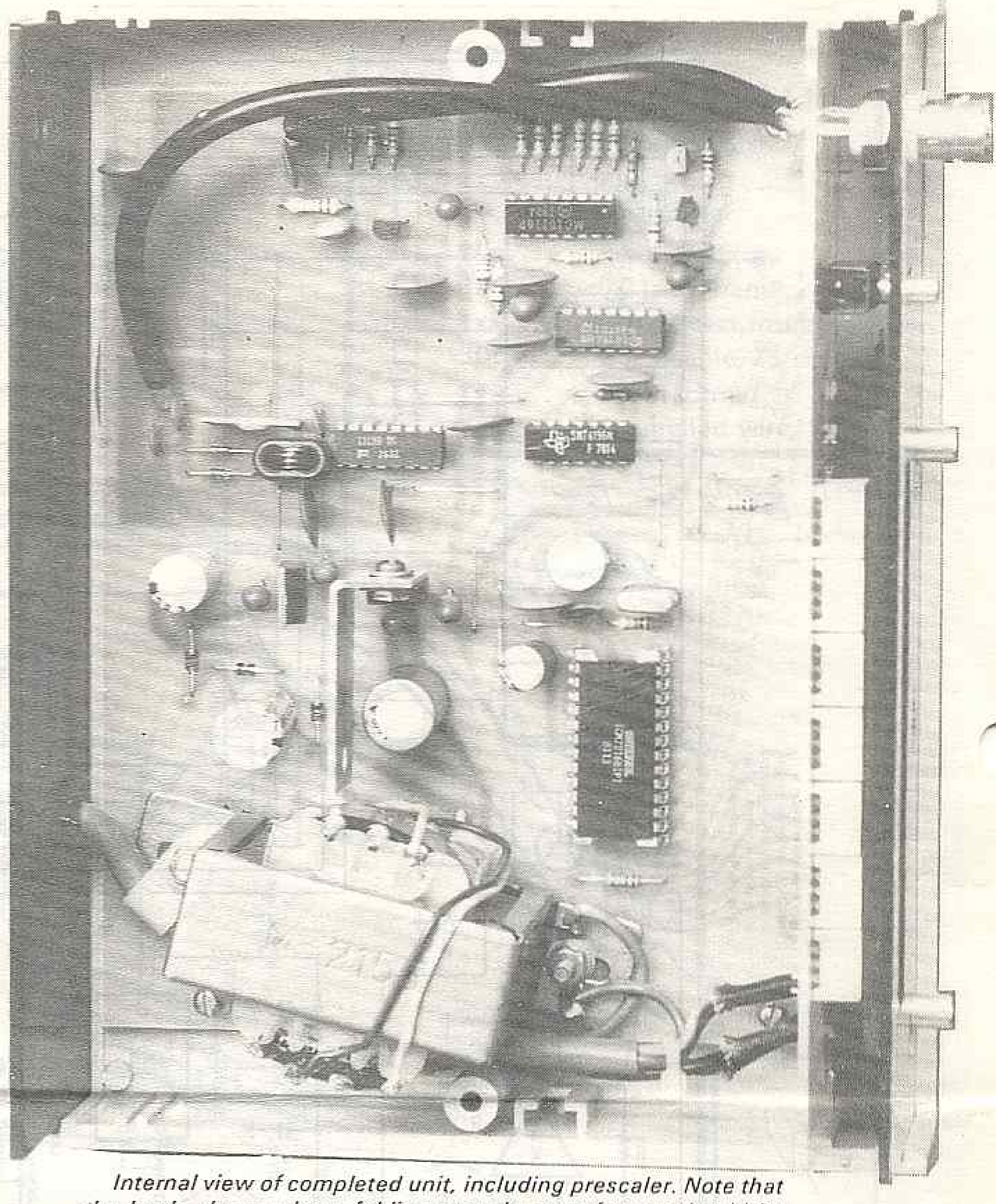
☐ Push all of the four function switches into the appropriate positions on the display board, but DO NOT solder yet.

☐ Now fit the front panel over the switches and slide the two pieces into the grooves in the case. Both parts should lay flat at the bottom of the case. If the display board edge does not lay completely flat along the case, it may be neccessary to file a small amount off each of the four corners to achieve a perfect fit.



Photograph above shows method of tack soldering switches for alignment in the front panel.

☐ Slide the two panels into their slots and align the main board to both the display PCB and four of the plastic standoffs. The case has been designed to accommodate a number of size boards, therefore standoffs which lie directly below solder pad mounts should be cut or shaved a little. If this is not done, the PCB will not sit flat on the standoffs, hence creating problems at final assembly into case.



Internal view of completed unit, including prescaler. Note that the leads shown above folding over the transformer should be redirected around the transformer. This is due to the limited space between the transformer and case lid.

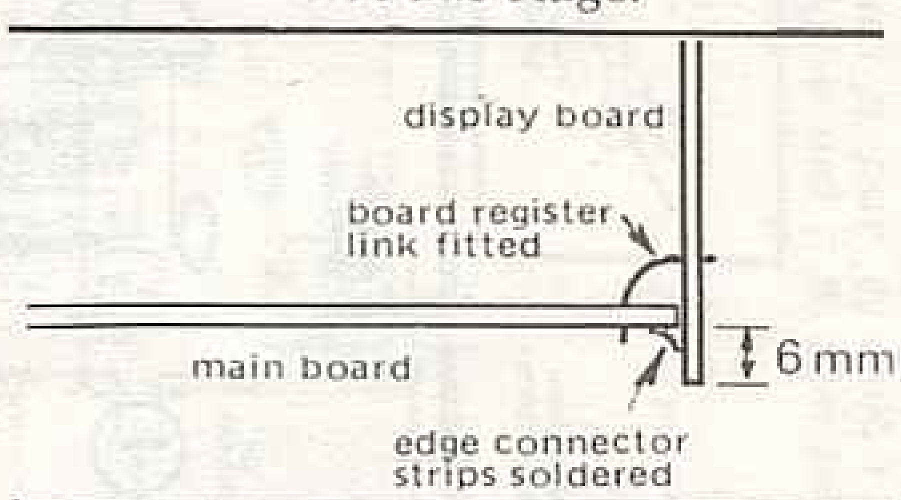
☐ When everything fits, align the switches in their slots. You may have to touch-solder one pin of each switch to accomplish this. After you have ensured that each switch operates correctly in its position, solder them into place.

☐ At the front of the main board on the sides of the edge connectors are two free pads. These are used for aligning the two boards. Solder a length of tinned copper wire to the pads so that it sticks up at least 10mm. Now place the board on its mounts so that it butts up against the display board. Push the two wires through into the matching holes in the display board. With this completed and the edge connectors matching, solder the wires to the display board. Carefully slide the two boards out of the case. The wires will maintain their relationship to one another.

☐ Now solder two of the outer edge connectors to each other, ensuring that the two boards are at 90° to each other. Check by sliding the unit back into the case. If all is well, solder the rest of the connectors.

☐ Cut the coaxial cable for the 50MHz and 500MHz inputs and terminate them at the main board only.

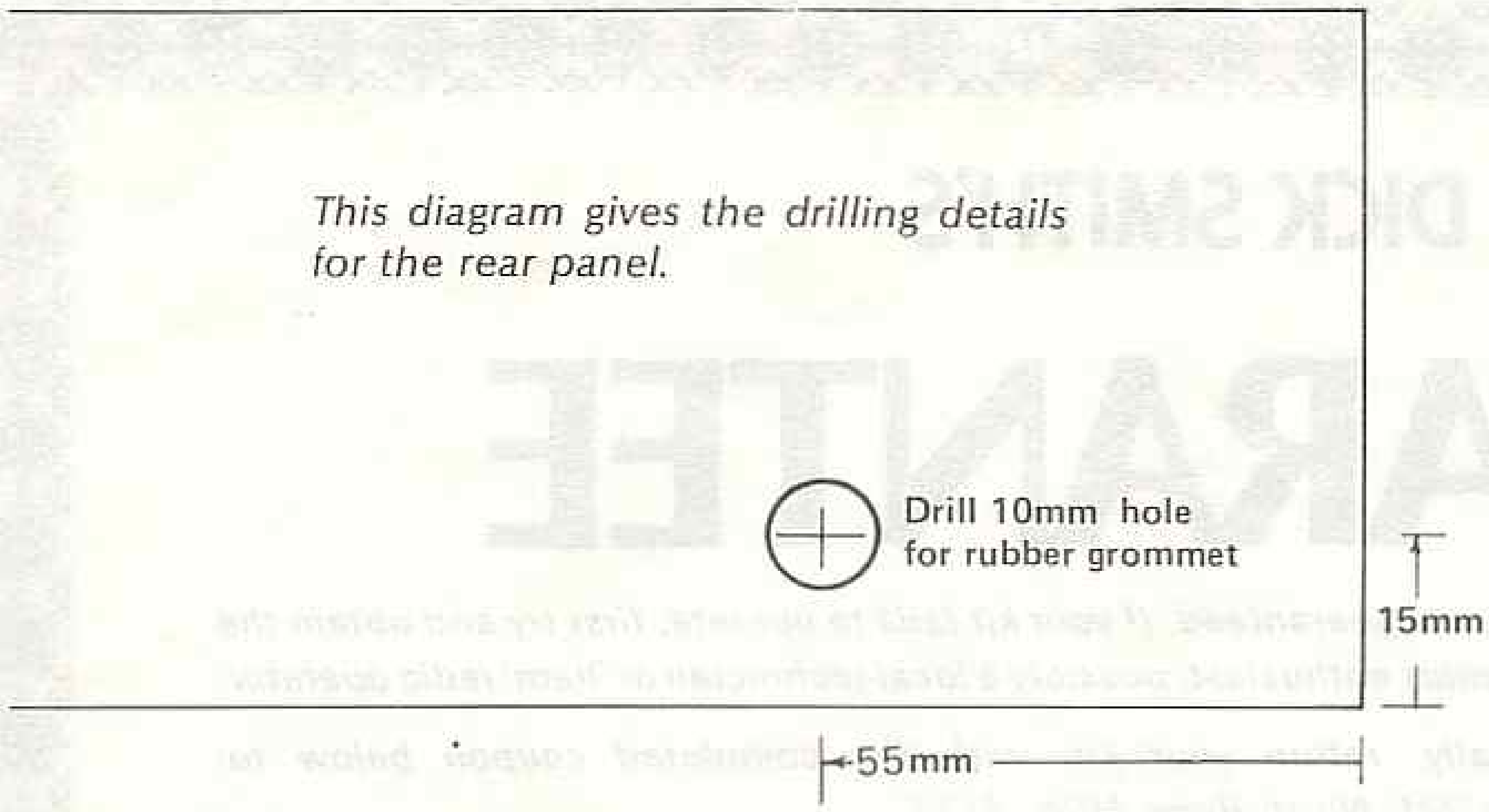
☐ Solder a 200mm length of green hookup wire to the pad underneath the board on the earth DC isolation capacitor (0.1u) at the rear of the 10-50MHz stage. Leave the other end of the lead free at this stage.



☐ Mains switch wiring and low voltage ac wiring should be done before the transformer is mounted. Drill a 10mm hole in the rear of the case as shown. Fit the rubber grommet and mains cable.

☐ Connect the three secondary wires to the board but not to the transformer. Then fit the mains and associated wiring.

☐ If not pre-cut, strip not more than 40mm of outer PVC covering from the cable and not more than 5mm of insulation from the conductors.

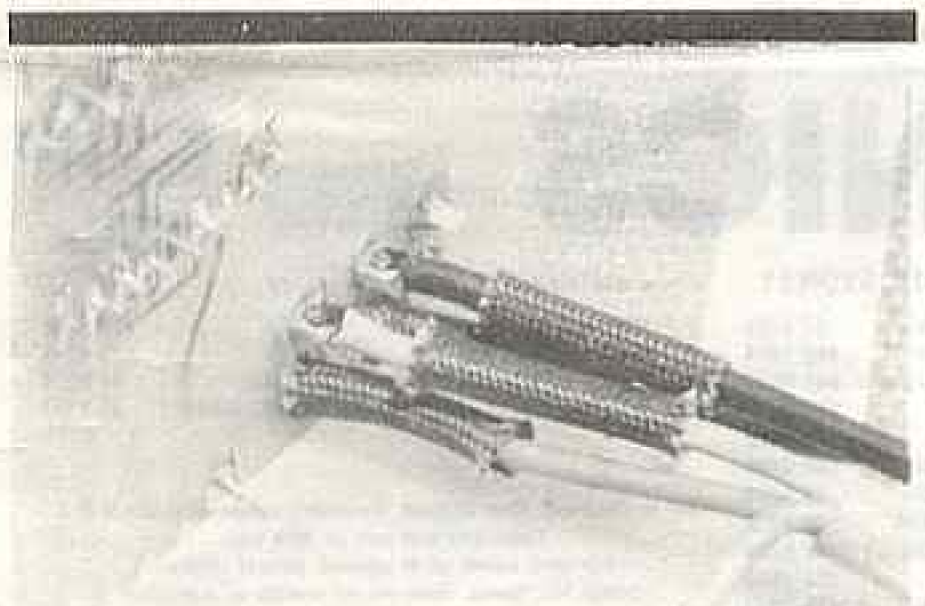


This diagram gives the drilling details for the rear panel.

The red filter supplied in this kit is fixed to the rear of the display cutout in the front panel. Glue the filter to the panel using a small amount of contact adhesive

Accuracy of the meter without calibration is typically .005%±1 count, which is adequate for most applications. For those requiring greater accuracy, full calibration details will be available from future issues of Electronics Australia, as well as a useful troubleshooting guide that may be used in the event of any trouble.

☐ It is most important that the mains wires are terminated as follows: Slide a 20mm piece of spaghetti over the brown (active) and blue (neutral) wires. Twist the bare ends between your fingers so that they are tightly bunched and then feed them through the eyelet in the mains switch. The brown wire is terminated to the bottom inside terminal, the blue goes to the top inside terminal. After the wire is through the eyelet (every strand!) bend it back on itself so that it wraps around the terminal. Now solder to the terminal along with the PCB pad. Slide the spaghetti over the joint so that it butts up against the PCB.



Above photograph shows detail of mains switch wiring. Follow it carefully.

☐ The wires that go back to the primary of the transformer are now terminated in the same way. The red goes to the bottom centre terminal of the switch and the black to the top centre. Don't forget the spaghetti over each wire.

☐ Place the transformer on its mounting points and cut the red and black wires to length. Again, don't forget the spaghetti over the terminations.

☐ Mount the transformer using the screws, nuts and washers supplied. The earth lug is bolted on the screw closest to the mains switch and the mains clamp slips over the mains cord and is bolted to the other mounting screw.

☐ Now connect the secondary wires from the PCB to the transformer. Don't confuse the wires. The centre wire goes to the 7.5V terminal. One wire goes to 0V, the other to 15V.

☐ The green earth wire from the mains is soldered to one side of the earth lug and the remaining green wire from the PCB is soldered to the other side.

☐ Remove the bridge from each set of Molex pins for the 7216. Do not insert the IC at this point.

☐ To keep the unit running cool and thus minimise any variation in crystal frequeny, it is recommended that a row of 5mm holes be drilled in the bottom of the case, about 20mm from the front and a second row of 5 holes along the top of the back panel. This will facilitate convection. The 5V regulator gets quite hot during operation and should be fitted with a small heatsink. The 11C90 IC gets quite hot too, whilst the 7216 IC gets warm.

☐ Complete the wiring using the diagram. Note that 75 ohm coax should be used for wiring up the BNC connectors.

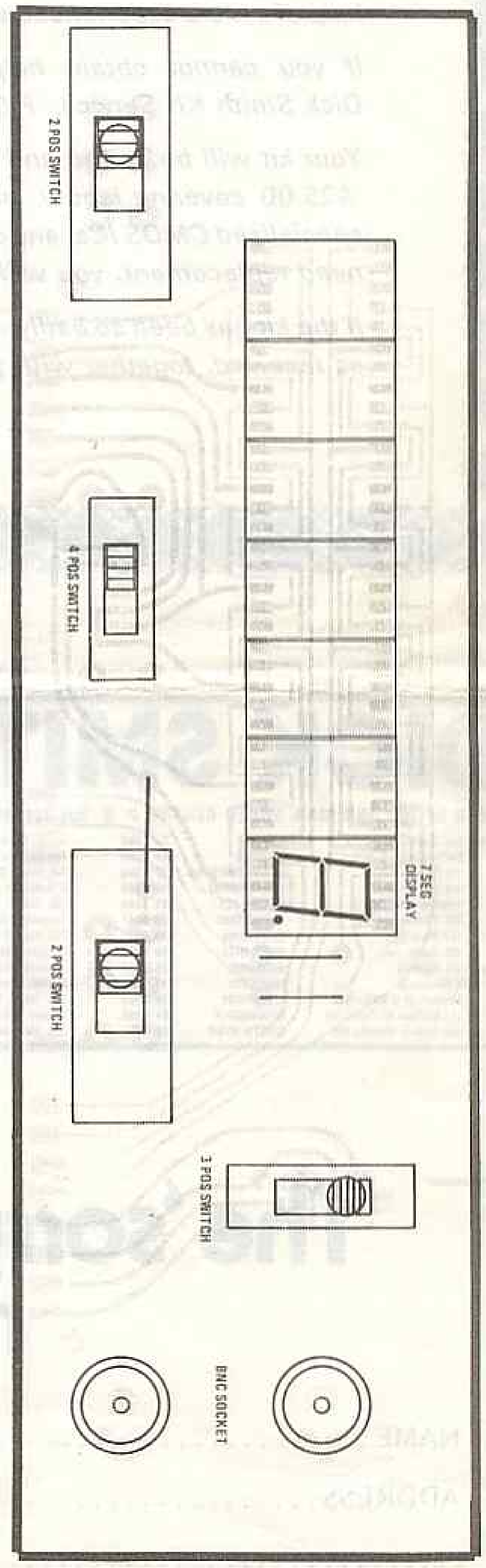
TESTING

Recheck your wiring and component orientation and when satisfied, switch on. (The 7216 IC should not be inserted yet). Check the +5V and +12V supplies. If these are OK, turn the unit off and insert the 7216 IC taking the usual precautions against static damage.

When the unit is switched on again, the display should show 4 zeros with the gating time set to the 10s position, 3 in the 1s position, 2 in the 0.1s position and one in the 0.01s position. Don't worry if the display shows an occasional low count. That's just noise in the immediate environment getting into the sensitive input stage.

In fact, this noise can be used to help check out the counter. Insert a short length of tinned copper wire into the 1M input and set the unit to 0-10MHz frequency and 1s gating. The display should now show a high random reading and, by touching the wire, you may even get all seven digits to light. The other ranges can be checked in a similar fashion, the actual number of digits displayed being dependant on the frequency of the noise.

If you have access to a signal generator it may be used to give the DFM a final checkout. Alternatively, you may use the meter to measure several known frequencies, eg, CB radio or Amateur transceiver, or the 4.433619MHz PAL indent frequency found in colour TV receivers.



Above is the component layout for the display board.

The 'sorry Dick it doesn't work' return coupon

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DATE KIT PURCHASED .... PURCHASED FROM ....

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I AM A – COMPLETE BEGINNER ☐ HOBBYIST ☐ EXPERIENCED ☐

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