INSTRUMENT HANDBOOK

ISSUE 1 (246)

Applicable to Serial No. 24008

MODEL bwd 503

5" SINGLE BEAM OSCILLOSCOPE

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INSTRUMENT HANDBOOK

MODEL bwd 503

1. GENERAL

Model bwd 503 Oscilloscope is a versatile instrument designed for absolute simplicity of operation and reliable long life. Special attention has been paid to isolating the complete circuitry so that it is practically impossible to damage either the Oscilloscope or equipment connected to it by incorrect connection. The external cabinet is grounded to the mains earth for complete safety.

1.1 Both Vertical and Horizontal Amplifiers are D.C. coupled enabling the Oscilloscope to be used as an A.C. or D.C. volt or milli-voltmeter, D.C. plotting table, LF phase comparator. Additionally, with suitable resistor across the input (e.g. 1Ω), it will operate as a direct reading ammeter or milli-ammeter, in addition to all normal Oscilloscope functions.

1.2 The Time Base as a 100,000 to 1 frequency range of 1.0μSec/cm down to 0.1Sec/cm, and incorporates completely Automatic Triggering. The stability control has been completely eliminated, the new solid state trigger circuit being self setting, and always ready to receive any input signal.

1.3 When used with Model bwd 112B or 141 Oscillators, measurement and display of the complete audio spectrum can be made, and in conjunction with the unique Model bwd 603 Generator/Power Supplies Combination, a complete demonstration in the field of physics is open from basic magnetism and electricity, right through to R.F. transmission and reception, modulation, voltage and power amplification, phase relationships etc. (Request Data Sheet 600 and leaflets for further information).

2. SPECIFICATION

2.1 C.R.T. TYPE — 5" flat faced, 5UPI - F.

Phosphor — P1 normally supplied; P7 available to special order.

E.H.T. — 1.5KV.

Graticule — Fitted with 8 x 10cm. graticule and blue light filter (orange filter for P7 Phosphor).

2.2 VERTICAL AMPLIFIER

Bandwidth — D.C. or 2Hz (A.C. coupled) to 3MHz, -3db at all sensitivities. Referred to 4cm. at 50kHz.

Sensitivity — 20,50,100,200,500mV, 1,2,5,10,20,50 and 100V per cm.

2. SPECIFICATION (Cont'd.)

2.2 VERTICAL AMPLIFIER

Rise Time	< 100 nano Seconds constant.
Calibration	Better than 10%.
Input Impedance	1MΩ and less than 40pf.
Max. Input Voltage	500V D.C. or 250V A.C.

2.3 TIME BASE

Range	1µSec/cm to 0.1 Sec/cm in 5 decade ranges with VERNIER control.
Switch Calibration	Better than 10% with VERNIER in CAL position.
Blanking	A.C. coupled to C.R.T. grid.

2.4 TRIGGER

Facilities	Switch selection + or – (Internal)
Sensitivity	20Hz to over 1MHz with <2cm deflection 5Hz to > 3MHz with <4cm deflection.

2.5 HORIZONTAL AMPLIFIER

Bandwidth	D.C. to 100kHz – (-3db).
Sensitivity	Range greater than 600mV to 6.5V per cm. Continuously variable.
Input Impedance	100K and 30pf approximately.

2.6 Deleted.

2.7 POWER REQUIREMENTS

190 to 260V)
95 to 130) 50 to 60Hz., approximately 25 watts.

2.8 DIMENSIONS & WEIGHT

24 x 19 x 42cm deep. Weight approximately 7kg. 8.5kg packed.

2.9 ACCESSORIES

Supplied with Instrument –

1 Handbook
1 Power Cord.

2. SPECIFICATION (Cont'd.)

2.10 OPTIONAL ACCESSORIES

See Catalogue.

3. FUNCTION OF CONTROLS

Front panel controls are grouped for ease of use and are clearly designated. The functions of these controls are described below.

3.1 INTENSITY CONTROLS & ON-OFF SWITCH

Fully anti-clockwise, this control switches the instrument OFF. When rotated clockwise the instrument is switched ON and further rotation controls the trace intensity (brightness) from zero to max.

3.2 FOCUS

Controls the sharpness of the trace. May require slight readjustment over the full intensity control range.

3.3 HORZ. POSITION

Moves the trace horizontally on the CRT.

3.4 HORZ. VERNIER

Varies the Time Base speed over a 12-1 range to provide a continuously variable range in conjunction with the TIME/CM switch from 0.1Sec/cm to 1μSec/cm. When the TIME/CM switch is turned and switched to HORZ AMP it switches off the Internal Time Base, permitting an external signal to be fed into the HORZ INPUT socket. The Horizontal Vernier now varies the sensitivity from 0.6V to 6V per cm approximately.

3.5 TIME/CM (TIME BASE) SWITCH.

When the Time Base Vernier control is turned clockwise to the CAL position, the five time base speeds on this control will be accurate to within 10%. The speeds of 10 and 1mSec. and 100, 10 and 1μSec represent the fastest speed on each range; anti-clockwise rotation of the Horizontal Vernier Control wil reduce the selected speed over a 12 - 1 range, e.g. on the 1mSec range the Vernier will vary the time base from 1mSec down to less than 10mSec/cm when fully anticlockwise.

3.6 + OR - SWITCH

Selects the polarity of the trigger waveform.

3.7 VERTICAL POSITION

Moves the trace vertically on the CRT.

3.8 VOLTS/CM (ATTENUATOR)

Switch adjusts the sensitivity of the Vertical amplifier from 20mV per cm. (6mV RMS) to 100V per cm. in a 1,2,5,10 series of steps. Attenuator accuracy is 3% and the overall Oscilloscope accuracy within 10% on any step.

3. FUNCTION OF CONTROLS (Cont'd.)

3.9 AC-DC SWITCH — The DC position provides direct coupling to the amplifier the AC position places a capacitor in series with the input to block the DC component.

3.10 TERMINALS & SOCKETS :

3.11 INPUT — Red terminal is the signal input connection to the vertical amplifier.

3.12 COMMON — Black terminal should be connected to the ground side of the signal being measured. This terminal is not connected to the Oscilloscope chassis and may be taken to ±400V from ground.

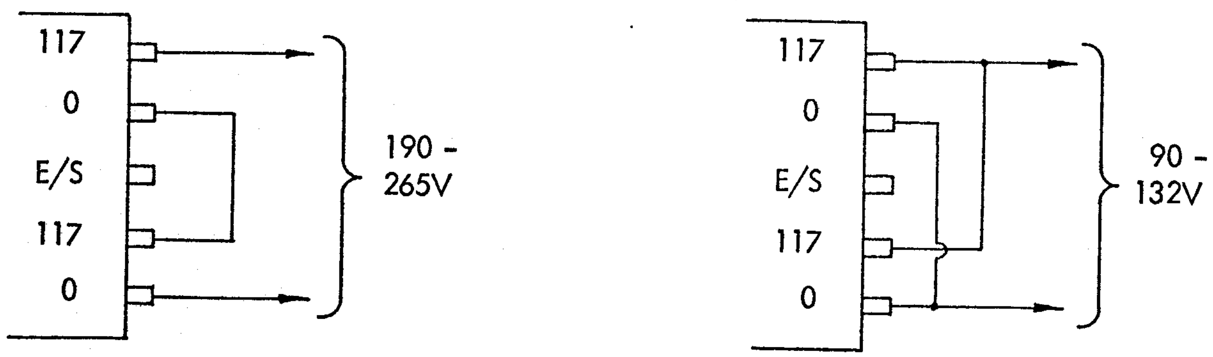
3.13 GROUND — This terminal is connected to the instrument cabinet and will normally be linked to the Common terminal directly above it unless isolated ground measurements are required.

3.14 HORIZONTAL INPUT — When the Time/cm Switch is turned anticlockwise to HORZ. AMPL. signals may be fed into this socket to produce a horizontal display, input is DC coupled. An external capacitor must be used if a high voltage DC is present on the signal to be displayed, which causes the trace to be deflected off the screen.

4. FIRST TIME OPERATION

Check tapping on power transformer for correct connection for local supply mains. Instrument is fitted with universal primary for 100 to 240V operation, connect as shown below to suit local power line voltage.

Instruments connected for other than 220-265V tapping have a label attached stating supply voltage.



POWER TRANSFORMER PRIMARY CONNECTIONS.

4. FIRST TIME OPERATION (Cont'd.)

4.1 Set the controls as follows before switching on:

Intensity	Fully anticlockwise
Focus	Centred
Horz. Position	Centred
Horizontal Vernier	Clockwise - CAL
Time/cm	10mSec.
+ - Selector	+
Vertical Position	Centred
Volts/cm	5V
DC - AC	DC

4.2 Plug instrument into power line outlet. Connect links of wire from a supply such as a 6.3V transformer to the vertical input socket on the L.H. side.

Switch on by rotating the intensity control about 3/4 of a turn. A display will appear after a few seconds.

5 cycles of the calibration waveform should be present on the CRT. Adjust the horizontal and vertical position controls to centre the display and the focus and intensity for a sharp, bright image.

4.3 Now turn the Volt/cm switch to 2V and the display will expand over full screen height, turning the knob around to 10V, 20V etc., will progressively reduce the height of the dispaly, below 1cm amplitude the trace may start to lose stability.

4.4 Set the attenuator at the 0.2V position and feed in a 1V p-p square wave at 50Hz. The effect of the DC - AC switch on low frequencies can now be seen by sliding the switch to the AC position. The top and bottom edges of the display will tilt indicating a loss of the DC and the lowest frequency components in the square wave. Always use the DC position for frequencies below 100Hz., provided the waveform can be positioned on the screen with the vertical position control, if DC is present on the signal. Change input back to the 6.3V waveform as in 4.2. Now turn the Horizontal Vernier control, the waveforms will compress together. Switch the Time/cm switch to 1mSec and adjust the vernier to give two complete waveforms on the CRT. Change the ± switch and note how the triggering point changes.

4.5 Finally, we can check the HORZ. INPUT. Turn the Time/cm switch to Horz.Amp. Connect a lead from a 1V AC source to the Horz. input socket. A horizontal line will appear whose length can be varied by the HORZ. VERNIER control.

THE FOLLOWING SECTIONS EXPLAIN THE OPERATION OF MODEL bwd 503 WHEN USED TO MAKE SPECIFIC MEASUREMENTS.

5. MEASUREMENT OF DC (DIRECT) VOLTAGES

5.1 For an initial test take a $1\frac{1}{2}$V dry cell and set the attenuator to 0.5V. Connect the negative end to the BLACK COMMON terminal, set the trace to the centre of the graticule, touch a lead from positive end of the battery to the DC terminal, the trace will move up 3cms., 3 x 0.5V = 1.5V.

5.2 Now reverse the connections to the battery and note how the trace moves down 3cms. This illustrates how an oscilloscope can display positive or negative voltages or both simultaneously, e.g. when viewing a sine or square wave.

5.3 NOTE: The 1MΩ input impedance of the Oscilloscope must be taken into account when measuring high impedance points such as the gate of a FET or the base of a transistor.

5.4 The DC input facility may be used to measure AC waveforms swinging about a DC voltage, as at the collector of a transistor or the anode of a valve, to check for bias settings or anode bottoming, etc., Max DC input should not exceed x10 input attenuator setting if it is required to re-centre the trace to view signal superimposed on it.

6. MEASUREMENT OF AC (ALTERNATING) VOLTAGES

6.1 Set the Attenuator to 50V (if the input voltage is unknown). Connect a lead from the COMMON (Black) input terminal to the ground (earth) side of the signal source. (Model bwd 112B, 141 or 603 Sine Wave Oscillators are ideal for initial experiements in this test).

Increase the Vertical sensitivity by the VOLTS/CM switch until a display between 2 and 8cm exists. Now adjust the Time Base switch and Vernier to enable the waveform to be readily seen. To measure the voltage of the displayed waveform measure its overall height in centimetres by the calibrated graticule, then multiply this by the Attenuator setting and the result is in Volts p-p, e.g. if the display is 6cm high and the Attenuator is set to 0.5V then the amplitude is 6 x 0.5 = 3V peak to peak, to convert to RMS voltage for sine waves - divide the 3V by 2.84,

e.g. $\frac{3}{2.85} = 1.06\text{V RMS}$

6.2 The frequency of the waveform can be found by turning the Time Base VERNIER to CAL (clockwise), then switch the TIME/CM switch to a range where the signal can be clearly seen, e.g. if a waveform is 2cm. long and the switch is on 100μSec, then the duration of the waveform is 2 x 100μSec. The frequency of the displayed waveform can be found by dividing 1 second by the waveform duration, e.g. $\frac{1{,}000{,}000\mu\text{Sec}}{200\mu\text{Sec}} = 5{,}000\text{Hz}$.

7. ISOLATED MEASUREMENTS AC OR DC.

With the isolated ground of Model bwd 503 measurements can be made between any two points of a circuit, even if neither are at ground potential. The COMMON terminal has an impedance to ground of 1MΩ and is shunted by a 0.1μF capacitor - this must be taken into account when connecting the COMMON to a point of high impedance. Maximum voltage that may be applied to the COMMON terminal is + or - 400V DC.

8. CURRENT MEASUREMENTS AC OR DC.

As this Model is isolated, it may be used to measure the voltage drop across a known resistor, and by use of Ohms Law; this may be converted to current. With 1 1Ω resistor across the vertical input terminals, the attenuator reads in mA and AMPS directly.

8.1 If this resistor is placed in series between a source and a load, the Oscilloscope will read the current flowing, either AC or DC in mA or AMPS, e.g. o.1V on the Attenuator = 0.1A, 0.2V = 0.2A, etc., and unlike a meter will show the actual current waveform - a practical application is the charging current in a filter capacitor of a power supply or the current through a rectifier, etc.

9. MEASUREMENTS WITH AN EXTERNAL HORIZONTAL INPUT.

As the Horz. Input is directly coupled, the CRT display can be used for X-Y plotting over an 8 x 10cm area.

9.1 First calibrate the Horizontal Amplifier by feeding in 5V p-p waveform and adjusting the HORZ. GAIN until the display equals 5cm. long; now set the Vertical Attenuator to 1V/cm. The Oscilloscope has now identical X and Y sensitivities, of 1V per cm. (Other sensitivies can be used with equal or unequal sensitivities, as required).

9.2 Remove the calibrate waveform and centre the spot. Positive or negative voltages may now be applied to X and Y inputs and the result plotted on tracing paper placed over the CRT or transferred to a ruled graph paper. AC signals will show phase displays or Lissajous figures. With the vertical input switched to DC there is less than 3° phase shift DC to 20kHz between X and Y input.

10. CIRCUIT DESCRIPTION

NOTE: As the circuit is isolated from gound, all measurements must be made with respect to the COMMON terminal on the front panel.

10.1 Vertical Amplifier. Signals applied to the Input terminal are switched straight through to the attenuator in the DC position of S1 or via C1 to block the DC component in the AC position. Switch S2A-D attenuates the input signal in a 2,5,10,20 sequence. Section S2A & B attenuate the signal in a 1,10,100,1000 sequence every 3rd step. Sections

S2C and D steps the input in the 2,5,10 sequence. As the two sections are cascaded the result follows the 2,5,10,20 sequence. To maintain constant AC to DC ratio the resistor dividers are parallel by capacitors, adjusted such that the C x R value of the series arm is equal to the C x R value of the shunt arm to each step. The vertical amplifier comprises a balanced series shunt compensated stage driving a cascade deflection amplifier stage.

10.2 Q1 and Q2 FET's are the input series compensated amplifiers which provide a high impedance for the input signal from the attenuator and a constant current source for the following shunt compensated stage. Input protection for Q1 is provided by reversed biased low leakage diodes D1 and D2. In the event of a positive overvoltage being applied to the input, D1 will conduct into the low impedance of R31, whilst D2 conducts via C20 and the zener D9 with large negative signals.

The zener in the sources of Q1 and Q2 changes the amplifier gain in opposition to changes of line voltage and thus maintain a constant calibration sensitivity irrespective of line voltage variation. To further minimise line effects on the display, Q1 and Q2 are accurately matched for both gain and operating current and RV3 balance potentiometer provides the final adjustment to virtually eliminate all line or signal variations on the DC rails.

Amplifier calibration is adjusted by shunt resistor RV2, whilst positioning voltages are applied from RV1 via R20 and R21 and mixed with the input signal at Q1 and Q2 drains where it is directly coupled to the shunt feed back stage Q3 and Q4. This stage provides a high gain and wide bandwidth with very low output impedance enabling it to drive the output stage directly. The output cascode stage Q5 to Q8 incorporates high frequency compensation located between Q5 and Q6 emitters.

CRT Y - plates are directly coupled to Q7 and Q8 collectors whilst internal trigger take off from the collectors is via resistors R50 and 51.

10.3 Trigger Circuit. Internal + or - trigger signals are selected by S3 and applied via C30 to Q9 trigger input.

Q9 and Q10 form a Schmitt Trigger which generates a precise amplitude fast rise and fall pulse from any input signal large enough to trigger it.

The action is as follows:-

With Q9 conducting its collector will bottom and Q10 will be cut off by the voltage divider across R54,55,58 and RV4. A negative going input will cut off Q9, its collector will rise pulling Q10 into conduction so producing a negative going voltage drop across its collector load R59. Q9 and Q10 have a common emitter load R56, therefore current through Q10 will hold Q9 cut off until the input signal changes polarity and rises positively reversing the switching action.

Trigger sensitivity is set by RV4 sensitivity preset.

10.4 Time Base. This circuit consists of Q11 and Q12 bi-stable trigger, Q14 FET Miller integrator and Q15 emitter follower output. D3 is the Auto gating diode driven by Q13 the blanking generator. Diode D6 gates the Miller stage, D4 and D5 clamp Q11 and Q12, D8 sets the trace length and D7 the starting level of the saw tooth waveform.

10.5 The operation is as follows:

Assuming Q11 in conducting, Q12 will be cut off, its collector will rise and D12 will conduct, pulling the gate of Q14 positive. The drain of Q14 will fall to approximately +3V pulling down Q15 base. At this point diode D7 connected into the emitter load of Q15 passes below zero, conducts and pulls Q12 collector down reducing the conduction of D4.

10.6 The circuit stabilises in this quiescent state with the trace ready for a trigger input pulse from Q10 via C33. A negative pulse on Q11 base will cause its collector to rise taking Q12 base positive. This causes current to flow through Q12 through the emitter resistor R72, biasing Q12 saturates. D6 becomes reverse biased, Q14 is left with its gate at -1V approximately and connected through the timing resistor R74 and 76 as selected by S4C to a negative potential on RV5A. This voltage will endeavour to pull Q14 towards cut-off. However, the timing capacitors selected by S4C are in circuit between the gate and drain of the Miller FET Q14 and will be charged by the current through the timing resistor.

10.7 Q14 FET gate presents a high impedance to the charging circuit enabling high value charging resistors to be utilised with small high stability timing capacitors. Q15 emitter follower provides a low output impedance to charge the timing capacitors and drive the output amplifier and gating circuits. As Q14 gate falls its collector rises and via Q15, R77 and C35 a charge is applied to the selected timing capacitor on S4C.

The result of this negative feedback is to linearise the charging rate of the timing capacitor and to produce a positive going sawtooth waveform at the drain of Q14 and via the DC coupling to Q15 where it is available at low impedance from the emitter. The sawtooth voltage continues to rise until the potential at the junction of RV7 and D8 reaches approximately -6V, D8 then conducts and charges C42, 44, 45, 46 as selected by S48 . It also takes the base of Q11 positive to its emitter potential and continues positively until Q11 conducts causing its collector to fall, cutting off Q12 and at the same time transferring the emitter current from Q12 to Q11. D6 conducts pulling the gate of Q14 positively, its drain voltage falls, rapidly discharging the timing capacitor until Q15 emitter falls sufficiently to cause D7 to conduct and pull D6 back to a quiescent condition and stabilise the circuit condition ready for the next trigger pulse. This will initiate the next trace once the hold-off capacitor C42, 44, 45 and 46 to have discharged through R62 and the base current of Q11 to allow D4 to clamp the base of Q11 in its ready state.

10.8 The Auto Time base operation is obtained as follows. During the sweep time Q12 is conducting, its collector is negative to ground so Q13 whose base is connected via R71 to Q12 collector is negative to ground so Q13 whose base is connected via R17 to Q12 collector conducts and via D3 clamps R60 near ground potential discharging capacitors C32 and C43-46 as selected by S4A. During the return trace period Q12 ceases to conduct, its collector rises and turns off Q13, D3 disconnects allowing the selected Auto capacitor to charge through the divider R56, 61 and 62. The junction of R60 and 61 falls and if no trigger signal is present to initiate the circuit, it will continue negatively until D4 becomes forward biased pulling down the diode clamp divider and causing Q11 to become reversed biased thus initiating the time base to produce one sweep. This action is repeated until a trigger pulse is generated to lock the time base, thus providing a bright base line at all sweep speeds when no trigger signal is present.

10.9 CRT blanking during the return trace is performed by PNP transistor Q13 which is held by the divider R70 and R71. When Q12 is cut off during the return trace its collector rises and via R70 and 71, Q13 cuts off causing its collector to fall towards -50V. The fall in voltage is applied to the CRT grid via C57 to blank the trace. Diode D10 clamps the blanking pulse to ensure a constant brightness at all time base speeds. At the start of the forward trace Q12 again conducts heavily biasing Q13 on via R71. The collector rises rapidly to -0.2V. The positive going pulse from the collector to the CRT grid to unblank it is fed through C51.

10.10 Horizontal Amplifier. Q16 and 17 amplifies the time base sawtooth waveform on an external horizontal input. They form an emitter coupled long tail pair.

Four input signals feed Q16 base, these are:-

1. The time base waveform via R78 from Q15.
2. Via R81 from the X input socket and HORZ vernier control.
3. Horizontal position voltage via R84 from position control RV8.
4. A centering voltage via R85 from the -46V rail.

10. CIRCUIT DESCRIPTION (Cont'd.)

When the time base is turned off for X-Y operation, all switching is accomplished by S4. S4B connects R103 to the -46V rail and turns off the time base, Q14 gate is connected to Q15 emitter. Q15 falls to zero leaving all inputs to Q16 at approximately zero potential leaving the position control able to vary it over a + and - range.

As the Ext. input is applied to the same input transistor as the positive going time base signal, +ve inputs will deflect the spot to the right.

10.11 CRT. Negative EHT is obtained by voltage doubling the 500V AC winding by D11 to 14 and capacitors C52 - 55 both doubling and filtering. Blanking is obtained as previously discussed. Intensity is adjusted by RV11 connected in a divider with R107, focus control RV10 and R101 across the EHT supply.

Astigmatism is preset by RV9 internally.

10.12 Power Supplies.

+ 44V. D17 half wave rectifies a 51V AC winding which is followed by a three stage filter C61, C59-61, this supplies the +44V requirements.

-46V. The same 51V AC winding is also half wave rectified by D18 and followed by C62, 63 and 64 three stage filter for the -ve 46V supply.

The -50V tapping on the filters used to supply Q13 blanking amplifier and Q1 and 2 input amplifiers.

+180V. An 82V winding is doubled by D15 and D16, C57 and C58 and filtered by a single stage R96 and C56 for the horizontal and vertical output stages.

11. ADJUSTMENTS AND MAINTENANCE

11.1 A number of preset controls are contained in this instrument which may require periodical adjustments to maintain its full calibration.

Before removing the top cover, disconnect the instrument from the mains. Remove the two screws holding the handle, then withdraw the cover. The bottom cover may be removed by unscrewing the feet.

To aid fault finding, the voltages and waveforms present at various points are shown on the circuit.

11.2 If the input FET requires replacing they must be replaced with a selected pair balanced for current and gain to ensure correct calibration and minimum trace movement with input line change.

11.3 Alignment Procedure. When instrument functioning and trace aligned to graticule, check the following details prior to alignment with Time Base switched to 1mSec.

11.4 Check operation of Time Base and Vernier on each Time Base range.

11.5 Turn Time Base switch to HORZ. AMP. spot should move ±5cm with Horizontal Shift.

11.6 General Check of Controls:-

(a) Intensity: Complete control over intensity range.

(b) Focus: Adjustment available either side.

(c) Vert. Position: Trace should move completely off screen above and below centre.

11.7 CRT Trace Alignment. If a 1000Hz sine wave signal is available, feed this into the Vertical Amplifier and adjust waveform for 6cm deflection T.V. to 1mSec. Vernier at Cal.

The astigmatism preset RV9 at the rear of the P.C. board is adjusted in conjunction with the Focus control to obtain the best resolution over the entire screen area when intensity is adjusted to maximum brightness but without fly back showing.

11.8 Attenuator and Calibration. Test equipment required 1kHz Square Wave Generator.

Set attenuator to 0.02V, feed in 100mV p-p (1% accuracy) square wave. Adjust RV2 for 5cm display. Vertical amplifier of oscilloscope is now correctly calibrated.

The following chart indicates the adjustments necessary to fully align the attenuator.

Attenuator Setting	Input Voltage	Adjustment for Square Wave
0.02	100mV	-
0.05	200mV	C14
0.1	500mV	C15
0.2	1V	C5
0.5	2V	C12
1	5V	C13
2	10V	C6
5	20V	-
10	50V	-
20	100V	-
50	100V	-
100	100V	-

Attenuator will be automatically aligned at attenuator positions where there is no capacitor.

11.9 Vertical Amplifier

Test equipment required 100kHz Square Wave Generator, less than 50nSec. rise time. (bwd 112B is suitable if terminated by 100Ω at input terminals of scope).

Attenuator to 0.2V, input selector to AC, signal input 1V p-p 100kHz T. B. range 1μSec Vernier to Cal. Check square wave is a good shape. No adjustment is available but R36 can be varied if necessary.

Check bandwidth with a constant amplitude sine wave generator. Adjust deflection for 4cm at 50kHz, display should not drop to less than 2.8cm at 3MHz.

11.10 Horizontal Amplifier

Test equipment 1Hz to 1MHz Sine Wave Generator (Model bwd 141). Feed in 50kHz sine wave to Vertical Amplifier. Time Base to 100μSec/cm, Vernier anticlock. Adjust RV7 to set trace length to 10.2cm.

Now disconnect oscillator from vertical input and reconnect to Horizontal Input. Adjust display for 6cm deflection at 1kHz, increase frequency and note frequency when trace drops to 4.2cm length - it should be above 100kHz.

Sensitivity: Feed in 1kHz square wave 6V p-p amplitude, trace should be approximately 10cm long at maximum gain and 1cm long at minimum gain.

11.11 X - Y Phase Measurement

Turn attenuator to 1V/cm, feed in 6V p-p 1kHz sine wave to both vertical and horizontal inputs. Adjust Horz. Vernier for a 45° line on CRT, i.e. equal X - Y sensitivities. Now increase frequency, line should not open in the centre of the wave more than 3mm at frequencies to 20kHz. At maximum sensitivity.

11.12 Trigger Sensitivity

Feed in 50kHz sine wave, time base to 10μSec/cm, + or - trigger selection. Reduce amplitude of input signal until trace ceases to lock. Adjust RV4 (centre front of board) for maximum sensitivity of trigger - <1cm display amplitude. Increase display to 3cm deflection increase frequency of input up to >3MHz, note that trace remains locked both + or -ve selection.

To check low frequency trigger use a bwd 141 oscillator. 1cm deflection will trigger to 20Hz and 3cm down to 5Hz.

11.13 Time Base

Test equipment required <1% accuracy generator with 1µSec to 0.1Sec output in decade steps. Set Time Base Range to 1mSec, Vernier to Cal. Feed in 1mSec pulse to amplifier and adjust RV6 (T.B. Cal. front right of P/C board) to display 1 pulse per cm. Check the following steps with the frequency indicated and if necessary adjust RV9 for a compromise setting to obtain the minimum error at each step.

T.B. Range	Input Frequency	
1µSec	1MHz)	all ranges set by RV6
10µSec	10kHz)	
1mSec	1kHz)	
10mSec	100Hz)	

12. REPLACEMENT PARTS

12.1 Spares are normally available direct from the manufacturer. When ordering, it is necessary to indicate the serial number of the instrument. If exact replacements are not to hand, locally available alternatives may be used, provided they possess a specification not less than, or physical size not greater than the original component.

12.2 As the policy is one of continuing research and development, the Company reserves the right to supply the latest equipment and make amendments to circuits and parts without notice.

13. WARRANTY

13.1 The equipment is guaranteed for a period of six (6) months from the date of purchase against faulty materials and workmanship with the exception of cathode ray tubes, which are covered by their manufacturers own warranty.

13.2 Please refer to Guarantee Card No. 15621 which accompanied instrument for full details of conditions of warranty.

REPLACEABLE PARTS.

1. This section contains information for ordering replacement parts, it provides the following details:-

   (a) Description of part (see list of abbreviations).
   (b) Typical manufacturer or supplier of the part (see list of abbreviations).
   (c) Manufacturer's Part Number, and
   (d) Defence Stock Number, where applicable.

2. Ordering - Please quote Model Type No., e.g. bwd 511, Serial No. Circuit Reference No. and component details as listed in parts list.

COMPONENT DESIGNATORS.

A	Assembly	H	Heater	RV	Resistor Variable
B	Lamp	J	Jack (socket)	S	Switch
C	Capacitor	L	Inductor	T	Transformer
D	Diode	M	Meter	TH	Thermistor
DL	Delay Line	P	Plug	V	Valve
E	Misc. Elect. Part	Q	Transistor	VDR	Voltage Dependent Resistor
F	Fuse	R	Resistor		

ABBREVIATIONS

Amp	Ampere	L	Inductor
C	Capacitor	lin	Linear
cc	Cracked Carbon	Log	Logarithmic Taper
c	Carbon	m	Milli = 10^{-3}
cd	Deposited Carbon	MHz	Mega Hertz = 10^{6}Hz
comp	Composition	MF	Metal Film
CDS	Ceramic Disc Capacitor	ma	Milli Ampere
cer	ceramic	MΩ	Meg Ohm = $10^{6}\Omega$
Com	Common	mfr	Manufacturer
DPST	Double Pole Single Throw	MO	Metal Oxide
DPDT	Double Pole Double Throw	MHT	Polyester/Paper Capacitor
elec	Electrolytic	MPC	Metalised Polyester Capacitor
F	Farad	Ne	Neon
f	Fuse	NPO	Zero temperature co-efficient
FET	Field Effect Transistor	nsr	Not separately replaceable
Ge	Germanium	NC	Normally Closed
H	Henry(ies)	NO	Normally Open
H.S.	High Stability	ns	Nano second
HTC	High Temp Coating	obd	Order by Description
ins	Insulated	OD	Outside Diameter
kHz	Kilo Hertz = 10^{3}Hz	p	Peak
KΩ	Kilo Ohm = $10^{3}\Omega$	pf	pico farad = 10^{-12}F

COMPONENT ABBREVIATIONS (Cont'd.)

PL	Plug	SPDT	Single Pole Double Throw
PS	Socket	SPST	Single Pole Single Throw
Preset	Internal Preset	S. Shaft	Slotted Shaft
PYE	Polyester	Si	Silicon
pot	Potentiometer	Ta	Tantalum
prec	Precision	tol	Tolerance
PC	Printed circuit	trim	trimmer
PIV	Peak Inverse Voltage	V	Volt(s)
PYS	Polystyrene	var	variable
p-p	Peak to Peak	vdcw	Volts Direct Current Working
P. Shaft	Plain Shaft	w	Watt(s)
Q	Transistor	ww	Wire Wound
R	Resistor	Z	Zener
rot	rotary	*	Factory Selected value, nominal value may be shown
R log	Reverse Logarithmic Taper		
rms	Root Mean Squared	**	Special component, no part no. assigned.

MANUFACTURERS ABBREVIATIONS.

AB	A.B. Electronics	J	Jabel
AEE	AEE Capacitors	McH	McKenzie & Holland (Westinghouse)
AN	Anodeon	MAS	Master Instrument Co. Pty Ltd.
AST	Astronic Imports	MOR	Morganite (Aust.) Pty. Ltd.
AWA	Amalgamated Wireless of Aust.	MSP	Manufacturers Special Products (AWA)
ACM	Acme Engineering Pty. Ltd.	McM	McMurdo (Aust.) Pty Ltd.
AMP	Aircraft Marine Products (Aust.) Pty. Ltd.,	MOT	Motorola
		NU	Nu Vu Pty. Ltd.
AR	A & R Transformers	NAU	A.G. Naunton Pty. Ltd.
AUS	Australux Fuses	NS	National Semiconductor
AWV	Amalgamated Wireless Valve Co.	PA	Painton
		PAL	Paton Elect Pty. Ltd.
ACA	Amplifier Co. of Aust.	PI	Piher Resistors (Sonar Electronics)
ARR	Arrow	PH	Philips Electrical Industries Pty. Ltd.
BWD	B.W.D. Electronics Pty. Ltd.	PL	Plessey Pacific
BL	Belling & Lee Pty. Ltd.	PRO	Procel
BR	Brentware (Vic.) Pty. Ltd.	PV	Peaston Vic
BU	Bulgin	RC	Radio Corporation (Electronic Inds.)
CF	Carr Fastener	RCA	Radio Corporation of America
CAN	Cannon Electrics Pty. Ltd.	RHC	R.H. Cunningham
CIN	Cinch	STC	Standard Telephone & Cables
DAR	Darstan	SI	Siemens Electrical Industries
DIS	Distributors Corporation Pty. Ltd.	SIM	Simonson Pty. Ltd.
		SE	Selectronic Components
ELN	Elna Capacitors (Sonar Elec. Pty. Ltd.)	SON	Sonar Electronics
		TR	Trimax Erricson Transformers
ETD	Electron Tube Dist.	TI	Texas Instruments Pty. Ltd.
F	Fairchild Australia Pty Ltd.	TH	Thorn Atlas
GRA	General Radio Agencies	UC	Union Carbide
GE	General Electric (USA)	W	Wellyn Resistors (Cannon Elec. Pty. Ltd.)
GEC	General Electric Co. (UK)	WH	Westinghouse
GES	General Electronic Services	Z	Zephyr Prod. Pty. Ltd.
HW	Hurtle Webster		
HOL	R G. Holloway		
H	Haco Distributors (National)		
HS	Hawker Sidney		

CCT Ref.					Mfr. or Supply	PART NO.	
	RESISTORS						
R1	900K	2%	1/4Watt	CC			
R2	1MΩ	2%	1/4Watt	CC			
R3	111K	2%	1/4Watt	CC			
R4	9K2	2%	1/4Watt	CC			
R5	1K	2%	1/4Watt	CC			
R6	800K	2%	1/4Watt	CC			
R7	1M2	5%	1/2Watt	CC			
R8	1M2	5%	1/2Watt	CC			
R9	250K	2%	1/4Watt	CC			
R10	680K	2%	1/4Watt	CC			
R11	220K	5%	1/4Watt	CC			
R12	1M	5%	1/2Watt	CC			
R13	82	5%	1/2Watt	CC			
R14	1M	5%	1/2Watt	CC			
R20	100K	5%	1/2Watt	CC			
R21	100K	5%	1/2Watt	CC			
R22	2K2	5%	1/2Watt	CC			
R23	10K	5%	1/2Watt	CC			
R24	82	5%	1/2Watt	CC			
R25	1K8	5%	1/2Watt	CC			
R26	1K8	5%	1/2Watt	CC			
R27	10K	5%	1/2Watt	CC			
R28	1K	5%	1/2Watt	CC			
R29	1K5	5%	1/2Watt	CC			
R30	4K7	5%	1/2Watt	CC			
R31	270Ω	5%	1/2Watt	CC			
R32	560Ω	5%	1/2Watt	CC			
R33	12K	5%	1 Watt	CC			
R34	12K	5%	1 Watt	CC			
R35	5K6	5%	1/2Watt	CC			
R36	33Ω	5%	1/2Watt	CC			
R37	180Ω	5%	1/2Watt	CC			
R38	180Ω	5%	1/2Watt	CC			
R39	33Ω	5%	1/2Watt	CC			
R50	220K	5%	1/2Watt	CC			
R51	220K	5%	1/2Watt	CC			

CCT Ref.	DESCRIPTION				Mfr. or Supply	PART NO.	
	RESISTORS						
R52	22K	5%	1/2Watt	CC			
R53	180K	5%	1/2Watt	CC			
R54	1K	5%	1/2Watt	CC			
R55	10K	5%	1/2Watt	CC			
R56	27K	5%	1/2Watt	CC			
R57	6K8	5%	1/2Watt	CC			
R58	27K	5%	1/2Watt	CC			
R59	2K2	5%	1/2Watt	CC			
R60	33K	5%	1/2Watt	CC			
R61	2K2	5%	1/2Watt	CC			
R62	220K	5%	1/2Watt	CC			
R63	33K	5%	1/2Watt	CC			
R64	3K3	5%	1/2Watt	CC			
R65	6K8	5%	1/2Watt	CC			
R66	47K	5%	1/2Watt	CC			
R67	47K	5%	1/2Watt	CC			
R68	15K	5%	1/2Watt	CC			
R69	120K	5%	1/2Watt	CC			
R70	56K	5%	1/2Watt	CC			
R71	1K	5%	1/2Watt	CC			
R72	22K	5%	1/2Watt	CC			
R73	8K2	5%	1/2Watt	CC			
R74	1M5	5%	1/2Watt	CC			
R75	33K	5%	1/2Watt	CC			
R76	820K	5%	1/2Watt	CC			
R77	2K2	5%	1/2Watt	CC			
R78	100K	5%	1/2Watt	CC			
R79	10K	5%	1/2Watt	CC			
R80	22K	5%	1/2Watt	CC			
R81	100K	5%	1/2Watt	CC			
R82	8K2	5%	1/2Watt	CC			
R83	10K	5%	1/2Watt	CC			
R84	150K	5%	1/2Watt	CC			
R85	2M2	5%	1/2Watt	CC			
R86	33K	5%	1 Watt	CC			
R87	33K	5%	1 Watt	CC			
R88	390Ω	5%	1/2Watt	CC			
R89	8K2	5%	1/2Watt	CC			
R90	47K	5%	1/2Watt	CC			
R91	10M	5%	1/2Watt	CC			
R92	1M	5%	1/2Watt	CC			
R93	1M	5%	1/2Watt	CC			
R94	1M	5%	1/2Watt	CC			
R95	1M	5%	1/2Watt	CC			
R96	1K5	5%	1 Watt	CC			

PARTS LIST - MODEL bwd 503.

CCT Ref.	DESCRIPTION				Mfr. or Supply.	PART NO.	
	RESISTORS						
R97	470Ω	5%	1/2Watt	CC			
R98	680Ω	5%	1/2Watt	CC			
R99	270Ω	5%	1/2Watt	CC			
R100	470	5%	1/2Watt	CC			
R101	2M2	5%	1 Watt	CC			
R102	680K	5%	1/2Watt	CC			
	CAPACITORS						
C1	0.1μF -	400V	10%	PYE	PH	2202-315-51104	
C2	5.6pF	500V	10%	CDS	AC		
C3	18pF	500V	10%	CDS	AC		
C4	18pF	500V	10%	CDS	AC		
C5	2-10pF	TRIM CAP.			IRH	CT3	
C6	470pF	250V	5%	PYS	AC		
C7	4700pF	400V	10%	PYE	PH	2202-315-51472	
C8	0.1μF	400V	10%	PYE	PH	2202-315-51104	
C9	22pF	500V	10%	CDS	AC		
C10	5.6pF	500V	10%	CDS			
C11	15pF	500V	5%	CDS	AC		
C12	2-10pF	TRIM CAP.			IRH	CT3	
C13	2-10pF	TRIM CAP.			IRH	CT3	
C14	2-10pF	TRIM CAP.			IRH	CT3	
C15	2-10pF	TRIM CAP.			IRH	CT3	
C16	4.7pF	500V	5%	CDS	AC		
C17	0.0022μF	500V	10%	CDS	HS		
C20	100μF	25V		Electr.	PH	2222-016-16101	
C21	33μF	40V		Electr.	PH	2222-015-17339	
C22	22pF	250V	5%	PYS	AC		
C23	680pF	250V	5%	PYS	AC		
C24	47pF	250V	5%	PYS			
C30	0.1μF	160V	10%	PYE	PH	2202-315-31104	
C31	22pF	500V	5%	CDS	AC		
C32	0.01μF	160V	10%	PYE	PH	2202-315-31103	
C33	15pF	500V	5%	CDS	AC		
C34	22pF	500V	5%	CDS	AC		
C35	0.01μF	160V	10%	PYE	PH	2202-315-31103	
C36	22pF	500V	5%	CDS	AC		

CCT Ref.	DESCRIPTION				Mfr. or Supply	PART NO.	
	CAPACITORS						
C37	0.1μF	100V	10%	GREENCAP	ELNA		
C38	0.01μF	100V	10%	GREENCAP	ELNA		
C39	0.001μF	250V	5%	PYS	AC		
C40	100pF	500V	5%	CDS	AC		
C41	22pf	500V	5%	CDS	AC		
C42	680pF	250V	5%	PYS	AC		
C43	10μF	25V		Electr.	PH	2222-015-16109	
C44	1μF	63V		Electr.	PH	2222-015-18708	
C45	0.1μF	160V	10%	PYE	PH	2202-315-31104	
C46	4700pF	400V	10%	PYE	PH	2202-315-51472	
C48	68pF	500V	5%	CDS	AC		
C50	0.1μF	160V	10%	PYE	PH	2202-315-31104	
C51	0.01μF	2.5KV		CDH	D		
C52	8μF	450V		Electr.	ELNA		
C53	8μF	450V		Electr.	ELNA		
C54	8μF	450V		Electr.	ELNA		
C55	8μF	450V		Electr.	ELNA		
C56	40μF	200V		Electr.	PH	2222-040-12409	
C57	50μF	150V		Electr.	PH	2222-040-11509	
C58	50μF	150V		Electr.	PH	2222-040-11509	
C59	68μF	63V		Electr.	PH	2222-017-18689	
C60	68μF	63V		Electr.	PH	2222-017-18689	
C61	68μF	63V		Electr.	PH	2222-017-18689	
C62	68μF	63V		Electr.	PH	2222-017-18689	
C63	68μF	63V		Electr.	PH	2222-017-18689	
C64	68μF	63V		Electr.	PH	2222-017-18689	
C65	0.1μF	160V	10%	PYE	PH	2202-315-31104	

CCT Ref	DESCRIPTION		Mfr. or Supply	PART NO.	
	DIODES				
D1	Silicon Signal Diode		F	AN206	
D2	Silicon Signal Diode		F	AN206	
D3	Silicon Signal Diode		F	AN206	
D4	Silicon Signal Diode		F	AN206	
D5	Silicon Signal Diode		F	AN206	
D6	Silicon Signal Diode		F	AN206	
D7	Silicon Signal Diode		F	AN206	
D8	Silicon Signal Diode		F	AN206	
D9	33V Zener Diode		F	AN973B	
D10	Silicon Signal Diode		F	AN206	
D11	Silicon Power Diode	1000V	AEE	PAB2124	
D12	Silicon Power Diode	1000V	AEE	PAB2124	
D13	Silicon Power Diode	1000V	AEE	PAB2124	
D14	Silicon Power Diode	1000V	AEE	PAB2124	
D15	Silicon Power Diode		STC	EM404	
D16	Silicon Power Diode		STC	EM404	
D17	Silicon Power Diode		STC	EM404	
D18	Silicon Power Diode		STC	EM404	
	TRANSISTORS				
Q1	Silicon N Channel FET		NS	MPF106	Match Q2
Q2	Silicon N Channel FET		NS	MPF106	Match Q1
Q3	NPN Silicon Transistor		PH	BF194	
Q4	NPN Silicon Transistor		PH	BF194	
Q5	NPN Silicon Transistor		PH	BF194	
Q6	NPN Silicon Transistor		PH	BF194	
Q7	NPN Silicon Transistor		PH	BF337	
Q8	NPN Silicon Transistor		PH	BF337	
Q9	NPN Silicon Transistor		PH	BC147	
Q10	NPN Silicon Transistor		PH	BC147	
Q11	NPN Silicon Transistor		PH	BC147	
Q12	NPN Silicon Transistor		PH	BC147	
Q13	PNP Silicon Transistor		PH	BC157	
Q14	Silicon N Channel FET		NS	MPF106	
Q15	NPN Silicon Transistor		PH	BC147	
Q16	NPN Silicon Transistor		PH	BF337	
Q17	NPN Silicon Transistor		PH	BF337	

CCT Ref	DESCRIPTION				Mfr. or Supply	PART NO.	
	POTENTIOMETERS						
RV1	100KΩ	'A' Curve	Pot				
RV2	470Ω	Preset	Pot	C	PH	2322-411-022/470E	
RV3	100Ω	Preset	Pot	C	PH	2322-411-022/100E	
RV4	22KΩ	Preset	Pot	C	PH	2322-411-022/22K	
RV5	100KΩ	'A' Curve	Dual Pot				
RV6	100KΩ	Preset	Pot	C	PH	2322-411-022/100K	
RV7	4.7K	Preset	Pot	C	PH	2322-411-022/4K7	
RV8	100KΩ	'A' Curve	Pot				
RV9	100KΩ	Preset	Pot	C	PH	2322-411-022/100K	
RV10	1MΩ	'A' Curve	Pot				
RV11	220KΩ	'A' Curve	Pot with DPST SW.				
	SUNDRIES						
V1	CRT 5" Single Gun				Hitachi	5UP1F	
B1	Neon 240V Red				S	MB227	
T1	Power Transformers				BWD	T122A	
S1	2 Pole 2 Pos. Slide Switch				McM	SW014-02-02	
S2A-D	12 Pos. 4 Deck Rot. Switch				MSP	69003-011	
S3	2 Pole 2 Pos. Slide Switch				McM	SW014-02-02	
S4A-D	6 Pos. 3 Deck Rot. Switch				BWD	SR49B	
S5	2 Pole 2 Pos. Rear of RV11						

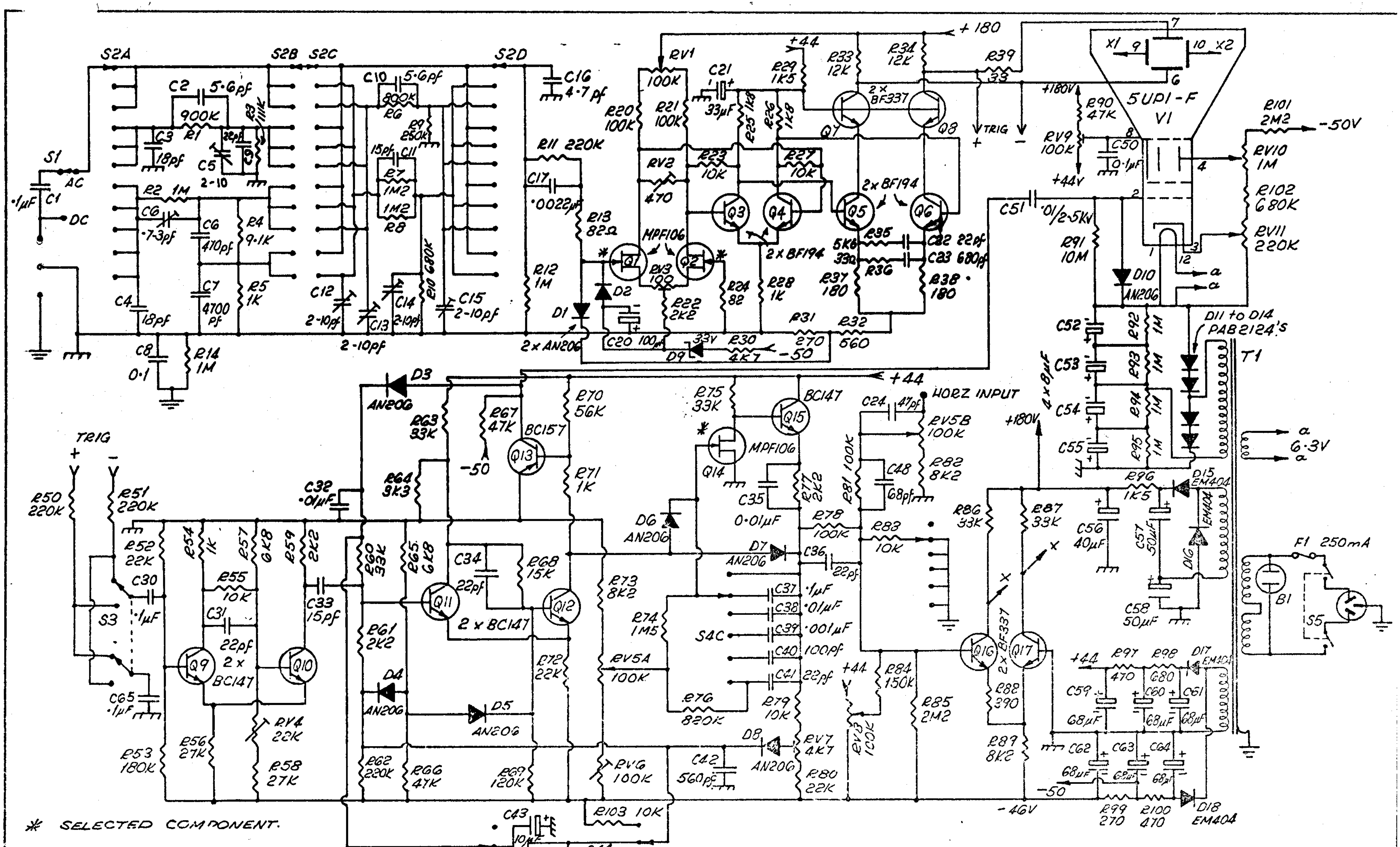
ALL OTHER ITEMS ORDER BY DESCRIPTION

R1 ↓ R102	MODIFICATIONS	SWITCHES	WAVEFORMS
C1 ↓ C65		S1 – AC–DC INPUT.	
D1 TO D18		S2A-D INPUT ATTENUATOR	
Q1 ↓ Q17		S3 + OR – TRIGGER.	
		S4A-D TIME BASE RANGE.	
		S5 A.C. POWER ON-OFF (REAR RV11)	

CONTROLS

RV1	VERTICAL POSITION.	
RV2	VERTICAL GAIN CALIBRATE.	φ
RV3	D.C. BALANCE	φ
RV4	TRIGGER SENSITIVITY	φ
RV5A & B	HORIZONTAL VERNIER	
RV6	TIME BASE CALIBRATE.	φ
RV7	TRACE LENGTH.	φ
RV8	HORIZONTAL POSITION	
RV9	ASTIGMATISM	φ
RV10	FOCUS	
RV11	INTENSITY.	

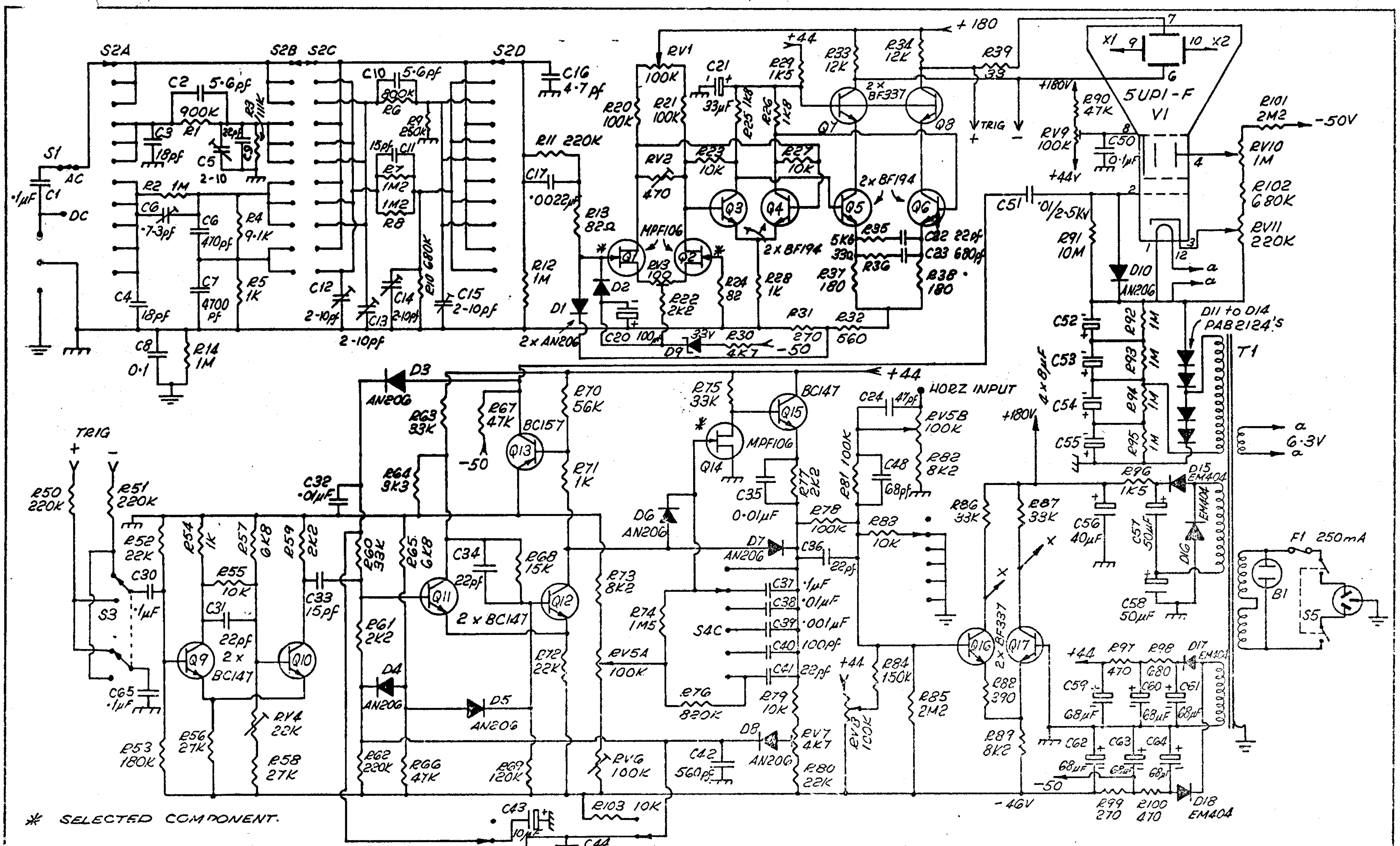
φ = PRESET



* SELECTED COMPONENT.

COMPONENTS MAY VARY FROM THOSE DESIGNATED DUE TO AVAILABILITY OR TO OPTIMISE PERFORMANCE.

1 / 11-73	DRAWN M.D TRACED L.P. CHECKED DATE 16-4-73	5" OSCILLOSCOPE (503)	DRG.NO. 1092



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1 / 11-73	DRAWN M.D. TRACED L.P. CHECKED DATE 16-4-73	5" OSCILLOSCOPE (503)	DRG.NO. 1092