TG501

Function Generator

Service Manual

Book Part Number 48591-0130 - Issue 5

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General

Service Handling Precautions

Service work should only be carried out by skilled engineers. Please note that the tracks on the printed circuit board are very fine and may lift if subjected to excessive heat. Use only a miniature temperature controlled soldering iron and remove all solder with solder wick or suction before attempting to remove a component.

Dismantling the Instrument

WARNING!

Opening the instrument is likely to expose live parts. The instrument shall be disconnected from all voltage sources before any adjustment, replacement or maintenance and repair during which it shall be opened. If afterwards any adjustment, maintenance or repair of the opened instrument under voltage is inevitable, it shall be carried out only by a skilled person who is aware of the hazards involved.

1. Remove the 8 side screws and lift off the case upper and lower.
2. Access to all components is now possible, further dismantling is not necessary.
3. All small knobs are push on types. To remove the dial, remove the cap in the centre of the knob using a knife blade, then loosen the nut about 1 turn. The knob and dial can then be pulled off.
4. Transistors Q32, Q34 and Q39 and IC22 are insulated from the rear panel.
5. Reassemble in reverse order.

Operating Voltage

See the Power Supply section for details of changing the operating voltage from 220/240 to 110/120 and vice-versa.

Specification

(All specifications apply after warm-up in an ambient temperature range 18°C-28°C.)

OPERATING RANGE

Frequency Range: .005Hz to 5MHz in 7 overlapping decade ranges with fine adjustmentby calibrated vernier.

Internal Mode

Vernier Range: 1000:1 within each range.

Vernier Accuracy: Better than ±5% of full scale.

External (Sweep) Mode:

Sweep Range: 1000:1 within each range.

FUNCTIONS

(Specifications apply for vernier between 0.5 and 5.0 and output 10V peak-to-peak into 50Ohm termination).

Sine

Distortion: Less than 0.5% to 50kHz, less than 1% to 500kHz; all harmonics >30dB below fundamental on 1M range.

Amplitude Flatness: ± 0.2dB to 500kHz; ±1dB to 5MHz.

Triangle

Linearity: Better than 99% to 500kHz.

Squarewave

Rise and Fall Times: <45ns.

Mark: Space Ratio: 1:1 ±1% to 100kHz; ± 5% to 5MHz

DC

Range: ±10V from 50 Ohm.

OPERATING MODES

Run

Generator runs continuously at the selected frequency.

Triggered

Generator is quiescent until triggered by an external input at TRIG IN or by pressing MANUAL. One complete cycle is then generated at the selected frequency, starting and stopping at the phase set by the START/STOP PHASE control.

Gated

Generator is quiescent until gated by an external signal at TRIG IN or by pressing MANUAL. Generator then runs continuously at the selected frequency for duration of gate signal, starting and stopping at the phase set by the START/STOP PHASE control. Last waveform started is completed.

Manual

Manually operates generator as described in Triggered and Gated sections.

Start/Stop Phase

The START/STOP PHASE control varies the triggered and gated signal start/ stop point from approximately -90° to +90° up to 500kHz.

Symmetry

When SYM is selected the SYMMETRY control varies the duty cycle from 1:19 to 19:1 to produce sawtooth and variable pulse-width waveforms. The indicated frequency is divided by 10 with SYM selected.

INPUTS

Sweep Input

Input Impedance:	10kOhm
Input Sensitivity:	0 to 4V for 1000:1 sweep
Maximum Allowable Input Voltage:	±10V
Sweep Linearity:	Better than 1%
Maximum Slew Rate of Input Voltage:	0.1V/us

Trigger Input:

Frequency Range:	DC - 5MHz.
Signal Range:	TTL compatible levels; maximum input 20V.
Minimum Pulse Width:	50ns.
Input Impedance:	Typically 2kOhm.

OUTPUTS

50 Ohm

Amplitude Control:	>20dB vernier control within each attenuator range. Maximum output 20V peak-to-peak from 50Ohm (10V into 50Ohm).
Attenuator:	Additional switch-selectable attenu- ation of 0, -20 or -40dB. Minimum output <20mV peak-to-peak from 50Ohm (<10mV into 50Ohm).
DC Offset Control Range:	±10V from 50Ohm. DC offset plus signal peak limited to ±10V (±5V into 50Ohm). DC offset plus waveform attenuated proportionally in -20dB and -40dB positions.

TTL

Amplitude:	Fixed TTL level output at frequency and symmetry of main output. Capable of driving 20 TTL loads.

GENERAL

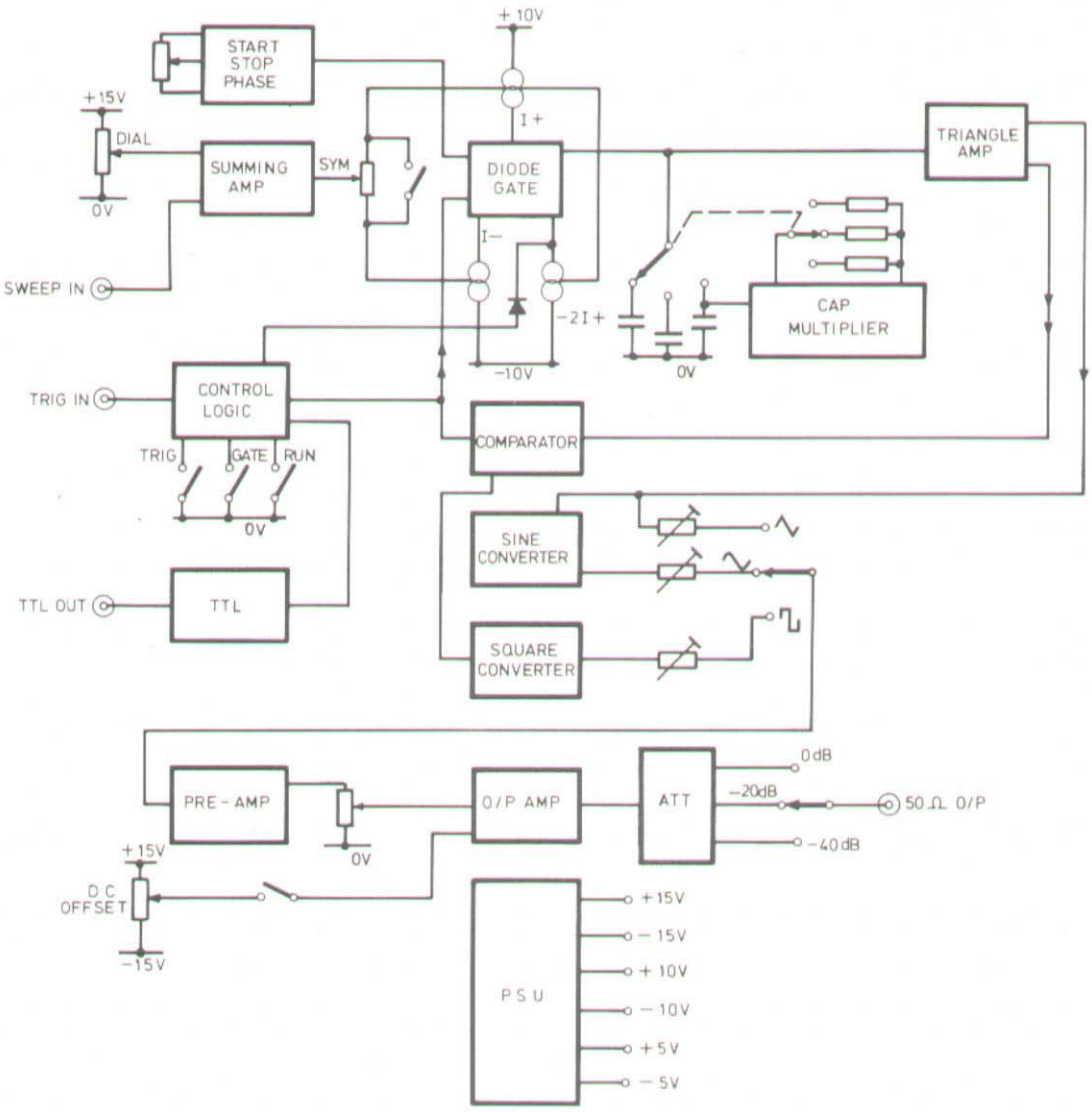
Power Requirements

Input Voltage:	110/120V AC nominal 50/60Hz or 220/240V AC nominal 50/60Hz, adjustable internally. The TG501 will operate safely and meet specification within normal AC supply variations viz. 100-130V AC and 200-260V AC respectively.
Power Consumption:	30VA Max.

Environmental Operating

Range:	+5^{o}C to +40^{o}C, 20% to 80% RH.
Storage Temperature Range:	-40^{o}C to +70^{o}C.
Size:	300mm wide x 100mm high x 230mm deep
Weight:	3.4kg

Functional Description



The relationships between the major circuit elements are shown in the block diagram opposite.

The summing amplifier sums the voltages from the dial and from the sweep input, and its output controls the magnitude of the complementary current source and current sink. This current varies from approximately 5.2uA to 5.2mA for a 1000:1 frequency change (.005-5.0).

The symmetry control adjusts the ratio between current source and current sink.

The diode gate steers current into or out of the range multiplier capacitor and is controlled by the comparator output. When the comparator output is high the charge on the capacitor will rise, linearly, producing the positive going triangle slope. When the comparator output is low the charge on the capacitor will fall linearly producing the negative going triangle slope. The triangle amplifier has unity gain and buffers the triangle wave on the multiplier capacitor to drive the comparator and output circuits.

The comparator operates as a window detector with fixed limit points set to the triangle peaks. One of its two outputs drives the TTL circuit and is also level shifted to drive the diode gate. The other output drives the squarewave shaper. When the comparator output to the diode gate is high, the triangle wave is positive going until this reaches approximately +1.2V, the comparator output then switches low. When the comparator output is low the triangle wave is negative going until this reaches approximately -1.2V, when the comparator output goes high, and the cycle is repeated.

This is the basic function generator loop in the Run mode and is shown by the double arrows in the block diagram. Triangle and squarewave are generated simultaneously as shown.

The control logic determines Trig, Gate or Run modes. In Trig or Gate modes the waveform is clamped by the -2I+ current sources and the diode gate, at a point determined by the Start/Stop Phase control. A signal applied to Trig In releases the clamp and a single cycle is produced in the Trig mode or a burst in the Gate mode, the waveform is then clamped again.

To achieve the 1, 10 and 100 ranges the 1k range capacitor is multiplied by 1000, 100 or 10 by the capacitor multiplier circuit.

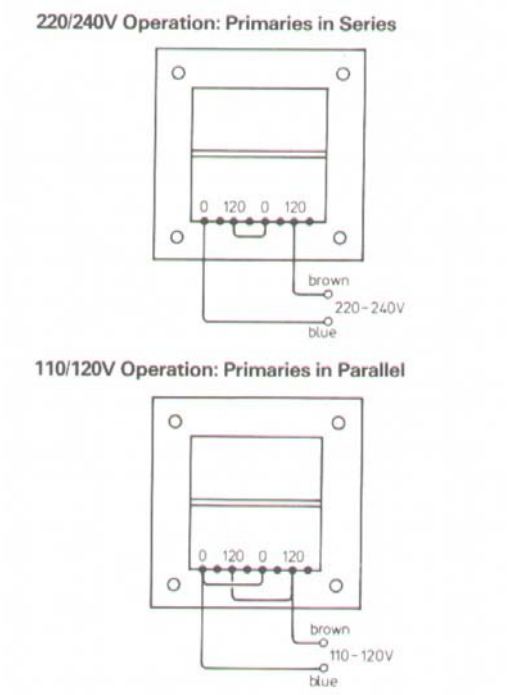
The TTL circuit buffers one of the comparator outputs to drive the TTL output socket.

The squarewave shaper converts the comparator output to a current signal and applies it to the squarewave function switch. The sinewave converter uses the non-linear characteristics of a transistor pair to convert the triangle wave into a sinewave, which is applied to the sinewave function switch. The selected function is sent to the pre-amplifier where it is inverted and buffered and applied to the output amplitude control. The signal is summed with the voltage from the DC offset control at the output amplifier. This amplifier inverts and amplifies the signal up to 20V peak to peak to drive the 50 Ohm output socket.

The power supply converts the incoming AC line voltage to the DC rails required by the instrument.

Power Supply - Mains connections

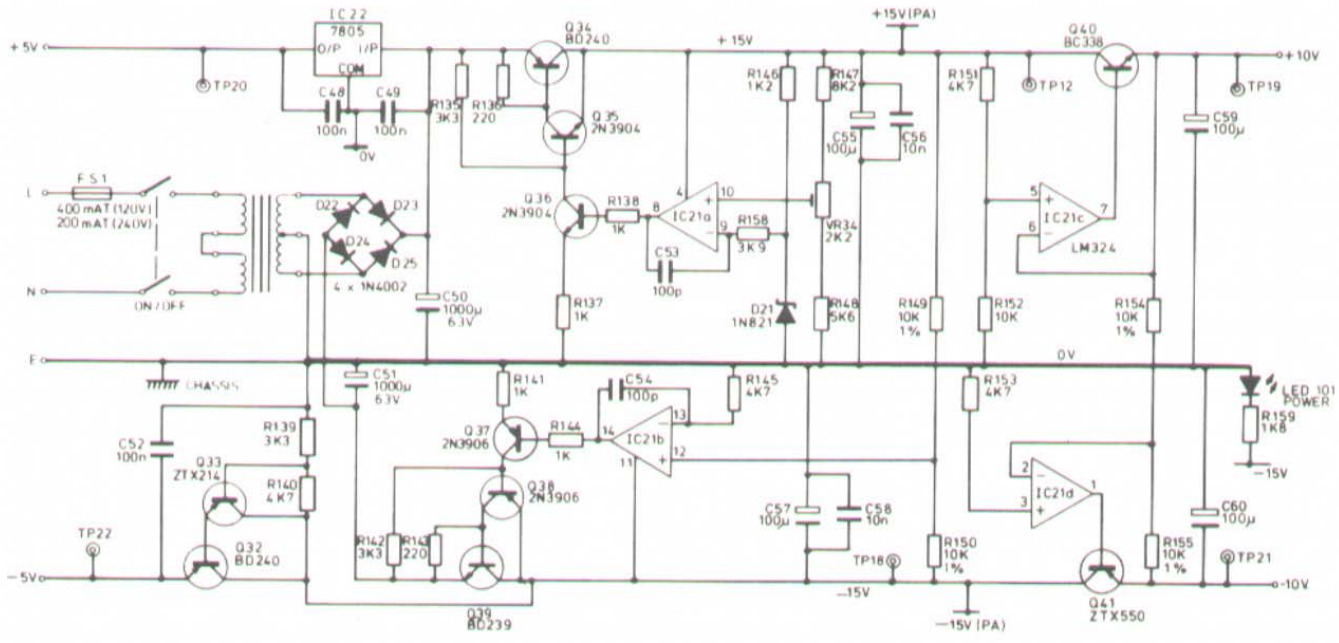
The operating voltage of the instrument is shown on the rear panel label. Should be it necessary to change the operating range from 220/240V AC to 110/120V or vice-versa, change the transformer connections following the appropriate diagram below.



If a change is made, the operating voltage label and fuse should also be changed.

For 220/240V operation use 200mA 250V time-lag

For 110/120V operation use 400mA 250V time-lag



WARNING! THIS INSTRUMENT MUST BE EARTHED

Any interruption of the protective conductor inside or outside the instrument or disconnection of the protective earth terminal is likely to make the instrument dangerous. Intentional interruption is prohibited.

Power Supply - DC Regulation

Diodes D22 to D25 rectify the transformer output and C50 and C51 are the reservoir capacitors of the unregulated DC rails.

Q34, Q35, Q36 and IC21a form the +15V regulator, Q34 and Q35 form the compound series pass element and Q36 its driver. IC21a is the error amplifier and a temperature compensated zener D21 provides the reference (6V2). The +15V output is set by VR34.

The -15V regulator is made up of Q37, Q38, Q39 and IC21b and complements the +15V regulator. The -15V tracks the +15V by sensing the voltage at the junction of R149, R150 at the input of IC21b.

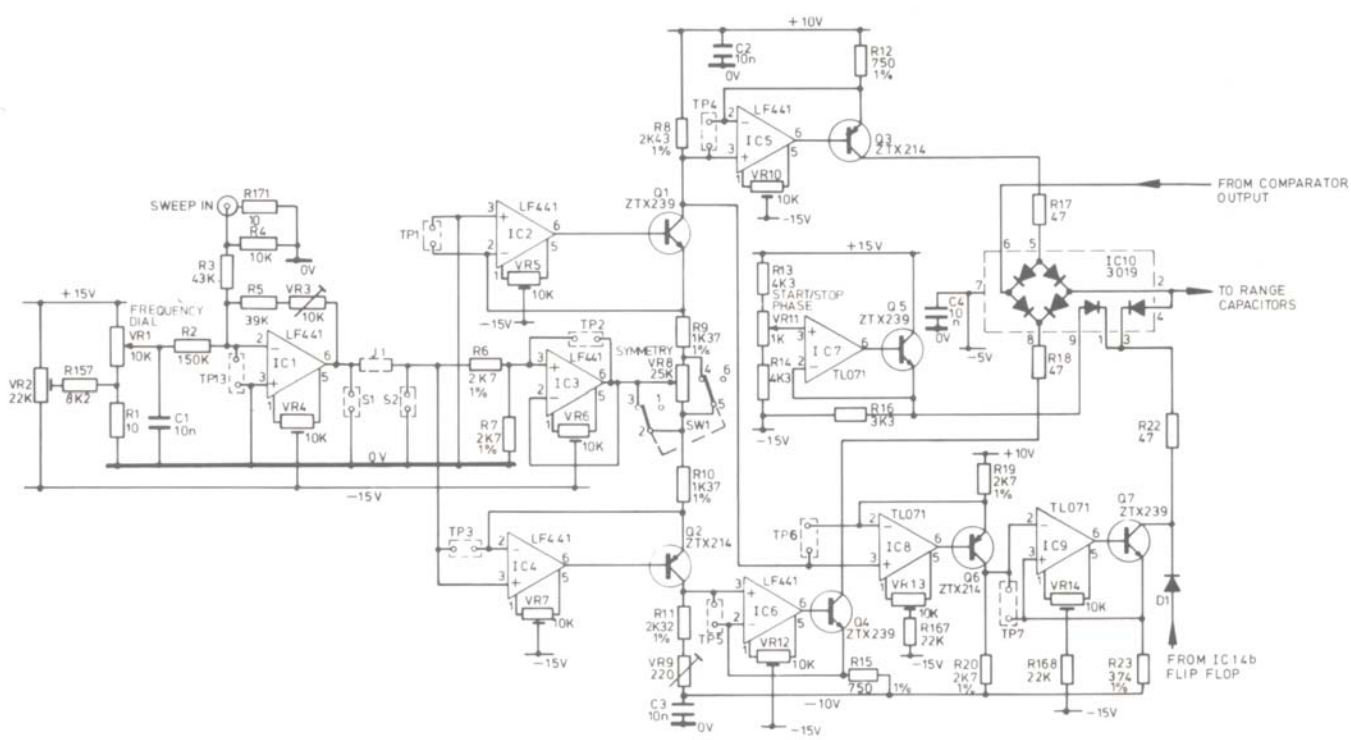
The +10V rail is derived by dividing down the +15V rail; R151 and R152 provide the reference from the +15V for the regulator IC21c and Q40.

The -10V regulator is formed by Q41 and IC21d and is the complement of the +10V regulator. The -10V tracks the +10V by sensing the voltage at the junction of R154,R155 at the input of IC21d.

The +5V rail uses a standard 3 terminal regulator IC22.

The -5V rail is divided down from the -15V by R139, R140 and buffered by a darlington emitter follower Q32 and Q33.

Waveform Generation - Summing Amplifier and Current Sources



The dial and sweep voltages are summed by IC1, the gain of which is set by VR3. VR3 is, in fact, used to calibrate the high end of the dial. The output range of the amplifier is approximately -4mV (with the dial at .005) to -4V (with the dial at 5.0). This voltage is used to drive the complementary current source and current sink as follows.

The emitter of Q1 is held at pseudo ground by IC2. If the dial is at 5.0, the -4V at the output of IC1 is forced at the emitter of Q2 by IC4. This -4V is also halved by R6, R7 and IC3 forces this voltage (-2V) at the junction of R9, R10. A voltage dependant current is therefore set up through R8, R9, R10 and R11.

IC5 is a current source controlled by the voltage on the collector of Q1 and IC6 is a current sink controlled by the voltage on the collector of Q2. These two currents are steered into and out of the range capacitor by the diode gate IC10, under the control of the comparator output.

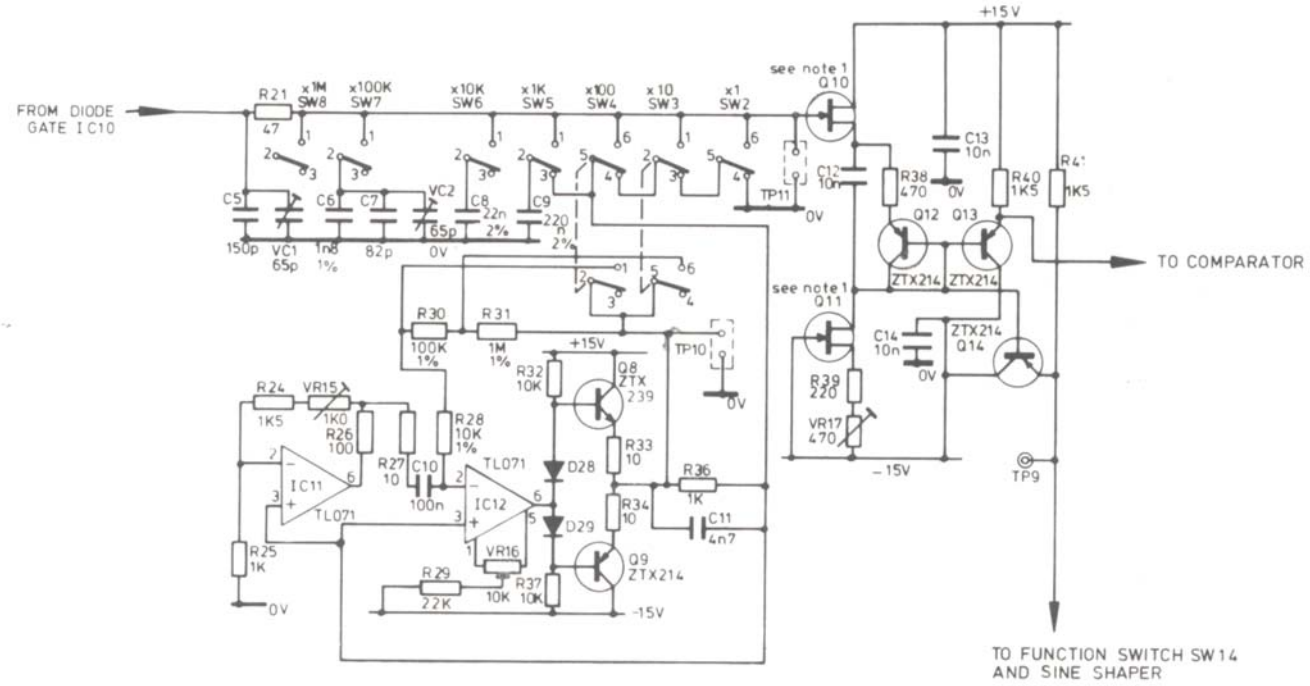
When the symmetry button is depressed the short across VR8 is removed and the total resistance between Q1 and Q2 emitters is increased from R to 10R. This lowers the current through this resistor chain by a factor of 10 and so the frequency is divided by 10. Rotating VR8 imbalances the current through Q1 and Q2 to give a duty cycle of up to 1:19 or 19:1.

With the symmetry button out, the waveform symmetry is set by VR9 at the top of dial (5.0). At the bottom of the dail, symmetry is determined by offsets on ICs 1-6 (refer to calibration procedure).

Current source IC8 tracks the I+ current source IC5 and IC9 mirrors this to become -2I+. The -2I+ current is used to clamp the waveform in the Trig and Gate modes. The ramp can only stop in the upward direction. When the Q output

of IC14b is set low, D1 is off. If the voltage at Q5 emitter is 0V (= to 0^{o}), the voltage on the range capacitor will ramp up and stop at 0V. When clamped the I+ current from the diode bridge flows through the diode between pins 4 and 3 into the -2I+ current sink. A current equivalent to I+ also flows through the diode between pins 9 and 1 into the -2I+ current sink to total 2I+. IC7 and Q5 buffer the voltage on the Start/Stop Phase control VR11 to give a low impedance voltage source on pin 9 of IC10. This voltage can be varied between approximately +/-1.2V by VR11 corresponding to the triangle peaks, giving +/-90^{o} of phase control. To release the clamp the Q output of IC14b is set high which pulls the -2I+ current sink high via D1, reverse biasing the two clamp diodes.

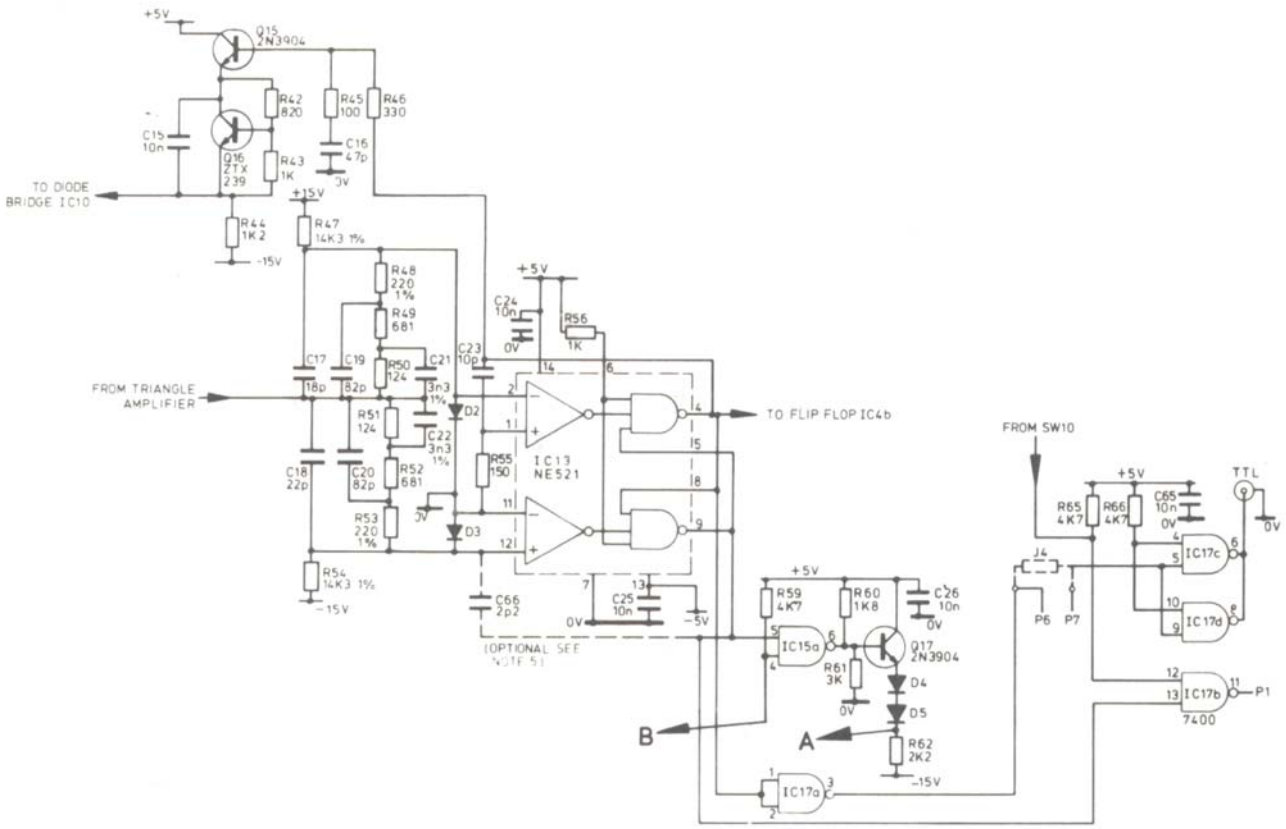
Waveform Generation - range selection and triangle amplifier



Range selection is by seven push-button switches, which steer the current sources into the appropriate multiplier capacitor. The lower four ranges use the same range capacitor C9; the lower three ranges use a capacitance multiplier. The capacitance multiplier steals current from the range capacitor via R36. The amount of current taken is determined by the gain setting resistors R28, R30 or R31 for the x100, x10 and x1 ranges respectively. The triangle wave on C9 is connected to the non-inverting inputs of IC11 and IC12. The triangle wave is amplified by IC11 which has a gain of 3; this is trimmed by VR15 to set the overall gain of the capacitance multiplier. Q8 and Q9 buffer the output of IC12.

The triangle buffer consists of a FET source follower Q10 with temperature compensation provided by current source Q11, which is I_{DSS} matched with Q10. Q13 and Q14 are emitter followers to provide 2 low impedance outputs. Q12 is strapped as a diode and compensates for the V_{BE}s of Q13 and Q14. VR17 trims the DC offset in this stage.

Waveform Generation - Comparator and TTL output

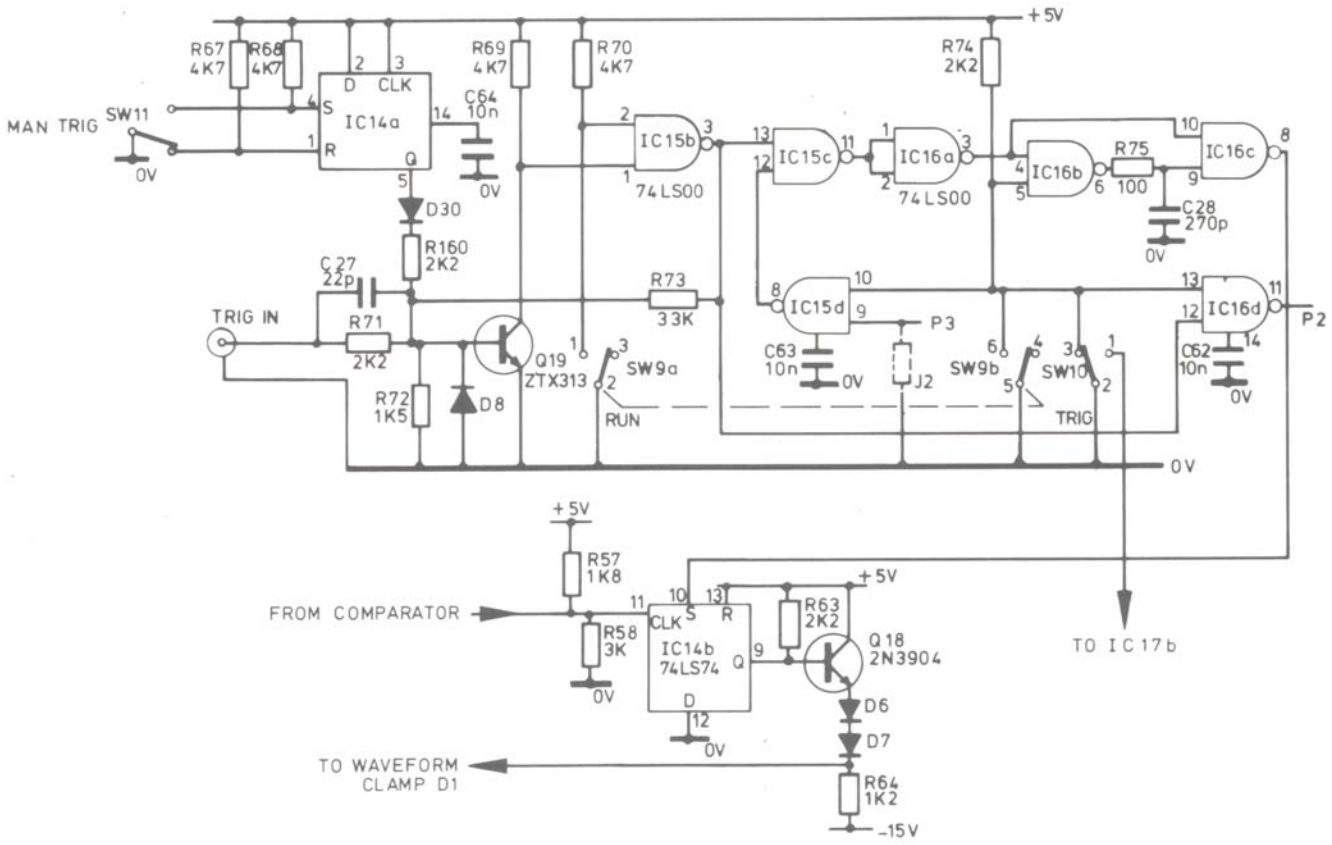


IC13 operates as a window detector and determines the peak to peak amplitude of the triangle wave on the range multiplier capacitor, which is approximately +/-1.2V. C17-C22 compensate for comparator and loop delays ensuring that the triangle wave amplitude remains constant with increase in frequency. The two internal NAND gates in IC13 are wired as a flip-flop to ensure positive switching of the comparator. C23 provides a small amount of positive feedback to ensure jitter free operation. Some comparators oscillate with the dial at 0.005; this can be prevented by fitting C66.

One of the comparator outputs is routed via IC17a to parallel gates IC17 c and d which drive the TTL output. Q15 level shifts IC13 output to be about ground to drive the diode gates. Q16 is a V_{BE} multiplier and its total voltage is just under two V_{BE}s. R45, R46 and C16 improve triangle linearity at 5MHz.

IC15a and level shifter Q17 are used to drive the squarewave shaper circuit. When the squarewave button is out, pin 4 of IC15a is held low and so the squarewave is gated off at the source.

Waveform Generation - Trigger Circuit



In the Trig or Gate modes the waveform is clamped at the Start/Stop Phase point under control of IC14b (described earlier).

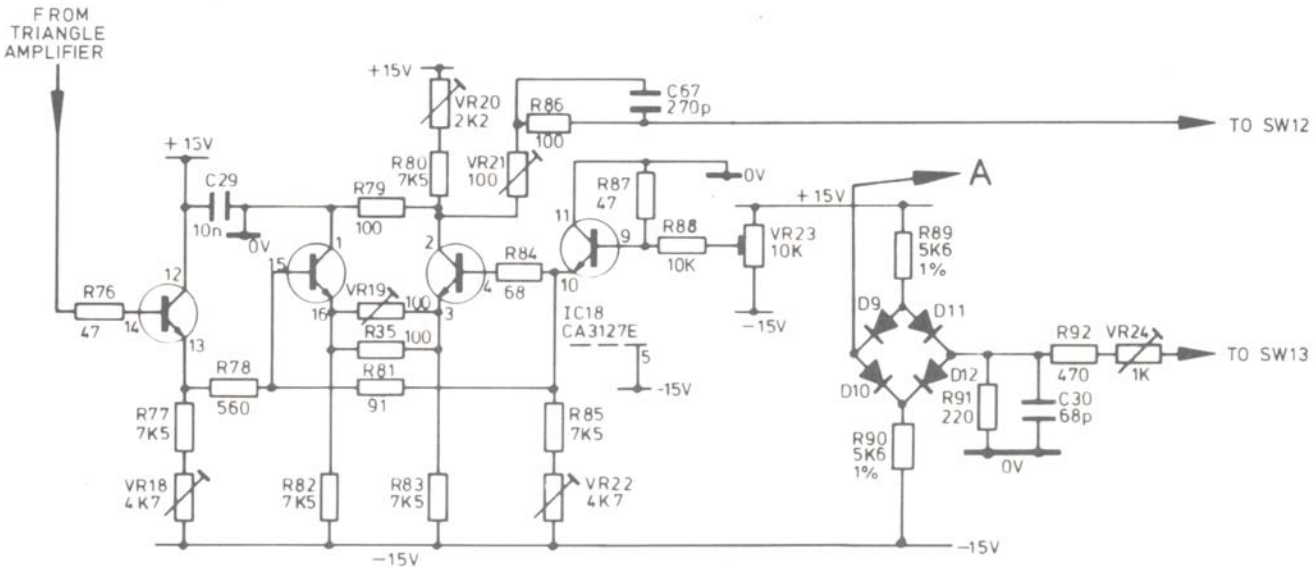
Q19 and IC15b form a Schmitt trigger which ensures correct operation from DC to 5MHz. R71 and R72 with C27 fix the input threshold at <1.5V over the whole frequency range.

In the trigger mode the output of IC15b is routed through IC15c and IC16a to the monostable formed by IC16b and c. For every high going transition at the trigger input or depression of the manual button a 50 nanosecond pulse at IC16c output is generated. This pulse goes from high to low, and back to high after 50ns and is used to set the flip flop IC14b which releases the waveform clamp. The flip flop now waits for a rising edge on its clock input; this occurs when the triangle wave changes from a negative slope to a positive slope. This edge resets the flip flop and enables the waveform clamp circuit which stops the waveform at a point determined by the Start/Stop Phase control.

In the gate mode the monostable around IC16b and c is disabled and the signal bypasses IC16b. When a high level signal is applied to Trig in, the output of IC16c goes low and releases the waveform clamp. The generator now free runs until the Trig in signal goes low and IC16c output goes high. IC14b flip flop now waits for a rising edge on its clock input as in trigger mode and stops.

In the run mode IC14b flip flop is permanently set by SW9b, disabling the waveform clamp so that the generator free runs.

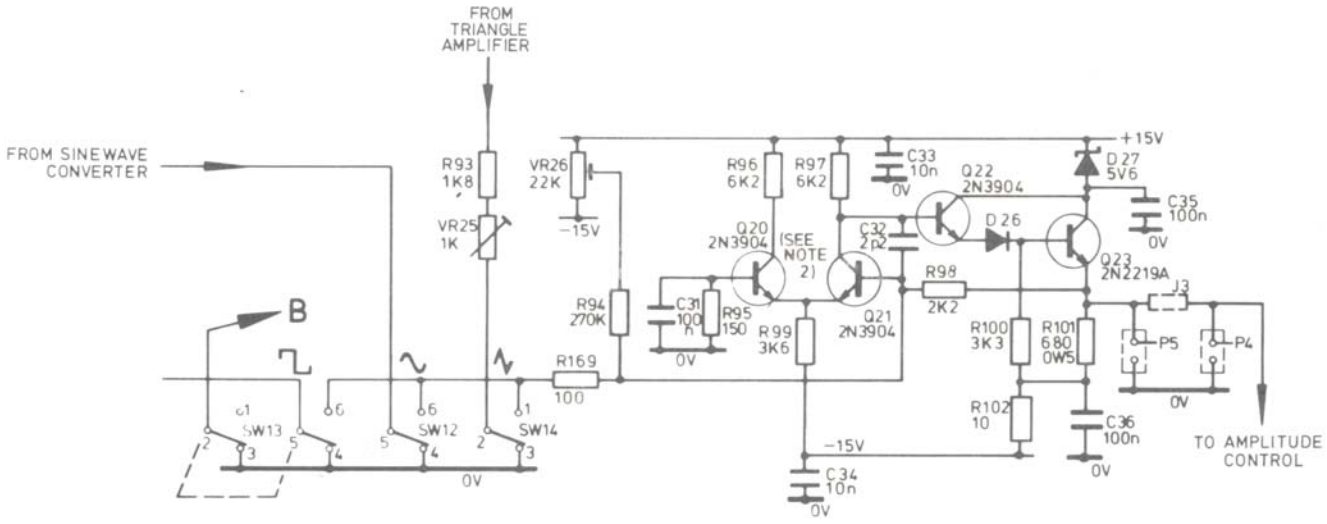
Waveform Generation - Waveform Shaping



The squarewave shaper is a diode bridge which steers current from either R89 or R90 into R91. This provides a squarewave with controlled rise/fall times, and thus no overshoot and ringing, which is symmetrical about ground. The drive signal comes from Q17.

The sine shaper comprises a monolithic transistor array IC18 which is driven by the triangle amplifier. The circuit has two non linear stages. A pair of emitter followers round the peaks of the triangle which are adjusted by VR18 for the bottom of the waveform and VR22 for the top of the waveform. The output from this stage is impressed across R78 and R81 in series and applied to the second stage. This comprises a long tailed pair driven almost into cut off and converts the clipped triangle wave into a sinewave. VR19 adjusts the gain of the long tailed pair to bring them close to cut off and therefore minimum sinewave distortion. VR23 adjusts the dc operating point of the sinewave convertor to give symmetrical operation on both positive and negative halves of the waveform. VR20 adjusts the dc output of the convertor and VR21 output amplitude.

Output Preamplifier



The selected waveform passes to the preamplifier. Q20 and Q21 form a long- tailed pair and are in thermal contact with each other to reduce dc drift. Q22 and Q23 are two cascaded emitter followers; feedback is via R98. The preamplifier is an inverting virtual earth type. DC offset is trimmed by VR26. Sine, square and triangle waveform amplitudes are set for 10V peak to peak into 50 Ohm at the 50 Ohm output by VR21, VR24 and VR25 respectively.

Output Amplifier and DC Offset

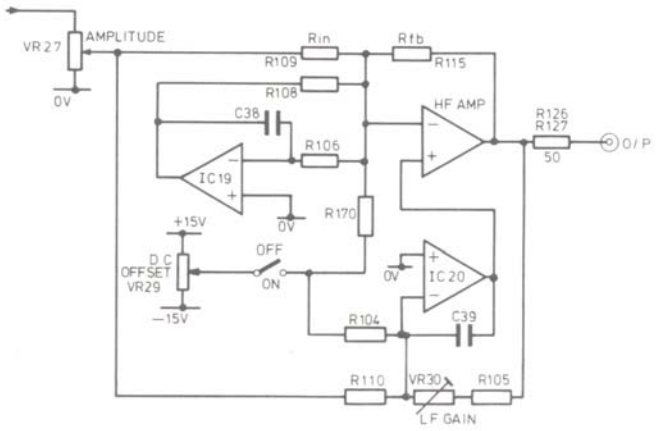


fig. a

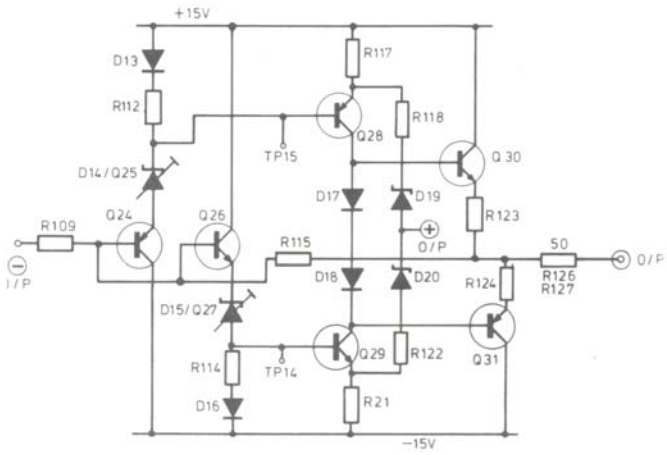


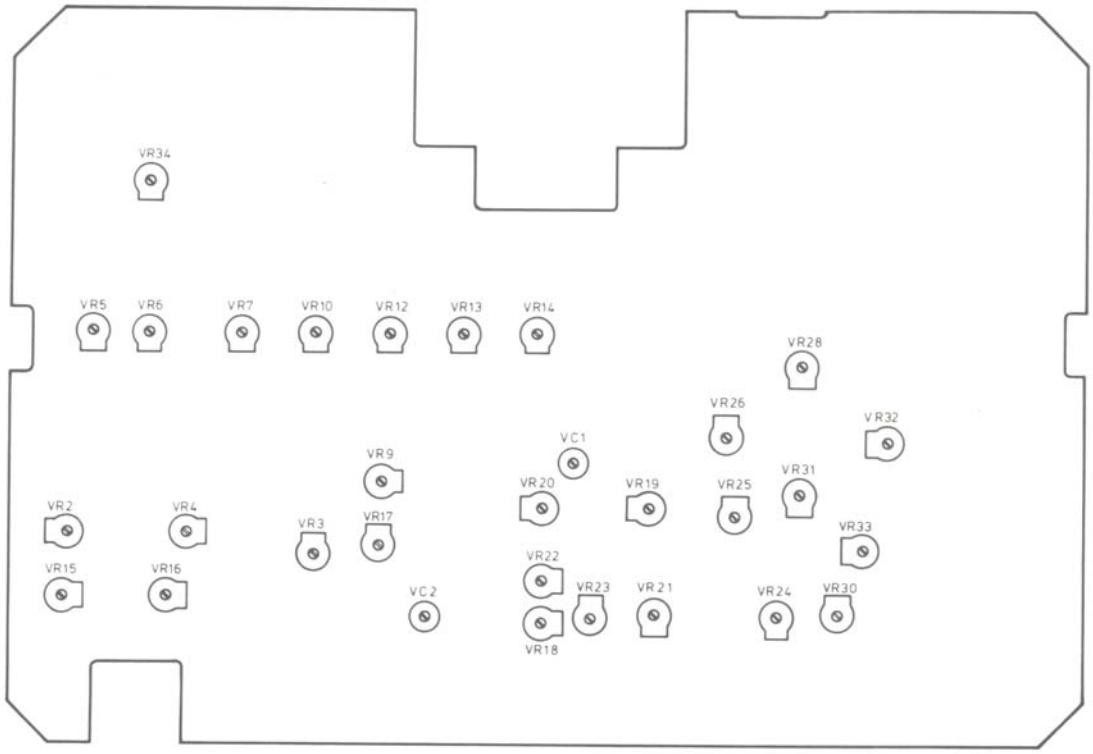
fig. b

The signal passes via the Amplitude control VR27 to the output amplifier. A simplified diagram is shown in fig. 7 and the following circuit description refers to this.

The HF amplifier is made up of discrete components and is in principle an inverting operational amplifier with a gain of -10 set by R109 and R115. This has offset voltages and currents which are compensated for by IC19 and IC20. IC19 compensates for input bias currents. IC20 controls dc offset and LF gain by driving the non-inverting input.

Refer now to fig. 8 for the description of the HF amplifier (simplified). Q24 and Q26 are complementary emitter followers to provide low drive impedance to the complementary class A amplifier stage Q28 and Q29. Level shifting is achieved by adjustable zener diodes, these are formed by a zener diode and a V_{BE} multiplier. Note incorrect setting of the level shifters will cause excessive current to flow in the class A stage causing damage to these devices. Refer to the calibration section for adjustment procedure. The output of the amplifier stage is buffered by complementary emitter followers Q30 and Q31 to drive the 50 Ohm output, D17 and D18 provide their bias.

The non-inverting input is effectively the emitters of the class A amplifier, D19 and D20 provide the necessary level shifting.



Calibration diagram

Equipment Required

Oscilloscope

Distortion meter

4.5 digit battery powered multimeter

Calibration should be carried out after the instrument has been on for 1 hour.

Note: If any work has been done to the output stage, VR32 and VR33 must be turned fully anti-clockwise before switching on.

The available calibration points are:

Dial calibration, high frequency (5.0) end, 10k range - VR3

Dial calibration, low frequency end (.005) - VR2

Waveform symmetry, high frequency end of dial (5.0) - VR9

Waveform symmetry at the low frequency end of dial (.005) is affected by offset nulling of ICs 2 to 6, see below.

Dial calibration 1M range - VC1

Dial calibration 100k range - VC2

Capacitance multiplier offset - VR16

Capacitance multiplier gain - VR15

DC offset of triangle amplifier - VR17

Sinewave distortion - VR18, VR19, VR22 and VR23

Sinewave dc offset - VR20

Sinewave amplitude - VR21

Squarewave amplitude - VR24

Triangle wave amplitude - VR25

DC offset of preamplifier - VR26

Output amplifier quiescent operating current - VR32 and VR33

Output amplifier dc offset - VR31

Output amplifier bias compensation - VR28

Output amplifier LF gain - VR30

+15Vrail - VR34

For best results the above adjustments should be carried out in the following manner:

After the instrument has warmed up the case upper is removed to make any adjustments, which should be done in a draft free environment.

Adjust VR34 for +15.0V +/-100mV at TP12

Check -15V rail is within +/-2% of the +15V rail at TP18

Check +10V rail is +10.2 +/-400mV at TP19

Check -10V rail is within +/-2% of the +10V rail at TP21

Check +5V rail is 5.0V +/-0.25V

Check -5V rail is -5.0V +/-0.25V

Select: Run, 1k range, dial at 5.0, dc offset out, squarewave, 0dB

Offset nulling of ICs 1 to 6 is critical for correct operation of the instrument. Gold plated test pins are provided and a gold plated 2 way header on the end of the leads to the DVM is recommended to make a good connection and help to avoid thermal e.m.f.s.

IC	TP	Adjust	DVM Reading
1	13	VR4	<40uV
2	1	VR5	<40uV
3	2	VR6	<40uV
4	3	VR7	<40uV
5	4	VR10	<40uV
6	5	VR12	<40uV
8	6	VR13	<100uV
9	7	VR14	<100uV
12	10	VR16	<100uV

Nulling of the triangle amplifier is achieved by shorting its input (TP11) and adjusting VR17 to give <2mV at TP9.

To null the pre-amplifier, deselect the waveform output by releasing the 3 function buttons. Connect a DVM to the right hand leg of the amplitude control (VR27) and adjust VR26 for <3mV.

Output stage adjustment must be carried out with great care to avoid circuit damage. Adjustment is easiest with 2 voltmeters, one connected to TP15 and the other to TP14. With only one meter available, alternately monitor the 2 test points. With no output waveform selected and the amplitude control at minimum, slowly adjust VR32 and VR33 for 13.4V to 13.5V at the two test points. Note

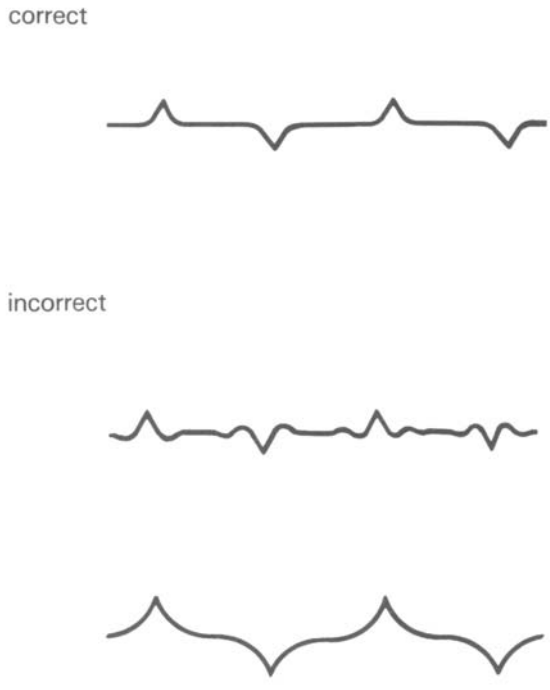
that the voltage on these test points (TP14 and TP15) must not go below 13.3V otherwise Q28 and Q29 will be damaged. VR32 and VR33 are interactive. Connect a DVM to TP16 and check that the voltage on this point is <+/-1V. If not, slightly adjust VR32 or VR33 ensuring that the voltages on TP14 and TP15 remain within 13.4V to 13.5V. Note that it may be necessary to add a low value resistor in the meter lead close to TP14 and TP15 to prevent instability in the amplifier. Connect a voltmeter to TP8 and adjust VR28 for <1mV. Connect a DVM to TP17 and adjust VR31 for <3mV. Frequency multiplier to 100 range, squarewave, adjust VR30 for a flat top squarewave. Note that the oscilloscope must be dc coupled for this adjustment.

Symmetry, select 1k range and adjust VR9 for equal mark: space ratio using the oscilloscope x10 X-multiplier to increase resolution and the trigger slope switch.

Before commencing the vernier calibration procedure, turn the dial fully clockwise and check that the 005 mark aligns with the mark on the front panel. If not, remove the cap in the centre of the knob, using a knife blade and loosen the nut one to two turns. The knob can now be slid around on its shaft to align the marks. Tighten the nut and check that the dial rotates freely against the front panel. Refit the knob cap. On later instruments a PTFE thrust washer is fitted between the dial and the front panel.

Dial	**Multiplier**	**Adjust**	**Reading**
5.0	10k	VR3	49.5 to 50.5 kHz
5.0	1M	VC1	4.9 to 5.1 MHz
5.0	100k	VC2	490 to 510 kHz
5.0	100	VR15	495 to 505 Hz
0.005	100k	VR2	465 to 475 Hz

Sinewave distortion, select sinewave, 1k range, dial at 5.0. Display the distortion meter output on CH2 of the oscilloscope. Position VR18 and VR22 fully clockwise. Adjust VR19 to give a flat response between peaks and VR23 to give a symmetrical display. Note, this is not minimum on the distortion meter, do not adjust these two presets to give minimum distortion at this stage.



Now slowly adjust VR18 and VR22 to remove these peaks. Check the distortion meter reading which should now be less than 0.5%, typically 0.3%. If not, very slightly adjust the above 4 presets to achieve this. (If the instrument fails to meet specification, check the following: amplitude, linearity and symmetry of triangle wave at TP9; pre and output amplifiers.) Adjust VR20 to trim dc output of the sinewave converter, measured on the oscilloscope or use a DVM connected to the 50 Ohm output (TP17). Adjust VR21 to give 10.2V peak to peak into 50 Ohm.

Triangle amplitude, adjust VR25 to give 10.2V peak to peak into 50 Ohm.

Squarewave amplitude, ajust VR24 to give 10.2V peak to peak into 50 Ohm.

Servicing Notes

The white printing on the pcb also shows all the points which are top soldered. The circles (teardrops) show track pins and the squares show which lead of a component is top soldered.

Insulating washers are fitted to IC22, Q32, Q34 and Q39. Heatsink compound is applied to regulators IC22, Q32, Q34 and Q39 and between transistor pair Q20 and Q21.

To help with trouble shooting the power supply etc., an external current limited (500mA) power supply of +/-17V can be used with its ground (0V) going to the TG501 ground (negative end of C50 or positive end of C51). The +17V supply is connected to the positive end of C50 and the -17V supply is connected to the negative end of C51.

Typical current drain from the +/-17V supply with output at minimum is -200mA and +240mA.

Input power with 240V input, 90mA maximum.

This service manual specifically covers issue 5 pcbs. Pre issue 5 boards have the following differences:

R35 100R was fitted in series with R36//C11 and not in the sinewave converter.

R142 was 4K7

pcb support brackets were not fitted.

PCB Assembly - Main

Ref	Description	Part No
R1	10RJ W25 CF	23185-0100
R2	150KJ W25 CF	23185-4150
R3	43KJ W25 CF	23187-3430
R4	10KJ W25 CF	23185-3100
R5	39KJ W25 CF	23185-3390
R6	2K7F W25 MF	23202-2270
R7	2K7F W25 MF	23202-2270
R8	2K43F W25 MF	23202-2243
R9	1K37F W25 MF	23202-2137
R10	1K37F W25 MF	23202-2137
R11	2K32F W25 MF	23202-2232
R12	750RF W25 MF	23202-1750
R13	4K3J W25 CF	23187-2430
R14	4K3J W25 CF	23187-2430
R15	750RF W25 MF	23202-1750
R16	3K3J W25 CF	23185-2330
R17	47RJ W25 CF	23185-0470
R18	47RJ W25 CF	23185-0470
R19	2K7F W25 MF	23202-2270
R20	2K7F W25 MF	23202-2270
R21	47RJ W25 CF	23185-0470
R22	47RJ W25 CF	23185-0470
R23	374RF W25 MF	23202-1374
R24	1K5J W25 CF	23185-2150
R25	1K0J W25 CF	23185-2100
R26	100RJ W25 CF	23185-1100
R27	10RJ W25 CF	23185-0100
R28	10KF W25 MF	23202-3100
R29	22KJ W25 CF	23185-3220
R30	100KF W25 MF	23202-4100
R31	1M0F W25 MF	23202-5100
R32	10KJ W25 CF	23185-3100
R33	10RJ W25 CF	23185-0100

Ref	Description	Part No
R34	10RJ W25 CF	23185-0100
R35*	100RJ W25 CF	23185-1100
R36	1K0J W25 CF	23185-2100
R37	10KJ W25 CF	23185-3100
R38	470RJ W25 CF	23185-1470
R39	220RJ W25 CF	23185-1220
R40	1K5J W25 CF	23185-2150
R41	1K5J W25 CF	23185-2150
R42	820RJ W25 CF	23185-1820
R43	1K0J W25 CF	23185-2100
R44	1K2J W25 CF	23185-2120
R45	100RJ W25 CF	23185-1100
R46	330RJ W25 CF	23185-1330
R47	14K3F W25 MF	23202-3143
R48	220RF W25 CF	23185-1220
R49	681RF W25 MF	23202-1681
R50	124RF W25 MF	23202-1124
R51	124RF W25 MF	23202-1124
R52	681RF W25 MF	23202-1681
R53	220RF W25 MF	23202-1220
R54	14K3F W25 MF	23202-3143
R55	150RJ W25 CF	23185-1150
R56	1K0J W25 CF	23185-2100
R57	1K8J W25 CF	23185-2180
R58	3K0J W25 CF	23187-2300
R59	4K7J W25 CF	23185-2470
R60	1K8J W25 CF	23185-2180
R61	3K0J W25 CF	23187-2300
R62	2K2J W25 CF	23185-2220
R63	2K2J W25 CF	23185-2220
R64	1K2J W25 CF	23185-2120
R65	4K7J W25 CF	23185-2470
R66	4K7J W25 CF	23185-2470
R67	4K7J W25 CF	23185-2470
R68	4K7J W25 CF	23185-2470

Ref	Description	Part No
R69	4K7J W25 CF	23185-2470
R70	4K7J W25 CF	23185-2470
R71	2K2J W25 CF	23185-2220
R72	1K5J W25 CF	23185-2150
R73	33KJ W25 CF	23185-3330
R74	2K2J W25 CF	23185-2220
R75	100RJ W25 CF	23185-1100
R76	47RJ W25 CF	23185-0470
R77	7K5J W25 CF	23187-2750
R78	560RJ W25 CF	23185-1560
R79	100RJ W25 CF	23185-1100
R80	7K5J W25 CF	23187-2750
R81	91RJ W25 CF	23187-0910
R82	7K5J W25 CF	23187-2750
R83	7K5J W25 CF	23187-2750
R84	68RJ W25 CF	23185-0680
R85	7K5J W25 CF	23187-2750
R86	100RJ W25 CF	23185-1100
R87	47RJ W25 CF	23185-0470
R88	10KJ W25 CF	23185-3100
R89	5K6F W25 MF	23202-2560
R90	5K6F W25 MF	23202-2560
R91	220RJ W25 CF	23185-1220
R92	470RJ W25 CF	23185-1470
R93	1K8J W25 CF	23185-2180
R94	270KJ W25 CF	23185-4270
R95	150RJ W25 CF	23185-1150
R96	6K2J W25 CF	23187-2620
R97	6K2J W25 CF	23185-2620
R98	2K2J W25 CF	23185-2220
R99	3K6J W25 CF	23187-2360
R100	3K3J W25 CF	23185-2330
R101	680RJ W50 CF	23179-1680
R102	10RJ W25 CF	23185-0100
R103	22RJ W25 CF	23185-0220

Ref	Description	Part No
R104	130KJ W25 CF	23187-4130
R105	82KJ W25 CF	23185-3820
R106	47KJ W25 CF	23185-3470
R107	22KJ W25 CF	23185-3220
R108	47KJ W25 CF	23185-3470
R109	470RJ W25 CF	23185-1470
R110	10KJ W25 CF	23185-3100
R111	560RJ W25 CF	23185-1560
R112	470RJ W25 CF	23185-1470
R113	560RJ W25 CF	23185-1560
R114	470RJ W25 CF	23185-1470
R115	4K7J W25 CF	23185-2470
R116	47RJ W25 CF	23185-0470
R117	47RJ W25 CF	23185-0470
R118	3K3J W25 CF	23185-2330
R119	10RJ W25 CF	23185-0100
R120	47RJ W25 CF	23185-0470
R121	47RJ W25 CF	23185-0470
R122	3K3J W25 CF	23185-2330
R123	10RJ W25 CF	23185-0100
R124	10RJ W25 CF	23185-0100
R125	10RJ W25 CF	23185-0100
R126	100RJ 1W CF	23183-1100
R127	100RJ 1W CF	23183-1100
R128	61R9F W25 MF	23202-0619
R129	249RF W25 MF	23202-1249
R130	61R9F W25 MF	23202-0619
R131	61R9F W25 MF	23202-0619
R132	249RF W25 MF	23202-0619
R133	121RF W25 MF	23202-1121
R134	124RF W25 MF	23202-1124
R135	3K3J W25 CF	23185-2330
R136	220RJ W25 CF	23185-1220
R137	1K0J W25 CF	23185-2100
R138	1K0J W25 CF	23185-2100
R139	3K3J W25 CF	23185-2330
R140	4K7J W25 CF	23185-2470
R141	1K0J W25 CF	23185-2100

Ref	Description	Part No
R142*	3K3J W25 CF	23185-2330
R143	220RJ W25 CF	23185-1220
R144	1K0J W25 CF	23185-2100
R145	4K7J W25 CF	23185-2470
R146	1K2J W25 CF	23185-2120
R147	8K2J W25 CF	23187-2820
R148	5K6F W25 MF	23202-2560
R149	10KF W25 MF	23202-3100
R150	10KF W25 MF	23202-3100
R151	4K7J W25 CF	23185-2470
R152	10KJ W25 CF	23185-3100
R153	4K7J W25 CF	23185-2470
R154	10KF W25 MF	23202-3100
R155	10KF W25 MF	23202-3100
R156	22KJ W25 CF	23185-3220
R157	8K2J W25 CF	23185-2820
R158	3K9J W25 CF	23185-2390
R159	1K8J W25 CF	23185-2180
R160	2K2J W25 CF	23185-2220
R161	ZERO OHM	23185-0000
R162	ZERO OHM	23185-0000
R163	ZERO OHM	23185-0000
R164	ZERO OHM	23185-0000
R165	ZERO OHM	23185-0000
R166	ZERO OHM	23185-0000
R167	22KJ W25 CF	23185-3220
R168	22KJ W25 CF	23185-3220
R169	100RJ W25 CF	23185-2100
R170	6K8J W25 CF	23185-2680
R171	10RJ W25 CF	23185-0100

***R35 was fitted in series with R36//C11 on pre issue 5 pcbs**

Ref	Description	Part No
VR2	Preset 22K	23377-3220
VR3	Preset 10K	23377-3100
VR4	Preset 10K	23377-3100
VR5	Preset 10K	23377-3100
VR6	Preset 10K	23377-3100
VR7	Preset 10K	23377-3100
VR9	Preset 220R	23377-1220
VR10	Preset 10K	23377-3100
VR12	Preset 10K	23377-3100
VR13	Preset 10K	23377-3100
VR14	Preset 10K	23377-3100
VR15	Preset 1K0	23377-2100
VR16	Preset 10K	23377-3100
VR17	Preset 470R	23377-1470
VR18	Preset 4K7	23377-2470
VR19	Preset 100R	23377-1100
VR20	Preset 2K2	23377-2220
VR21	Preset 100R	23377-1100
VR22	Preset 4K7	23377-2470
VR23	Preset 10K	23377-3100
VR24	Preset 1K0	23377-2100
VR25	Preset 1K0	23377-2100
VR26	Preset 22K	23377-3220
VR27	Pot 470R Lin	23347-0110
VR28	Preset 10K	23377-3100
VR30	Preset 22K	23377-3220
VR31	Preset 10K	23377-3100
VR32	Preset 2K2	23377-2220
VR33	Preset 2K2	23377-2220
VR34	Preset 2K2	23377-2220

***R142 was 4K7 on pre-issue 5 pcbs**

Ref	Description	Part No
C1	10NZ 63V Cer	23427-0325
C2	10NZ 63V Cer	23427-0325
C3	10NZ 63V Cer	23427-0325
C4	10NZ 63V Cer	23427-0325
C5	150PF 630V P/S	23647-0515
C6	1N8F 160V P/S	23646-0009
C7	82PK 30V P/S	23646-0708
C8	22NG 100V P/E	23620-0805
C9	220NG 100V P/E	23620-0804
C10	100NJ 100V P/E	23620-0207
C11	4N7K 63V Cer	23427-0346
C12	10NZ 63V Cer	23427-0325
C13	10NZ 63V Cer	23427-0325
C14	10NZ 63V Cer	23427-0325
C15	10NZ 63V Cer	23427-0325
C16	47PG 63V Cer	23427-0329
C17	18PG 63V Cer	23427-0337
C18	22PG 63V Cer	23427-0323
C19	82PG 63V Cer	23427-0349
C20	82PG 63V Cer	23427-0349
C21	3N3F 160V P/S	23646-0007
C22	3N3F 160V P/S	23646-0007
C23	10PC 63V Cer	23427-0328
C24	10NZ 63V Cer	23427-0325
C25	10NZ 63V Cer	23427-0325
C26	10NZ 63V Cer	23427-0325
C27	22PG 63V Cer	23427-0323
C28	270PG 63V Cer	23427-0347
C29	10NZ 63V Cer	23427-0325
C30	68PG 63V Cer	23427-0332
C31	100NS 63V Cer	23438-0007
C32	2P2C 50V Cer	23427-0524
C33	10NZ 63V Cer	23427-0325
C34	10NZ 63V Cer	23427-0325
C35	100NS 63V Cer	23438-0007

Ref	Description	Part No
C36	100NS 63V Cer	23438-0007
C37	Not used	
C38	100NJ 100V P/E	23620-0207
C39	1N0K 63V Cer	23427-0331
C40	0.47UF 35V Tant	23594-0231
C41	10UF 16V Tant	23594-0219
C42	10UF 16V Tant	23594-0219
C43	0.47UF 35V Tant	23594-0231
C44	100NS 63V Cer	23438-0007
C45	100NS 63V Cer	23438-0007
C46	10UF 16V Tant	23594-0219
C47	10UF 16V Tant	23594-0219
C48	100NS 63V Cer	23438-0007
C49	100NS 63V Cer	23438-0007
C50	1000UF 63V Elec	23557-0244
C51	1000UF 63V Elec	23557-0244
C52	100NS 63V Cer	23438-0007
C53	100PG 63V Cer	23427-0322
C54	100PG 63V Cer	23427-0322
C55	100UF 25V Elec	23557-0650
C56	10NZ 63V Cer	23427-0325
C57	100UF 25V Elec	23557-0650
C58	10NZ 63V Cer	23427-0325
C59	100UF 25V Elec	23557-0650
C60	100UF 25V Elec	23557-0650
C61	1P8C 63V Cer	23427-0310
C62	10NZ 63V Cer	23427-0325
C63	10NZ 63V Cer	23427-0325
C64	10NZ 63V Cer	23427-0325
C65	10NZ 63V Cer	23427-0325
*C66	2P2C 50V Cer	23427-0524
C67	270PG 63V Cer	23427-0347
VC1	4-64pF Poly/P	23984-0001
VC2	4-64pF Poly/P	23984-0001

Ref	Description	Part No
D1	Dio 1N4148	25021-0901
D2	Dio 1N4148	25021-0901
D3	Dio 1N4148	25021-0901
D4	Dio 1N4148	25021-0901
D5	Dio 1N4148	25021-0901
D6	Dio 1N4148	25021-0901
D7	Dio 1N4148	25021-0901
D8	Dio 1N4148	25021-0901
D9	Dio 1N4148	25021-0901
D10	Dio 1N4148	25021-0901
D11	Dio 1N4148	25021-0901
D12	Dio 1N4148	25021-0901
D13	Dio 1N4148	25021-0901
D14	Dio BZX79C11	25130-0910
D15	Dio BZX79C11	25130-0910
D16	Dio 1N4148	25021-0901
D17	Dio 1N4148	25021-0901
D18	Dio 1N4148	25021-0901
D19	Dio BZX83C11	25130-0908
D20	Dio BZX83C11	25130-0908
D21	Dio 1N821	25130-0226
D22	Dio 1N4002	25115-0907
D23	Dio 1N4002	25115-0907
D24	Dio 1N4002	25115-0907
D25	Dio 1N4002	25115-0907
D26	Dio 1N4148	25021-0901
D27	Dio BZX83C5V6	25130-0217
D28	Dio 1N4148	25021-0901
D29	Dio 1N4148	25021-0901
D30	Dio 1N4148	25021-0901

***C66 is optional. See circuit diagram**

Ref	Description	Part No
Q1	Tran ZTX239	25380-0229
Q2	Tran ZTX214	25341-0214
Q3	Tran ZTX214	25341-0214
Q4	Tran ZTX239	25380-0229
Q5	Tran ZTX239	25380-0229
Q6	Tran ZTX214	25341-0214
Q7	Tran ZTX239	25380-0229
Q8	Tran ZTX239	25380-0229
Q9	Tran ZTX214	25341-0214
*Q10	Tran BF245A	25601-0103
*Q11	Tran BF245A	25601-0103
Q12	Tran ZTX214	25341-0214
Q13	Tran ZTX214	25341-0214
Q14	Tran ZTX214	25341-0214
Q15	Tran 2N3904	25381-0404
Q16	Tran ZTX239	25380-0229
Q17	Tran 2N3904	25381-0404
Q18	Tran 2N3904	25381-0404
Q19	Tran ZTX313	25380-0230
Q20	Tran 2N3904	25381-0404
Q21	Tran 2N3904	25381-0404
Q22	Tran 2N3904	25381-0404
Q23	Tran 2N2219A	25377-0700
Q24	Tran 2N3906	25341-0218
Q25	Tran ZTX239	25380-0229
Q26	Tran 2N3904	25381-0404
Q27	Tran ZTX239	25380-0229
Q28	Tran 2N3906	25341-0218
Q29	Tran 2N3904	25381-0404
Q30	Tran 2N2219A	25377-0700
Q31	Tran 2N2905A	25344-0500
Q32	Tran BD240	25344-0020
Q33	Tran ZTX214	25341-0214
Q34	Tran BD240	25344-0020
Q35	Tran 2N3904	25381-0404

Ref	Description	Part No
Q36	Tran 2N3904	25381-0404
Q37	Tran 2N3906	25341-0218
Q38	Tran 2N3906	25341-0218
Q39	Tran BD239	25382-0500
Q40	Tran BC338	25383-0505
Q41	Tran ZTX550	25341-0215

***Q10 & Q11 are matched devices**

Ref	Description	Part No
IC1	LF441CN	27106-0621
IC2	LF441CN	27106-0621
IC3	LF441CN	27106-0621
IC4	LF441CN	27106-0621
IC5	LF441CN	27106-0621
IC6	LF441CN	27106-0621
IC7	TL071CP	27106-0604
IC8	TL071CP	27106-0604
IC9	TL071CP	27106-0604
IC10	CA3019	27164-0600
IC11	TL071CP	27106-0604
IC12	TL071CP	27106-0604
IC13	NE521N	27254-0010
IC14	74LS74	27223-0740
IC15	74LS00	27223-0000
IC16	74LS00	27223-0000
IC17	7400	27220-0000
IC18	CA3127E	27164-0504
IC19	TL071CP	27106-0604
IC20	TL071CP	27106-0604
IC21	LM324N	27106-0506
IC22	LM340T-5	27160-0009

Description		Part No.
Switchbank	12 Way	22225-0540
Switchbank	7 Way	22225-0550
Button, black	13 off	37113-0130
Button, grey	6 off	37113-0140
Stud 3mm x 10mmL (for pot bracket)	2 off	20205-0610
Track pins	16 off	22469-0502
Vero pins (LV AC from transformer, TP12,TP14 to 22 inc.)	12 off	22469-0200
Transistor pad (for Q23,30,31)	3 off	20661-0801
Heatsink,TO5 (for Q23,30,31)	3 off	20670-0040
Header, 2 Way (TP1 to TP11 inc, (TP13)	12 off	22573-0041
Zero ohm resistors (LK1 to LK69 inc., J1, J2, J3 & J4)	73 off	23185-0000
Socket IC 8 pin	13 off	22574-0118
Socket IC 14 pin	6 off	22574-0119
Socket IC 16 pin		22574-0120
Bracket, potentiometer (for VR27)		33141-0540
Spindle, extension (for VR27)		23347-0720
Washer, shakeproof, M3 (for pot bracket)	2 off	20037-0301
Wahser, M3 (for pcb bracket)	2 off	20030-0203
Nut, M3 (for pot bracket (2)), for pcb bracket (2))	4 off	20210.0101
PCB Support bracket	2 off	20663-0010
Screw M3 x 8mmL (for pcb bracket)	2 off	20234-0012
Adhesive pad (for C51,C52)	4 off	10300-0313
Terminal for T1	3 off	35311-0020
PCB, Main TG501/2/3		35555-0510

Front Panel Assy TG501

Description		Part No
Front Panel TG501		*33331-0710
Dial, single scale		37571-0060
Washer PTFE for dial		31122-0220
Knob, black, for dial		20657-0020
Cap, for dial knob		20657-0021
Knob, push-on	4 off	20657-0001
Cap, for knob	4 off	20657-0009
Pot 25KJ WW (VR8)		23356-0010
Pot 10KM CP (VR1)		23348-0010
Nut (for VR1)		23348-0700
Washer (for VR1)		23348-0701
Pot 1K0M CF (VR11)		23347-0029
Pot 10KM CF (VR29)		23347-0030
Pot 4700MM (VR27)		23347-0110
BNC Socket	4 off	22588-0004
Bushing, BNC insulating	8 off	22588-0700
LED.		25061-0200
Adhesive pad for LED		10300-0313
Sleeve for LED wire		10232-0303
Solder tag, shakeproof (for earth wire)		*20037-0400

Rear Panel Assy - TG501

Description		Part No.
Rear Panel		*33331-0820
AC Mains Receptacle		22520-0120
Shroud for receptacle		22458-0004
Fuseholder		22300-0210
Shroud for fuseholder		22458-0001
Fuse 200mA slow blow (for 220/240V input)	or	22315-0227
Fuse 400mA slow blow (for 110/120V input)		22315-0236
Switch, rocker		22219-0030
Connector, shrouded push-on for switch	4 off	22454-0030
Transformer (T1)		22115-0040
Spacer M4 x 15mmL (for T1)	4 off	20661-0224
Screw M4 x 45mmL (for T1)	4 off	20234-0030
Washer shakeproof M4 (for T1)	8 off	20037-0304
Nut M4 (for T1)	5 off	20210-0102

Description		Part No.
Screw M3 x 10mmL	2 off	20234-0011
Washer, shakeproof M3 (for Mains skt)	2 off	20037-0301
Washer, M3 (for Mains skt)	2 off	20030-0263
Nut, M3 Mains skt	2 off	20210-0101
Screw M4 x 8mmL (for Mains earth)		20234-0023
Solder tag, shakeproof 4BA (for earth wires)	2 off	20037-0401
Washer ,insulating TO220 (for Q32, 34, 39 & IC22)	4 off	20613-0006
Screw M3 x 8mmL nylon (for Q32, 34, 39 & IC22)	4 off	20224-0200
Nut M3 nylon (for Q32,34,39 & IC22)	4 off	20210-0200
Label, On/Off		37511-0340
Label, Serial No		37558-0460

Case Parts

Description		Part No.
Case Upper		*33537-0240
Case Lower		*33537-0250
Bracket, side	2 off	*31547-0140
Screw M3 x 8mmL mushroom head (case upper/lower to side brackets)	8 off	20237-0001
Screw M3 x 5mmL Taptite (PCB securing)	4 off	20062-0500
Washer M3 (PCB securing)	4 off	20030-0263
Screw M3 x 10mmL (Rear panel securing)	4 off	20234-0011
Washer M3, shakeproof (Front & Rear Panel securing)	12 off	20037-0301
Nut M3 (Front & Rear Panel securing)	8 off	20210-0101
Foot, swivel		20662-0200
Bracket,foot, pair		20662-0201
Foot, PVC, black	2 off	20662-0520
Hardware for all feet securing:		
Screw M4 x 12mml	4 off	20234-0029
Nut M4	4 off	20210-0102
Washer M5	2 off	20030-0267
Washer, shakeproof	4 off	20037-0304
Cable tie	4 off	20653-0204
Spring foot (silver bar)		33171-0130
Black feet (pair)		20662-0201

Packaging Parts

Description		Part No
Carton - TG501		*38114-0100
Load spreader for carton		*38114-0105
End Cap for carton	2 off	*20664-0170
Label, wiring instructions (for tinned ends Mains lead)		37541-0490
Mains Lead tinned ends or		22491-0010
Mains lead Euro plug or		22491-0020
Mains lead USA plug		22491-0040
Guarantee Card		48581-0230
Instruction Book		48591-0100

Parts Changes

From September 1988 a new case with changed cosmetics was introduced. This consisted of a different case upper and lower, front and rear panels, side support brackets and the use of case bezels to front and rear. The front panel earth wire connection by the shakeproof solder tag was no longer required. A new carton was also introduced to accomodate the new case. The old and new parts, which are not interchangeable, are as follows:

Old Parts

Description		Part No
Case Upper		33537-0240
Case Lower		33537-0250
Front Panel		33331-0710
Rear Panel		33331-0820
Side Bracket	2 off	31547-0140
Solder tag, shakeproof		20037-0400
Carton		38114-0100
Load spreader for carton		38114-0105
End Cap for carton	2 off	20664-0170

New Parts

Description		Part No
Case Upper		33537-0500
Case Upper		33537-0510
Front Panel		33331-1400
Rear Panel		33331-1410
Side Bracket	2 off	31547-0290
Bezel, Case	2 off	31711-0050
Carton		38114-0150
Load spreader for carton		38114-0155
End Cap for carton	2 off	20664-0200

PJ1 pin functions: 1 −10V, 2 +10V, 3 +5V, 4 +15V, 5 −5V, 6 −15V, 7 0V, 8 P2, 9 0V, 10 P3, 11 0V, 12 P7, 13 0V, 14 P1, 15 0V, 16 P6

NOTES
1. Q10 AND Q11 ARE A MATCHED PAIR, BF245A
2. Q20 AND Q21 ARE IN THERMAL CONTACT.
3. DIODES ARE 1N4148 UNLESS OTHERWISE SPECIFIED.
4. ALL SWITCHES ARE SHOWN IN THE OUT POSITION.
5. IF IC 13 OSCILLATES WITH THE DIAL AT ·005 FIT C66