Assembly Manual for the

FUNCTION GENERATOR

Cat. K-3520

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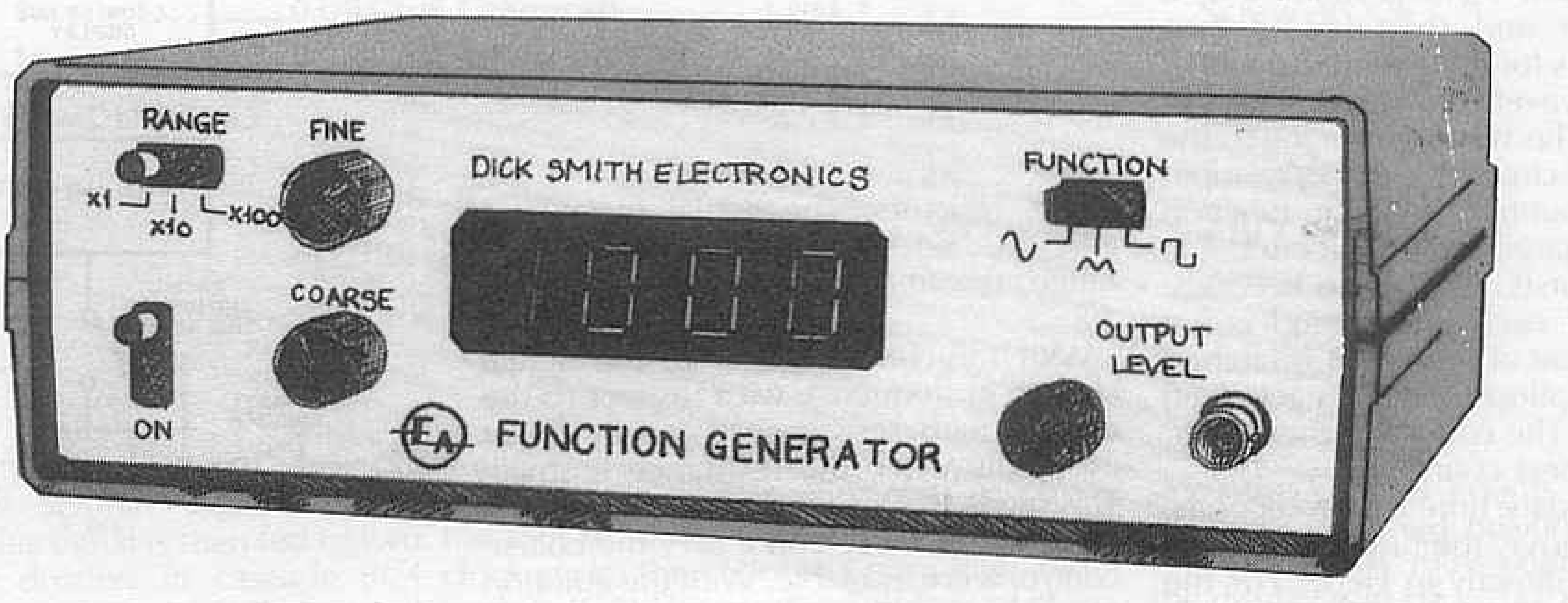
This Function Generator produces sine, triangle and square waves over a range from below 20Hz to above 160kHz with low distortion and good envelope stability. It has an inbuilt 4-digit frequency counter for ease and accuracy of frequency setting.



Apart from a good multimeter and a power supply, the next most useful piece of test equipment in the laboratory or home workshop is an audio generator. This would normally be a solid state Wien bridge oscillator, but more recently the function generator has come into its own, particularly where the potentially very low distortion of the former circuit is not required.

The particular advantage of a function generator is that it has good envelope stability. This means that the output level stays constant regardless of small or large changes in the frequency setting. This is not the case with typical solid state Wien bridge oscillators which are stabilised with a thermistor. These Wien bridge oscillators can fluctuate violently in output level when the frequency is changed and take several seconds to settle. This can be very frustrating when trying to measure the frequency response of a circuit or component such as a loudspeaker.

Using that attractive, low profile case for the Function Generator meant that a different approach was required to the conventional dial scale. If this was used it would have to be of small diameter and, in any case, it would be subject to the normal drawbacks of calibration accuracy, and considerable cramping at the high end of the scale.

This problem has been solved at one stroke by incorporating a 4-digit counter. This eliminates the need for any dial scale or any calibration procedure. The frequency counter uses the 50Hz mains as a timebase to give an accuracy of about ±2%.

Text and Illustrations courtesy of Electronics Australia

Block Diagrams

As can be seen in Fig. 1, the IC is capable of many operations including amplitude modulation (AM), frequency shift keying (FSK), and frequency modulation, via the current switches. The VCO is the major function block of the circuit, which generates the triangle and square waveforms at a frequency controlled by the current switches. Resistors tied from pins 7 and 8 are used to program the current switches and determine the VCO frequency.

The multiplier and sine wave shaper performs several tasks. It accepts the triangular waveform from the VCO and reshapes this to a sine wave. In addition, the output level of these two waveforms is controlled by a resistor at pin 3 to ground and with the voltage at pin 1. Either sine or triangle is selected with a resistor across the waveform adjust pins (13, 14), or open circuit, respectively, while the unity gain amplifier buffers the sine or triangle waveform.

The sync output at pin 11 is an open collector output that provides a square wave in synchronisation with the VCO frequency.

Fig. 2 shows a simplified block diagram of the frequency meter. This can be divided into three parts: counter and display, latch and reset and timebase. The timebase gives three counter update times: 20ms, 200ms and 2s. Let us look at the counter operation in the 2s update situation.

The 50Hz mains signal is squared by a Schmitt trigger and then fed to two decade dividers for an overall division of 100, giving a waveform with a period of two seconds. This waveform is fed to the latch and reset circuitry so that the input signal to be counted (from the function generator) is gated into the counter in one-second bursts, every two seconds. At the end of each one-second count period, the value of the count is latched (stored in 16 flipflops, four for each digit) and displayed. The counter is then reset, ready for the next count.

When the update time is two seconds, as discussed above, the display indicates the frequency directly in Hertz. For the 0.2 second update time, the reading must be multiplied by 10 and for the .02 second (20ms) update time, multiplied by 100.

Having discussed the circuit in block form, let us now look at the complete circuit diagram in detail.

IC1, the XR-2206 monolithic function generator, is connected to provide both the sine and triangle wave signals. R2 and R3 are trimpot resistors which are used to preset the level of the sine and triangle waves. When switch S1 is in position 2, a triangle wave is produced at pin 2 and the output level of this wave is determined by R2 since R3 is short circuited with S1c. When S1b is in position 1, a sine wave is produced and the output level of this is determined by R2 and R3. R3 is adjusted so that the sine wave level is the same as the triangle wave level.

In the sine wave mode, the sine wave shaper is brought into play to "round off" the peaks of the triangle wave. Critical adjustment of R4, between pins 13 and 14 of IC1, gives minimum distortion of the sine wave. R1, the symmetry adjustment between pins 15 and 16, is adjusted for equal positive and negative swings of the sine and triangle waveforms. Adjustment of these trimpots will be discussed later in this article.

S2a is used to select the three frequency ranges by switching separate timing capacitors across pins 5 and 6. Frequency adjustment is with the fine and coarse variable resistors and the 4.7kΩ resistor sets the maximum frequency for each range. The frequency of the generated signal is a function of the capacitor value between pins 5 and 6 and the frequency adjust resistors. The actual formula is $F = 1/RC$. Since C is a constant for each range, the frequency is proportional to 1/R.

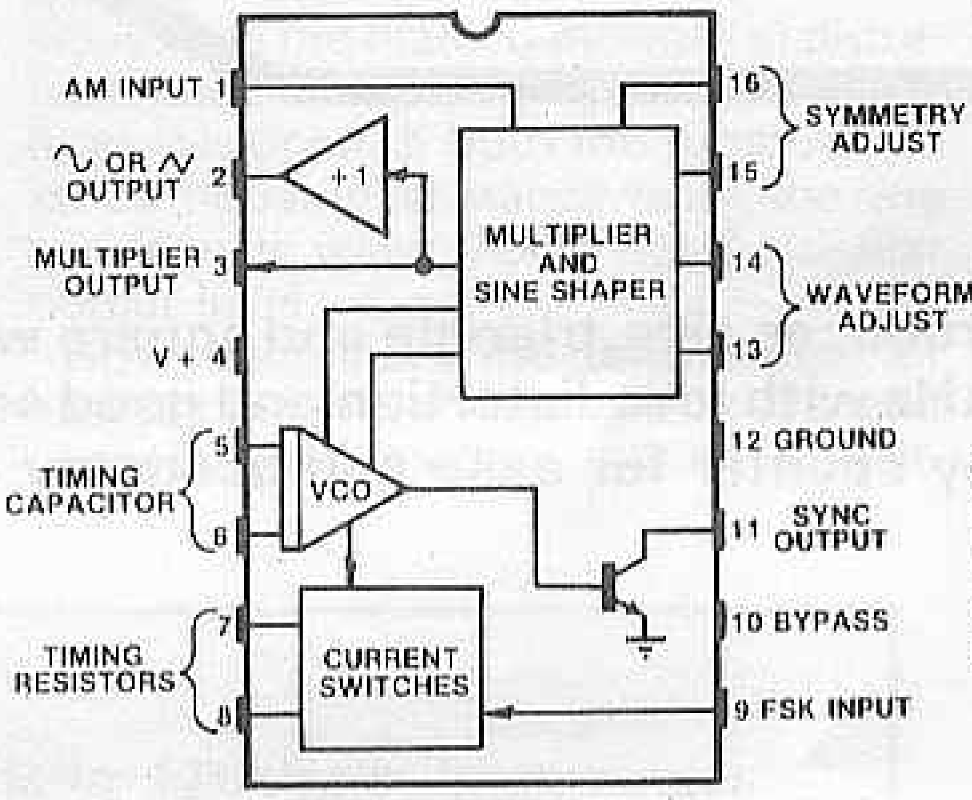


FIG. 1

The operation of the XR-2206 can be described in four blocks: a voltage controlled oscillator (VCO), an analog multiplier and sine wave shaper, a unity gain buffer and a set of current switches.

With this 1/R relationship, the actual change in frequency with respect to the change with resistance is hardly linear especially when the resistance is small. This tends to give an unusable control at the low resistance end if only the coarse control were available. With the addition of a low value fine control, frequency changes are easily accomplished at the low end of the resistance range. The fine control has little effect at the high resistance end of the coarse control since, at this end, large changes in resistance are required for a small change in frequency.

The open-collector square wave output of ICl1, pin 11, is provided with an external 2.2kΩ pullup resistor to drive the input of IC7a, a Schmitt trigger which provides buffering and further squaring of the waveform. IC7c acts as a further buffer to drive an attenuator and then the transistor output stage. The attenuator (voltage divider) consists of 1.8kΩ and 2.2kΩ resistors, to adjust the level of the square wave to the same peak-to-peak level.

S1a selects the sine, triangle or square wave and the signal is attenuated with the 22kΩ level potentiometer. The resulting signal from the wiper of the pot is fed to the input of the emitter follower output stage.

The emitter follower stage consisting of the NPN BD139 and PNP BD140 transistors is a complementary symmetry arrangement. The NPN transistor drives the output for positive input signals and the PNP transistor drives for the negative input signal. To prevent crossover distortion at the transition when one transistor takes over the signal from the other, the transistors are biased on so that a quiescent current flows through both transistors. 2.2kΩ and 1kΩ base bias resistors set this current at around 40mA.

Heavy supply decoupling, consisting of the 100Ω resistors and 47µF capacitors across each supply rail, ensures good ripple rejection. This allows the output signals to be attenuated, to millivolt levels without hum and noise swamping the signal.

Output impedance of the stage is a nominal 600Ω for all output levels.

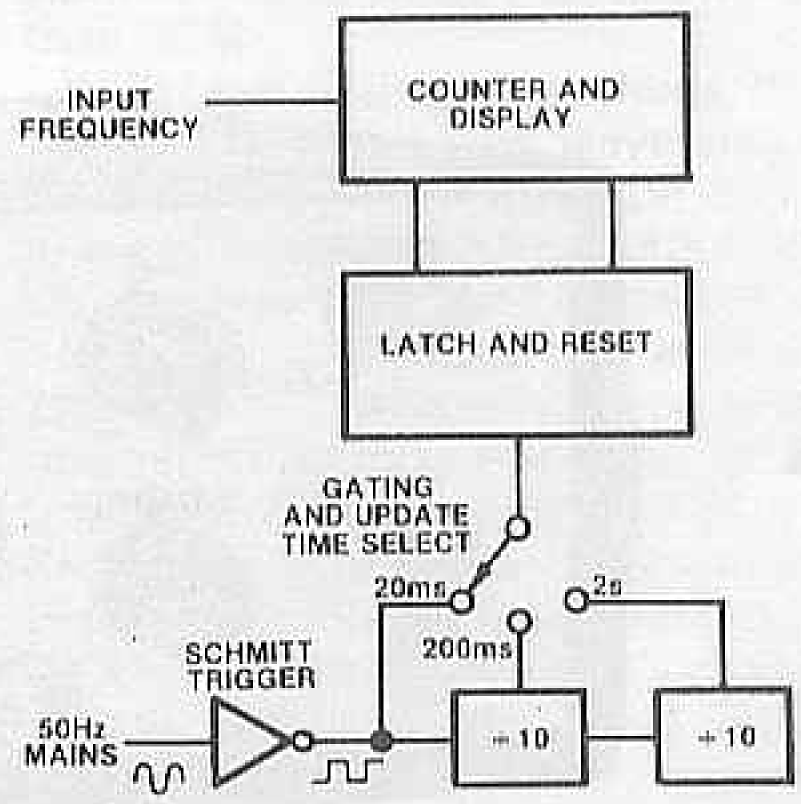


FIG. 2

Frequency Counter

IC2 is the heart of the frequency counter and is a 74C926, made by National Semiconductor. This is loosely described by the makers as a 4-decade counter with multiplexed 7-segment output drivers. As well as the 4-decade counters, it also contains a 4-bit latch for each decade (the four flipflops alluded to earlier), BCD to 7-segment decoder drivers and the multiplexing circuitry to drive the seven segment lines and the four digit driver transistors. It drives common cathode LED displays via BC337's which are used as digit drivers.

For the 50Hz timebase reference signal, a connection is made to the transformer secondary via a 10kΩ resistor. This is clipped by diodes connected to the positive and negative 5V supplies and then fed to the input of

PARTS LIST

RESISTORS

- ☐ 1x............10k (brn-blk-org)
- ☐ 1x............4k7 (yel-ppl-red)
- ☐ 4x............2k2 (red-red-red)
- ☐ 1x............1k8 (brn-gry-red)
- ☐ 2x............1k (brn-blk-red)
- ☐ 1x............560R (grn-blu-brn)
- ☐ 2x............100R (brn-blk-brn)
- ☐ 7x............27R (red-ppl-blk)
- ☐ 2x............22R (red-red-blk)
- ☐ 2x............100k trimpot
- ☐ 1x............22k trimpot
- ☐ 1x............470R trimpot
- ☐ 1x............1M potmeter LIN
- ☐ 1x............5k potmeter LIN
- ☐ 1x............22k potmeter LIN

CAPACITORS

- ☐ 2x............1000uF/16VW Electro
- ☐ 2x............470uF/10VW Electro
- ☐ 2x............10uF/16VW Electro
- ☐ 3x............10uF/10VW Tantalum
- ☐ 3x............1uF/16VW Tantalum
- ☐ 1x............0.12uF Greencap
- ☐ 1x............0.012uF Greencap
- ☐ 1x............0.0012uF Greencap
- ☐ 1x............0.0015uF greencap

SEMICONDUCTORS

- ☐ 1x............XR-2206 IC
- ☐ 1x............74C926 IC
- ☐ 3x............4017 IC
- ☐ 1x............74C14 or 40014 IC
- ☐ 1x............4011 IC
- ☐ 2x............7905 Regulator
- ☐ 1x............7805 Regulator
- ☐ 4x............1N4002 Diodes
- ☐ 2x............1N914 Diodes
- ☐ 1x............BD139 Transistor
- ☐ 1x............BD140 Transistor
- ☐ 4x............BC337 Transistor
- ☐ 4x............FND500/560 LED displays

MISCELLANEOUS

- ☐ 3x............Knobs
- ☐ 1x............Mainslead and plug
- ☐ 1x............2 pol 2 pos slide switch
- ☐ 1x............3 pol 3 pos slide switch
- ☐ 1x............2 pol 3 pos slide switch
- ☐ 1x............BNC socket
- ☐ 1x............Heatsink bracket
- ☐ 1x............Cable clamp
- ☐ 4x............self tap screws
- ☐ 21x............PCB pins
- ☐ 1x............A8 grommet
- ☐ 1½m............Solder
- ☐ ½m............Rainbow cable
- ☐ 1m............Tinned copper wire
- ☐ 1x............Screw ½"×⅛
- ☐ 1x............Screw ⅜"×⅛
- ☐ 1x............Flat washer
- ☐ 2x............Nut ⅛"
- ☐ 2x............Spaghetti
- ☐ 30cm............240V hookup wire
- ☐ 1x............plastic case

IC7d, another Schmitt trigger, to be squared up. This signal is then fed to two 4017 decade dividers in cascade (IC4 and IC5) to produce a 0.5Hz signal (2-second pulses) which gates the 4-digit counter, as described previously.

The timing operation of the circuit is best explained with the waveform diagrams of Fig. 3. Firstly we will assume S2b to be in position 1 for the purposes of explanation. When the waveform at the wiper of S2b is low, the output of IC6c, connected as an inverter, is high and the input frequency from IC7b is allowed to pass to the output of IC6a and to the clock input of IC2. IC2 then counts the number of clock pulses. When the wiper of S2b goes high, the output of IC6c goes low and the clock signal to IC2 is prevented from passing to IC6a and further clocking IC2. IC2 then stops counting the clock signal.

When switch S2b is in position 1, the 50Hz is divided by 100 and this signal is applied to pin 12 of IC6d, a NAND gate. The inverted signal from IC6c is also applied to the reset of IC3.

The clock signal is now able to pass through IC6d and clock IC3. After one clock cycle, the "1" of IC3 goes high and latches IC2. The counted pulses of IC2 are now stored in the latch of IC2. After another two clock pulses, the "3" goes high and IC2 is reset, ready to count the next set of clock pulses. When the "4" output goes high at the next clock cycle, the CE or clock enable is disabled (high) and remains high until reset with pin 10 of IC6c going high.

So the complete cycle of events in counting the clock pulses occurs in this sequence. The cleared counter of IC2 begins to count the clock pulses and is stopped counting when half the timebase period has completed. One clock cycle after this, the counter is latched and the latched count is displayed on the display. The counter is then reset with IC3 and IC3 waits for the end of the timebase cycle when it is reset.

With S2b in position 1, the displayed count is in Hz since the counter counts over the period of 1 second. When S2b is in position 2, the display is in Hz x 10 since the counter counts only over 0.1 seconds. The third position of S2b provides a .015 or 10ms counting time and the display is in Hz x 100. If the signal for this timebase were to be taken directly from the output of IC7d, the display would be updated every 20ms. This would lead to a very fast changing display and make the last digit appear as a flickering 8.

To alleviate the fast update time, the counting period has been kept the same but the number of counting periods has been reduced by 10. This is done with IC6b, which passes the 20ms timebase signal only when pin 10, the "4" output of IC4 goes high or once in every ten 20ms cycles.

Note that S2 selects both the gating time of the frequency meter section and the capacitor of the function generator, IC1.

Power for the circuit is derived from a full-wave centre tapped supply, providing positive and negative supply rails. Filtering is provided with 1000μF capacitors connected from each supply rail to ground.

There are three 5V regulators, one positive and two negative. One −5V regulator supplies IC1 and IC7 while the other supplies IC2 and the associated logic ICs. The reason for this unusual arrangement is to isolate the severe multiplexing noise generated by IC2, from the function generator, IC1. This results in an output waveform free from the noise generated on the other negative supply line.

The 1μF and 10μF capacitors connected at the input and output of each regulator prevent instability in the regulators and provide transient and ripple rejection at the regulated output.

It should be noted that while IC2 is powered from the negative 5V rail, its CK, LE and R inputs are driven from IC6 and IC3 which are powered from ±5V rails. This means that these signals will swing above the Vcc line for IC2 by +5V. However, although IC2 can only be operated from a maximum supply voltage of 6V it can safely handle signal voltages up to 15V without damage.

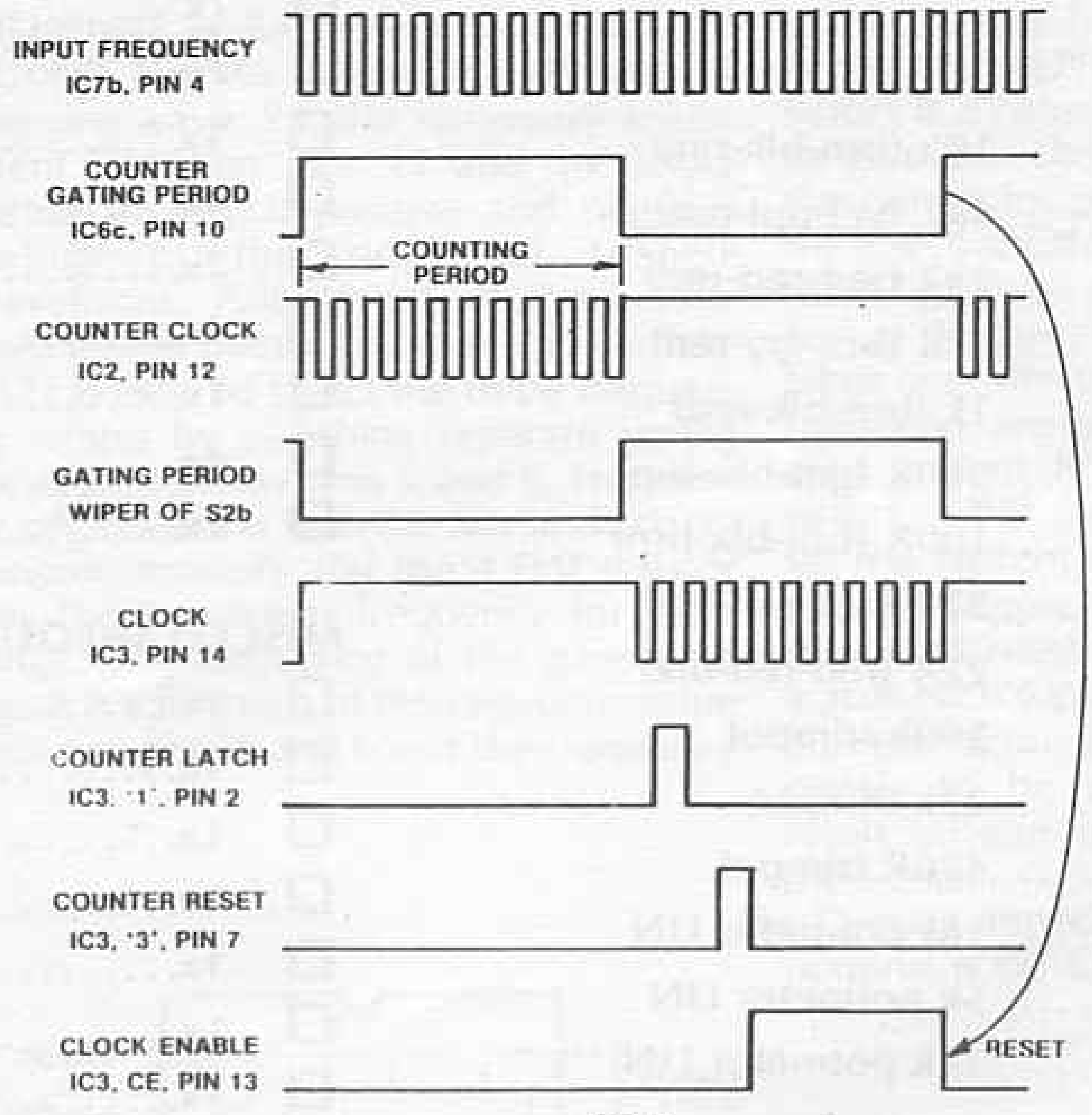


FIG. 3

These timing waveforms illustrate the operation of the inbuilt frequency counter in the Function Generator.

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 7-segment LED displays are mounted on a separate board, that butts up against the main PC board, and is soldered to it via edge connection strips. This display board also carries all switching facilities. Do not mount parts on the display board as yet—it is part of the final assembly.

☐ Firstly check that the copper runs right to the edge of the larger PC board. If not, file the board until the copper is flush to the edge.

☐ Insert and solder all the links required on the main board. Follow the circuit overlay closely to avoid errors. Then position and solder all PCB pins.

☐ Now mount the resistors and capacitors. Remember that electrolytic and tantalum capacitors are polarised, so care must be taken.

Then insert the trimpots; position these to allow easy access later on when trimming.

☐ All transistors can be mounted now, as well as the three regulators. Note the orientation of these components, then solder.

☐ Next position the four 1N4002 and the two 1N914 diodes. Make sure these are mounted correctly. Solder and trim the excess leads off close to the board.

☐ Now insert the ICs. Follow the PCB overlay closely; pay particular attention to orienting the ICs correctly. When soldering CMOS-ICs, solder the supply rails first and be careful not to apply excessive heat.

☐ Lastly mount the power transformer on the PC board, then solder.

☐ 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.

☐ Install all links on the display board. The topmost link is best mounted on the back of the board (copper side), and a piece of insulated wire should be used.

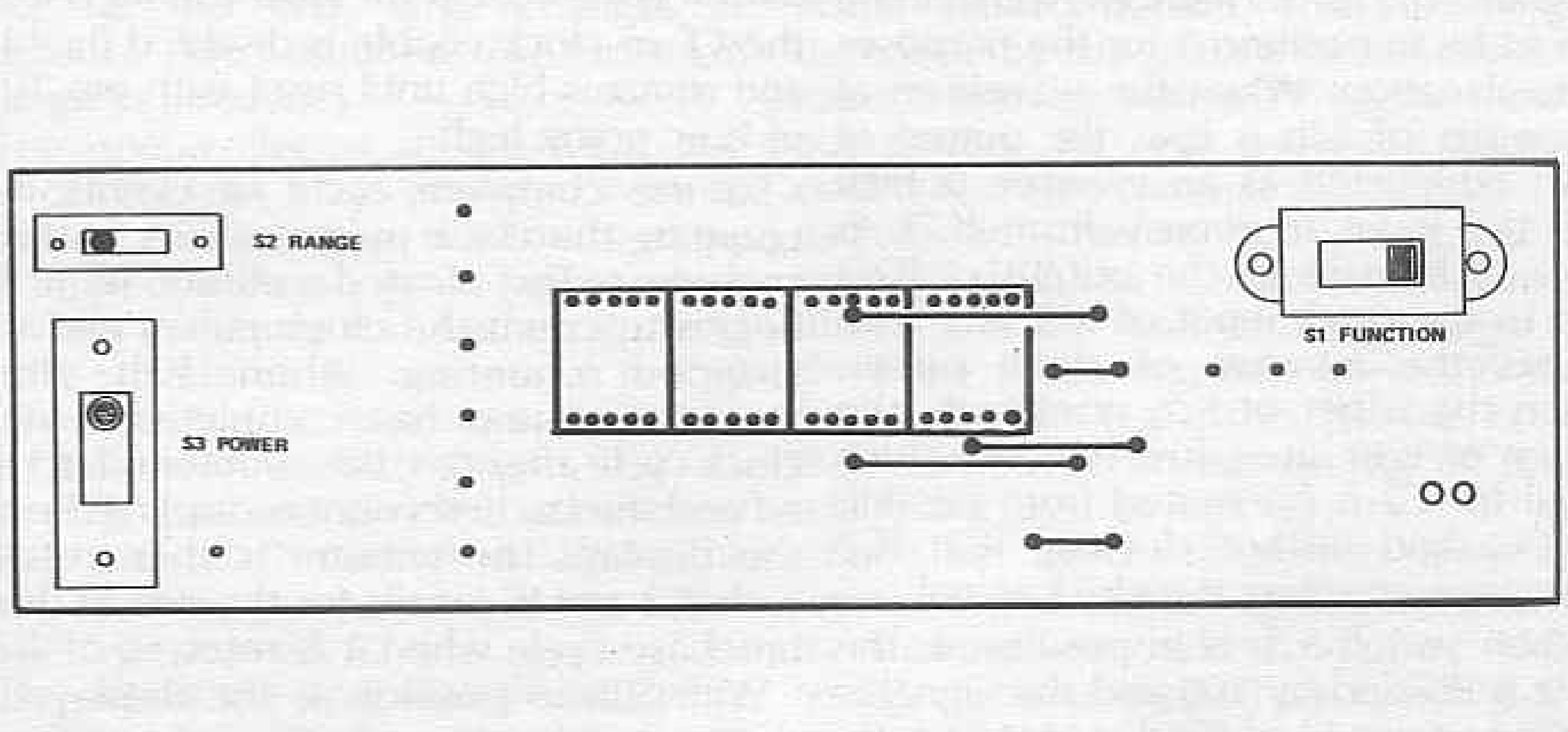
☐ Now push the switches into the appropriate positions on the display board, but DO NOT solder yet.

☐ 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 necessary to file a small amount off each of the four corners to achieve a perfect fit.

☐ 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.

☐ Now place the main PCB on its mounts, so that it butts up against the display board. It may be necessary to lift the main PCB up a little by means of one or two nylon washers on each mounting stud (to clear the solders joints). With a pencil, draw a fine line on the display PCB where the two boards meet.

☐ Take the boards out of the case again and line them up using the pencil mark as a guide, then 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.



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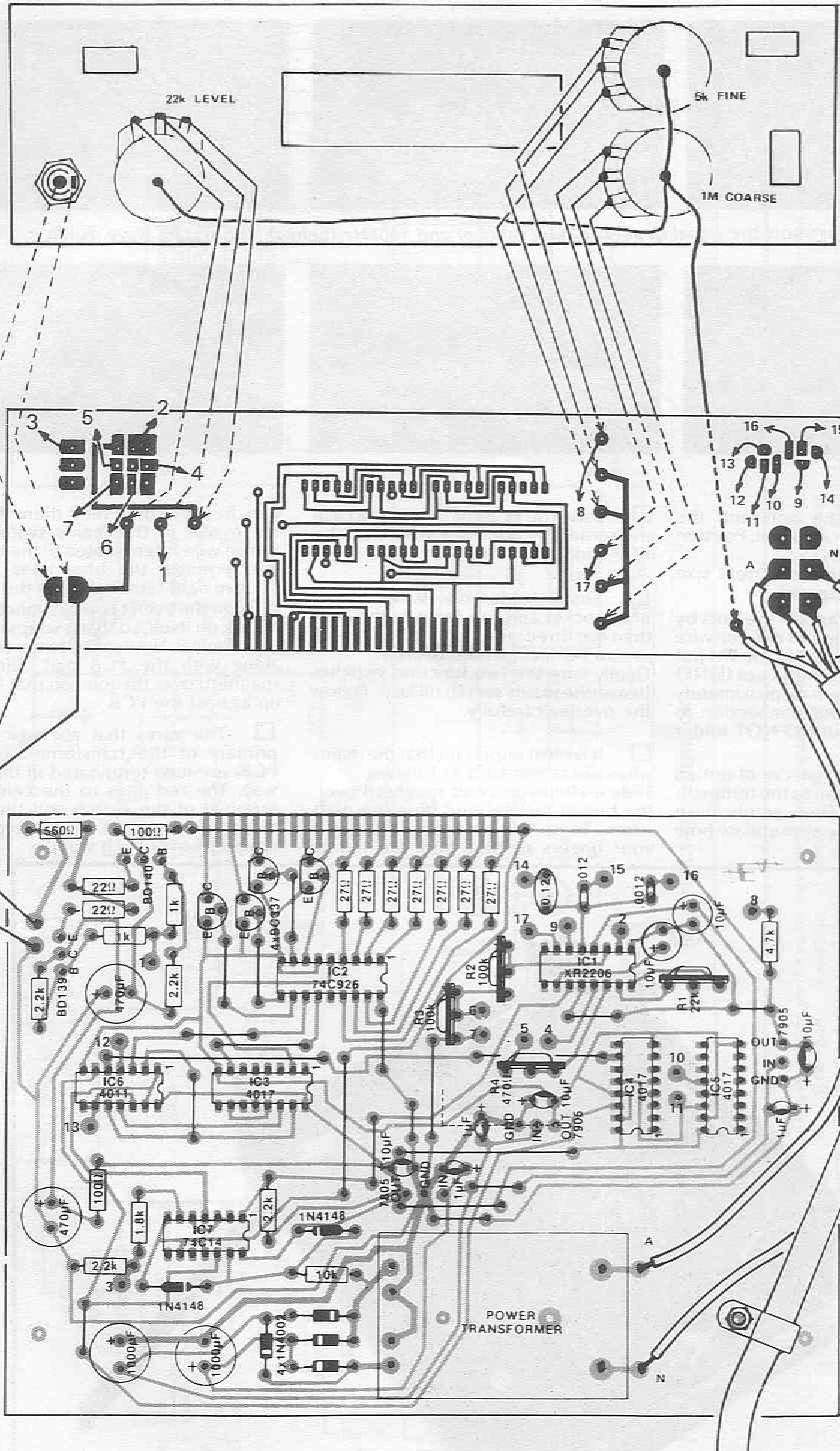
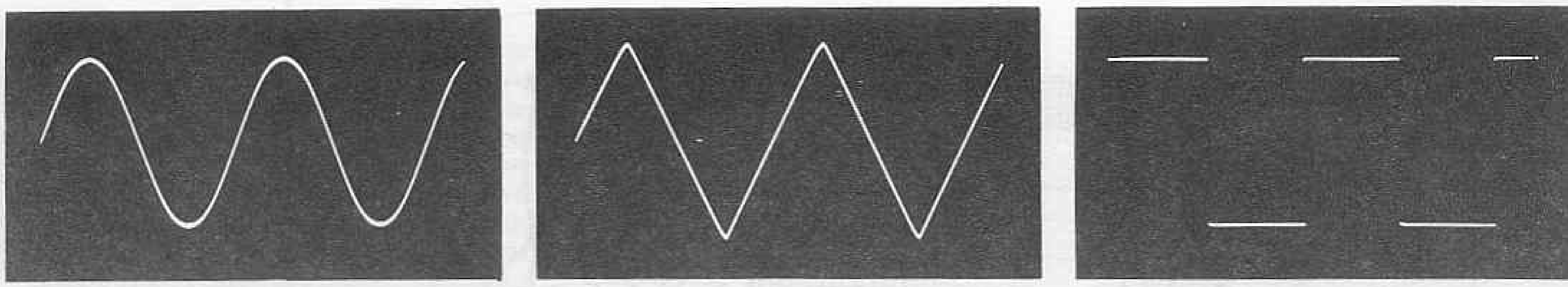
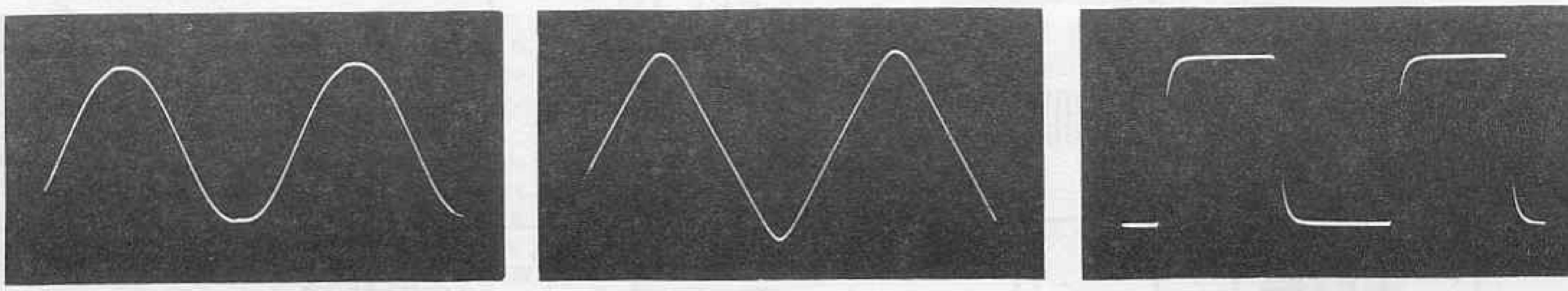


PCB overlay reproduced in part by kind permission of Electronics Australia. Please note that the heatsink bracket should be mounted on 7905 regulator (as shown by dotted lines).



These oscillograms show the signal quality at 1kHz (above) and 100kHz (below). The square wave risetime is 0.4us.



☐ Next mount the pots and the BNC socket on the front panel. Position exactly as per overlay.
Also cut the perspex to correct size and glue to the frontpanel.

☐ Connect the cases of the pots by running a length of tinned copper-wire from the 22k pot (LEVEL) to the 1M pot (COARSE), then from the 5k pot (FINE) to the 1M pot. Leave approximately 30mm of this wire for connection to the display board, but DO NOT solder as yet.

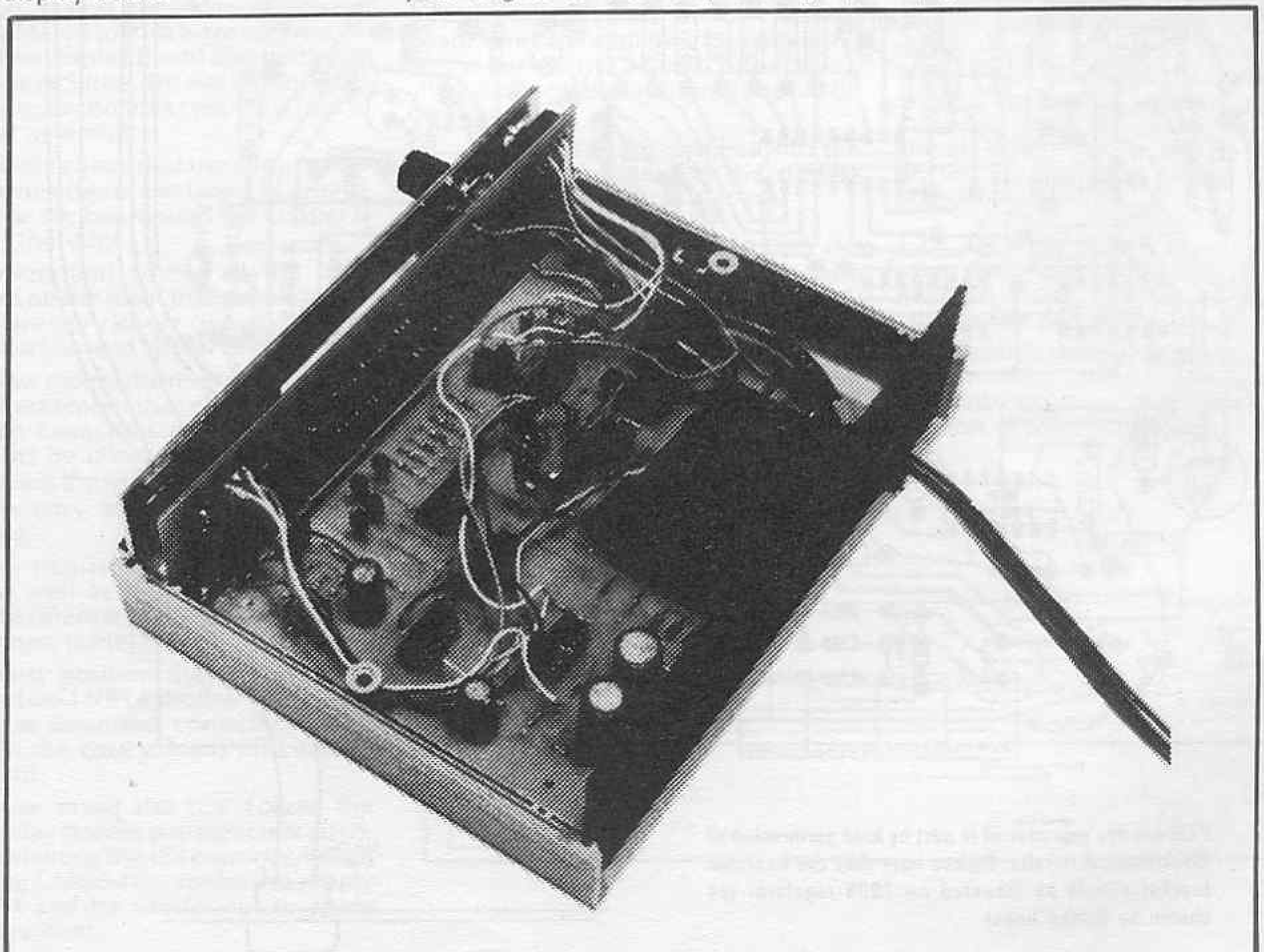
☐ Cut off nine (9) pieces of tinned copper-wire and solder to the terminals of the three pots. Then gently push each wire through the appropriate hole in the display board.

☐ Slide the PCBs back into the case and solder the pot wires, then start the inter-wiring.

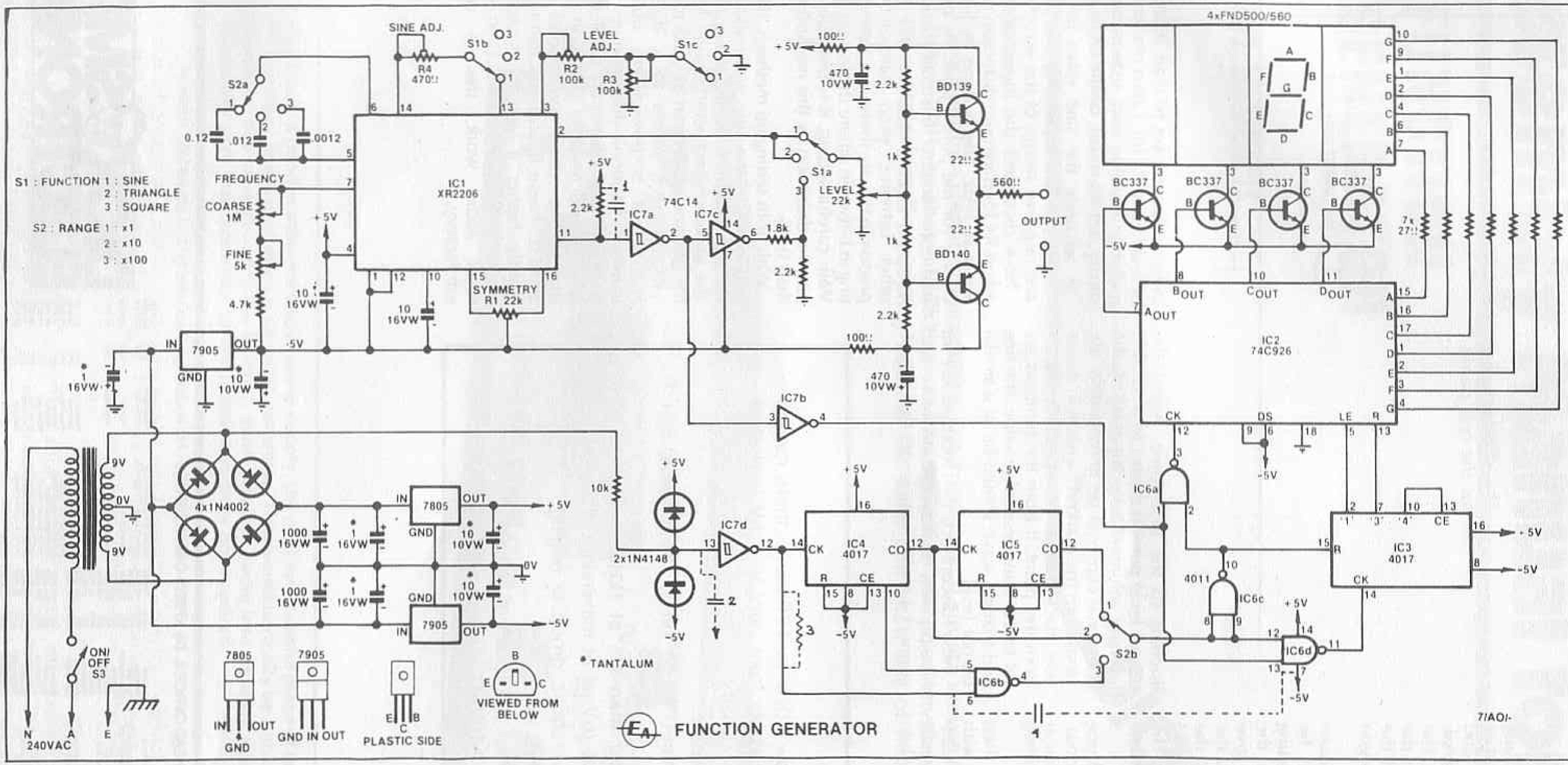
☐ Firstly solder two wires to the BNC socket and run them to the PCB, then run three wires (one for each pot), as can be seen on the overlay.
Finally wire the two function switches (leave the mains switch till last). Follow the overlay carefully.

☐ 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 left terminal, the blue goes to the bottom right 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 termina along with the PCB pad. Slide the spaghetti over the joint so that it butts up against the PCB.

☐ The wires that go back to the primary of the transformer (on the PCB) are now terminated in the same way. The red goes to the centre lef terminal of the switch and the black to the centre right. Don't forget the spaghetti over each wire!



Internal view of the Function Generator mounted in the case. Note the position of the display board.



In some cases, due to low level hash on the audio wave form, the frequency meter may indicate double the correct value. This can be cured by:
1. soldering a 0.0015uF capacitor across the 2k2 resistor connected to pin 11 of IC1.
Also, 2. to prevent spikes from reaching the Schmitt-trigger IC7d, it is desirable to place a 0.1uF capacitor from pin 13 of IC7d to the −5V rail.
Constructors experiencing problems with a flickering display on the x100 range may cure this problem by
3. creating a short delay in the 50Hz clock input to IC6b. This involves breaking the track between IC7d pin 12 and IC6b pin 6 and placing a 100R resistor in series between these two points.
4. A 1000pF capacitor is connected from pin 6 of IC6b to the negative rail of IC6b (pin 7).

Setting up

Setting up the Function Generator can be achieved in one of two ways: by using an oscilloscope (if available), or by using a loudspeaker or headphones. For either method, the symmetry trimpot, R1, and the sine adjust trimpot, R4, should initially be adjusted for a midway setting. The level adjust trimpot should be set to the minimum resistance setting (toward the rear of the case) and setting up begun with these settings.

When using an oscilloscope, the maximum level of the sine wave can be determined before clipping by adjusting either R2 or R3. Then switch to the triangle waveform and adjust R2 to give a triangle wave level the same as the previous sine wave setting. Return to the sine wave and adjust the level with R3 only to a level just before clipping. The triangle wave and sine wave levels should now be the same.

R4 can be adjusted for best visual sine wave output and the symmetry trimpot, R1, adjusted for a symmetrical waveform. The distortion trimming should be done at 1kHz.

If no oscilloscope is available, then satisfactory results can be achieved with either a loudspeaker or with headphones. Connect to the output terminals and increase R2 and R3 together when listening to the sine wave. Adjust the output level potentiometer to a suitable listening volume. The point at which the sine wave clips will be immediately obvious from the marked increase in distortion. Back the two trimpots off slightly from this point. If both the trimpots are set to the same resistance value, the sine and triangle wave should be of a similar output level.

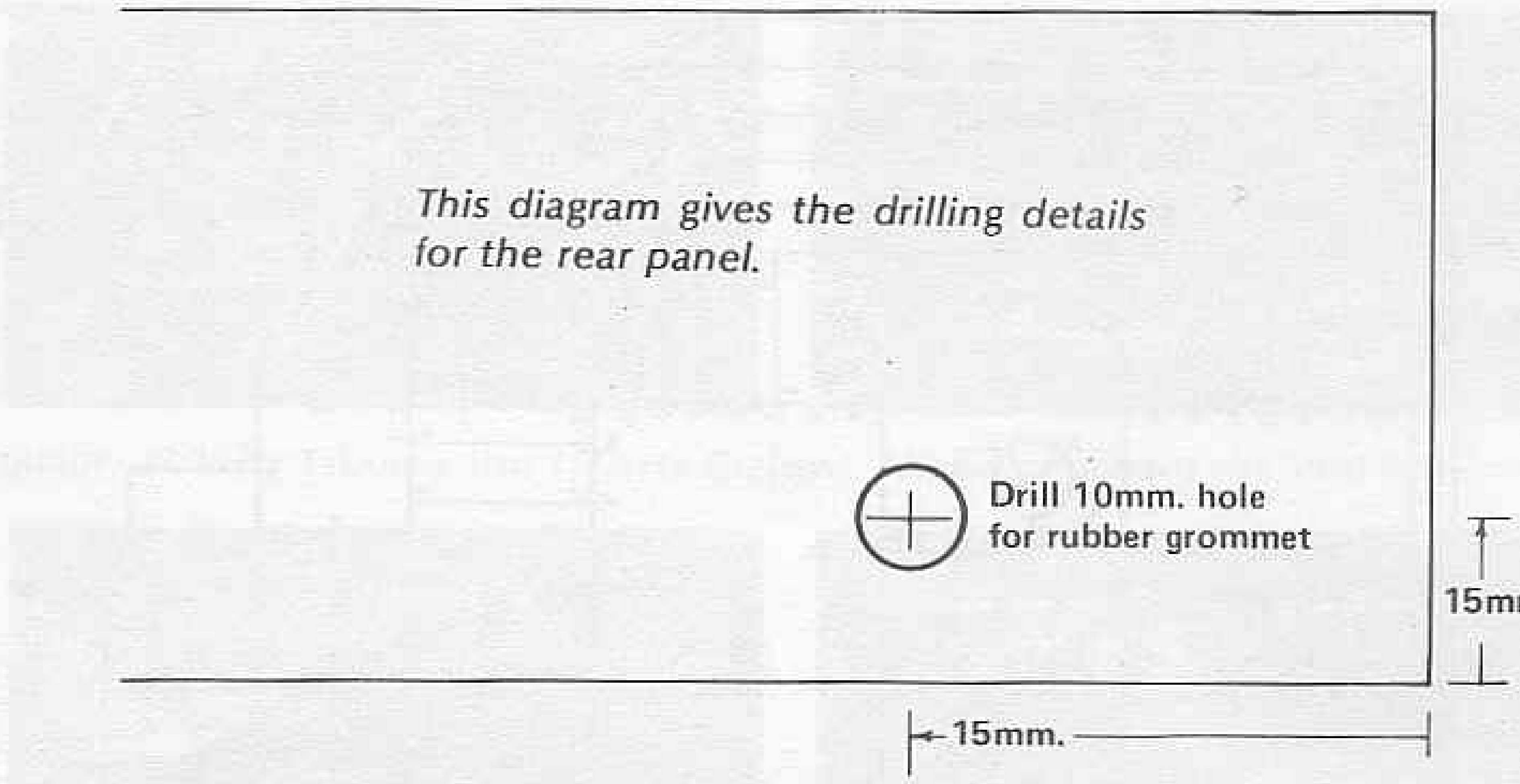
Now disconnect the loudspeaker or headphones, switch to sine wave and connect a multimeter across the output. With multimeter set to read 200mV DC or less, adjust R1 for a zero reading. If no meter is available with reasonable sensitivity, set R1 to the centre of its range.

In adjusting the sine wave for symmetry, you are equalising the positive and negative swings of the waveform.

Now reconnect the loudspeaker and adjust R4 for minimum distortion on sine wave at 1kHz. This is done by listening closely for the purest tone. At one extreme (minimum resistance) odd harmonics will predominate while at the other extreme, even harmonics will predominate, so there is a definite setting in between where the tone is purest. With careful setting, it is possible to adjust the distortion by this method to less than 0.7%.

With both setting up methods, the clipping point of the sine wave should be readjusted after trimming the distortion. The maximum expected output level of the sine wave is around 6V peak to peak.

If you have access to a distortion analyser, it is possible to obtain a minimum harmonic distortion of around 0.5% by critical adjustment of R1, R3 and R4. This will result in distortion of less than 1% at 10kHz and around 2% at 100kHz. These figures will naturally be slightly higher if you have used the methods described above. Even so, for most audio work, this is entirely satisfactory.



This diagram gives the drilling details for the rear panel.

SPECIFICATION

Frequency range: From below 20Hz to 170kHz in three ranges.

Output level: Continuously variable from 3mV to 2.5V peak-peak.

Output impedance: 600Ω (nominal).

Waveforms: Sine, Triangle, Square.

Sine wave distortion: Less than 0.7% at 1kHz; 1% at 10kHz and 2% at 100kHz.

Triangle wave linearity: Better than 1% at 1kHz.

Square wave rise-time: 0.4us (6V/us at maximum output level).

Overshoot, etc: Negligible overshoot, droop or ringing.

Readout accuracy: ±2% + one digit.

Amplitude stability: Better than 0.1dB on all ranges.

Power consumption: 7W at 240VAC.

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