MODEL bwd - 502

SOLID STATE 5" OSCILLOSCOPE

B.W.D. ELECTRONICS PTY. LTD.
331-333 BURKE ROAD, GARDINER
VICTORIA, AUSTRALIA

INSTRUMENT HANDBOOK

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INSTRUMENT HANDBOOK

MODEL bwd - 502

1. GENERAL Model bwd-502 Oscilloscope is a highly versatile instrument designed for 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.

Both Vertical and Horizontal amplifiers are directly 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, and with a suitable resister across the input, (e.g. 1Ω) it will operate as a direct reading amp or milliamp meter in addition to all normal oscilloscope functions.

The balanced input also allows measurement to be made across any circuit, from 240V A.C. power lines to transistors, without any possibility of shorting or loading.

The Time Base has a 5,000,000 to 1 frequency range of 0.2 μSec/cm to 1 Sec/cm and incorporates completely Automatic Triggering, Selective Trigger or Preset Trigger from Internal, External or 50 c's. The stability control has been completly eliminated, the new solid state trigger circuit being self setting and always ready to receive any input signal up to 5MHz.

When used with B.W.D. Model 190 or 112 Audio Oscillators, measurement and display of the complete audio spectrum can be made and in conjunction with the unique B.W.D. Model 602 Generator/Power Supplies Combination, a complete demonstration in the field of physics is open from basic magnetism and electricty, 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

C.R.T. Type: 5" Flat faced, 13/27 (GH) incorporating a spiral PDA and Beam Blanking.

Phosphor: GH, (P31) normally supplied, GL (P2) or GP (P7) available to special order

EHT: 3KV

Graticule: Fitted with 8 x 10 cm graticule and green light filter (orange filter for P7 phosphor)

VERTICAL AMPLIFIER

Bandwidth: D.C. or 2Hz (A.C. coupled) to over 3MHz, - 3 db at all sensitivities.

Sensitivity: 20, 50, 100, 200, 500mV, 1,2,5,10,20, and 50V p-p/cm.

Rise Time: 125 nano Seconds constant.

Calibration: Better than 5%.

Input Impedance: 1MΩ and approximately 35pf. single ended.
2MΩ and 18 pf balanced input.

Differential Rejection Ratio: Over 100-1 up to 0.05 p-p, over 20-1, 0.1V to 50V p-p/cm.

Max. Input Voltage: 500 D.C. or 250V A.C.

Common Terminal to Ground: 0.47uF and 1MΩ in parallel. Max. Voltage common to ground ±400V D.C. or 250V A.C.

TIME BASE

Range: 1μSec/cm to 1 Sec/cm in 6 decade ranges with calibrated VERNIER control.

Switch Calibration: Better than 5% from 10mSec to 1μSec/cm.
" " 10% at 100mSec.
" " 10% at x5 expansion all ranges.

Vernier Calibration: Approx. 10% all ranges.

Expansion: x1 to x5 continuously variable, calibrated both settings, extends top Time Base speed to 0.3μSec/cm

Blanking: Direct coupled to C.R.T. Blanking Electrode.

TRIGGER

Facilities: Switch selection INT or EXT, + or -
Control selection AUTO., Level Select or PRESET
50Hz TRIGGER by link connection from CAL output to EXT. TRIGGER

Sensitivity: Auto - 30Hz to over 5MHz with 1 cm deflection or 1V p-p external, sine or square wave.
Level Select - 1 Hz to 3MHz with 2 cm deflection or 2V p-p external.
Preset - 1 Hz to 1MHz for 2 cm deflection or 2V p-p external.

Level Select Range: ± 3 cm. min. internal
± 5V external.

Ext. trigger impedance: 250KΩ and 50 pf approx.

TRIGGER (Continued....)

Mechanical Trigger: Rear Panel sockets. With selector to PRESET and switches to EXT and -ve, a closing contact across the sockets will initiate the trace for a single shot.

HORIZONTAL AMPLIFIER

Bandwidth:	DC to 200 KHz (-3 db) at min. gain.
Sensitivity:	500mV to 5V p-p/cm. continuously variable.
Input Impedance:	1MΩ and 50pf approx.

VERTICAL TO HORZ. AMPL. PHASE SHIFT.

Less than 1° from DC to 5KHz. approx. 5° at 20 KHz.

'Z' MODULATION

Rear socket input to C.R.T. grid, input time constant 0.01MFD and 560KΩ. -20V will completely blank trace at normal intensity.

CALIBRATE WAVEFORM

1V p-p square wave 50Hz accuracy 2%. (negative going to common)

TIME BASE OUTPUT

Rear panel socket. 17V positive going sawtooth from -5V to +12V. Min. external load 100KΩ.

POWER REQUIREMENTS	210 to 250V, 50 to 60 Hz, approx. 35 watts.
DIMENSIONS	9" x 7" x 16" deep.
WEIGHT	approx. 18 lbs. (24 lbs packed).
ACCESSORIES	- Supplied with instrument 1 Standard handbook. 1 Power cord, complete with 3-pin plug
OPTIONAL ACCESSORIES	Refer Section 14 Page 19.

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:-

Intensity Controls: Fully anticlockwise, 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.

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

Horz. Shift: (Red Knob) Moves the trace horizontally on the C.R.T.

Horz. Gain: (Grey Knob) When the Time Base is in use, this control varies the length of the trace from 10 cms. to 50 cms, giving a X5 expansion. When an external Horizontal Input is used, the Horz. Gain varies the sensitivity from 500mV (0.5V) to 5V p-p/cm. approx.

T.B. Vernier: Varies the Time Base speed over a 10-1 range to provide a continuously variable range in conjunction with the TIME/cm switch of 1 sec/cm to 1μSec/cm. When the VERNIER control is turned and switched fully anti-clockwise it switches off the internal Time B se permitting an external signal to be fed into the HORZ. INPUT socket.

Time/cm (Time Base) Switch: When the Time Base Vernier control is fully clockwise in the CAL. position the six time base speeds on this control will be accurate to within 5%. The speeds of 100, 10 and 1mSec and 100, 10 and 1μSec represent the fastest speed on each range, rotation of the Time Base Vernier Control will reduce the selected speed over a 10-1 range, e.g. on the 1mSec range the Vernier will vary the time base from 1mSec down to 10mSec/cm. when fully anticlockwise.

+ - Switch: Selects the positive (+) or negative(-) slope of the displayed or external trigger waveform to initiate the time base.

EXT-INT Switch: Selects the Internal displayed waveform or an external waveform to trigger the time base.

Vertical Shift: Moves the trace up and down the C.R.T.

Atten. Balance: With trace centered and attenuator set to 0.2V Preset Balance is adjusted to eliminate vertical trace movement when attenuator is turned to 1V setting.

Auto, Trig. Level and Preset: Fully anticlockwise and switched to the AUTO position, any signal greater than 0.5 cm. in amplitude will trigger the time base and with no input signal an Automatic trigger pulse is generated to produce a base line, the trigger rate increases as the T.B. speed range increases. When the knob is switched out of the AUTO position, it selects the Level on a displayed waveform of ±3 cm or more to trigger the Time Base and fully clockwise selects the PRESET LEVEL position in which signals over 1cm will trigger the T.B.

Volts/cm (Attenuator)

Switch adjusts the sensitivity of the Vertical Amplifier from 20mV p-p (7mV RMS) to 50V p-p/cm in a 1,2,5,10 series of steps. Attenuator accuracy is 2% and the overall oscilloscope accuracy within 5% on any step. The attenuator varies the sensitivity of both + and - inputs simultaneously to maintain a balanced input.

D.C. - A.C. Switch:

In the D.C. position the amplifier is directly coupled from input to output and on the A.C. position a capacitor is placed in series with the input to eliminate any D.C. component and attenuate all frequencies below 2 c's.

TERMINALS AND SOCKETS FRONTPANEL

Vertical Input: + Red terminal. A positive input will cause the trace to move upwards. A negative input will cause it to move downwards.

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 or even connected directly to the 240V mains for special applications.

- Blue terminal. A positive input will cause the trace to move downwards. i.e. opposite to the + input. This provides a Balanced Input to the instrument and enables measurement to be made across practically any circuit as an impedance of 1MΩ exists on each input.

Horz. Input: When the Time Base Vernier is turned anticlockwise to T.B. "OFF", signals may be fed into this socket to produce a horizontal display, input is D.C. coupled, an external capacitor must be used if D.C. is present on the signal to be displayed.

CAL. 1V p-p: A 1 Volt peak to peak square waveform is available to check the amplifier calibration, T.B. calibration and for use as an external signal or when linked to the EXT. trigger socket below it, provides a 50 Hz trigger facility.

EXT. Trigger: When the Trigger Selection switch is in the EXT position signals from 1 to 20V will trigger the time base. Full selection of amplitude over a range of ±5V, PRESET 1V p-p or greater or AUTO with positive or negative selection are available.

REAR PANEL

Z Modulation: A 20V p-p square wave or a sine wave of 6V RMS or greater will blank the trace, negative going signals will blank the trace

Mechanical Trigger: A switch or contacts connected across the pair of terminals will initiate the trace for a single shot operation.

Time Base Output: A 17V p-p sawtooth swinging approx. -5 to +12V to ground is available at low impedance - min. external loading 100KΩ.

4. FIRST TIME OPERATION

Set the controls of Model bwd-502 as follows before switching on-

INTENSITY	Fully Anticlockwise
FOCUS	Centered
HORZ. SHIFT	Centered
HORZ. GAIN	Anticlockwise
TIME BASE VERNIER	Clockwise - CAL
TIME/CM	10mSec
+ - SELECTOR	+
INT-EXT TRIGGER	INT
VERT. SHIFT	Centered
TRIGGER LEVEL	Fully anticlockwise - AUTO
VOLTS/CM	0.2V
D.C. - A.C.	D.C.

Connect a link of wire from the CAL 1V p-p front panel socket to the +input terminal on the L.H. side. Connect instrument to power mains (210 to 250V A.C., 50 to 60 c's.)

Switch on by rotating the INTENSITY control about $\frac{3}{4}$ of a turn. A display will appear after about 10 seconds.

5 cycles of the calibration waveform should be present on the C.R.T., adjust the HORIZONTAL &VERTICAL SHIFT controls to centre the disply and the FOCUS &INTENSITY for a sharp, bright image.

Now turn the VOLTS/CM Switch to 0.1V and the display will expand over full screen height, turning the knob around to 0.5V, 1, 2, etc. will progressively reduce the height of the display. Below 0.5 cm. amplitude the trace may start to lose stability.

Return the attenuator to the 0.2V position. The effect of the D.C. - A.C. switch on low frequencies can now be seen by sliding the switch to the A.C. position. The top and bottom edges of the display will tilt indicating a loss of the lowest frequency components in the square wave. The trace will also move upwards and require recentreing, this is because the CAL waveform is negative going to ground and switching to A.C. eliminates the D.C. component.

Always use the D.C. position on frequencies below 100 Hz if possible, if no D.C. potential exists on the waveform sufficient to cause it to deflect off the C.R.T. Now turn the Time Base VERNIER Control, the waveforms will compress together, until at the anticlockwise position they are almost indistinguishable from each other and the trace will move slowly taking 1 second to traverse the screen. Switch the TIME/CM switch to 1mSec and again adjust the VERNIER to see the effect. Adjust the VERNIER to give 2 complete waveforms on the C.R.T. Now turn the TRIGGER LEVEL Knob clockwise, the display will disappear, then as the control is turned further it will re-appear. Notice how the start of the display moves slowly up the edge of the waveform until it disappears again at the top, bring the control back to centre and change the + and - slide switch over to -, the display will change so that the negative or falling slope of the waveform is triggering the display, rotation of the LEVEL control will again move the triggering point up or down the waveform. Return the control to AUTO and adjust the TIME/CM switch and VERNIER to give 5 waveforms across the C.R.T. Now turn the HORZ. GAIN control clockwise until one waveform is 10cm. long, this illustrates the trace expansion facility, if the HORZ. SHIFT is turned the trace can be tracked along to view any part of it from one end to the other with a linearity better than 5%.

Now turn the LEVEL CONTROL fully clockwise to the PRESET position. Again vary the amplitude of the signal by the attenuator and note how the trace disappears when the signal drops below 1 cm deflection. The greatest use of this facility is at low frequencies where the AUTO trigger cannot be used eliminating the need to set the LEVEL CONTROL.

Finally we can check the HORZ. INPUT. Turn the Time Base Vernier to T.B 'OFF' (anticlockwise) Connect a lead from the "CAL' socket to the HORZ. INPUT socket directly above it. A horizontal line will appear whose length can be varied by the HORZ. GAIN control from over 2cm. down to less than 2mm. The HORIZONTAL position of the trace can be set by the HORZ. GAIN control.

Mechanical trigger set controls as follows:

+ - selector to - INT-EXT to EXT, LEVEL CONTROL to PRESET
T.B RANGE to 100mSec VERNIER to 5
Short the rear panel TRIGGER SOCKET - yellow and black with a link of wire (only +6V exists on the yellow socket) and note how the trace is initiated each time the contact is made.
Z Modulation. Feed in an oscillator to the RED rear panel socket - ground connected to the BLACK trigger socket or Black front panel COMMON terminal.
With an input of 6VRMS or ±10V approx., trace will be intensity modulated at normal brightness level.

The more frequently the oscilloscope is used the more familiar becomes its operation and a greater number of uses and applications will be found for its use.

The following sections explain the operation of Model bwd-502 when used to make specific measurements.

NOTE: Measurements can be made between either the Red +ve terminal and the Black (common) or Blue -ve input. For most applications other than differential measurements the RED &BLACK should be used.

5. MEASUREMENT OF D.C. (Direct) VOLTAGES

Set LEVEL CONTROL. Switch the D.C. - A.C. switch to D.C. 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 + terminal, the trace will move up 3 cms. i.e. 3 x 0.5V = 1.5V. Now reverse the connections to the battery and note how the trace moves down 3 cms. This illustrates how an oscilloscope can display positive or negative voltages or both simultaneously, e.g. when viewing a sine input or square wave.

NOTE: The 1MΩ input impedance of the oscilloscope must be taken in to account when measuring high impedance points such as anode, grid or screen voltages of valves working with high value loads.

The D.C. input facility may be used to measure A.C. waveforms swinging about a D.C. voltage, as at the collector of a transistor or the anode of a valve, to check for bias settings or anode. bottoming, etc. Max. D.C. input should not exceed X10 input attenuator setting if it is required to re-centre the trace to view a signal superimposed on it.

6. MEASUREMENT OF AN A.C. (Alternating) VOLTAGE.

Set the D.C. - A.C. switch to A.C. and 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 to be measured, then connect a lead from the + (red) input terminal to the signal source. (B.W.D. Model 190, 112 or 602 Sine Wave Oscillators are ideal for initial experiments in this test.)

Increase the Vertical sensitivity by the VOLTS/CM switch until a display between 2 and say, 8 cm 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 6 cm 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. $\frac{3}{2.84} = 1.06$V RMS.

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 3 cm long and the switch is on 100 μSec, then the duration of the waveform is 3 x 100 μSec = 300 μSec. The frequency rate per second i.e. 1,000,000 μSec divided by the duration of the waveform $\frac{1,000,000}{300} = 3,333$ Hz.

7. INVERTED DISPLAYS

Where it is required to display a waveform inverted on the C.R.T., feed the signal into the -ve terminal and set the input selector to either A.C. or D.C. as required. All information relating to display and measurement of signals applied to -ve input is identical to the +ve input details. The calibration and accuracy are constant for either input.

8. BALANCED OR DIFFERENTIAL MEASUREMENTS

(a) A.C. MEASUREMENTS

To measure a signal appearing between two points in a circuit neither of which is at earth (ground) potential, e.g. across a push pull primary of an output transformer, between cathode and grid of a valve or emitter to collector of a transistor circuit or at the other extreme across a thyratron or S.C.R. load connected directly in a 400V A.C. power line with no isolation and at the same time suppress any signal common to both points such as H.T. ripple or A.C. power line frequency as much as possible, the following method is used.

Connect a lead from the +ve input socket to one side of the component across which the waveform is developed and another lead from the -ve input socket to the other side, The attenuator is adjusted to present a suitable display and the resultant C.R.T. trace is then a true indication of the waveform being developed between the points to which the leads are coupled. Measurement of voltage and time may be made as described previously as the calibration remains constant irrespective of the input facility employed.

If a large 'Common Mode' signal appears on the display, particularly when measuring signals on equipment connected in the A.C. supply, the COMMON terminal should be connected to the source of the interfering signal to obtain complete rejection of it.

The differential input coupling is almost essential when making low level measurements in the millivolt region even when one side of the signal source is grounded. This is because troubles due to ground loops generating hum and noise occur and can completely mask the signal. Connect leads from the +ve socket to the signal to be observed, the -ve socket to the nearest ground or common point to the signal on the equipment under test, and the COMMON to ground.

To measure A.C. signals which are superimposed on a high D.C. potential which would overload the input coupling capacitors (400V D.C. or A.C. p-p + D.C. combined) the COMMON terminal is taken to the D.C. potential around which the A.C. signal is swinging, subject to a maximum of ± 400V D.C. If still larger signals need to be accommodated a 10-1 high impedance probe B.W.D. Type P21 should be employed when signals to ±1000V D.C. or A.C. p-p may be displayed.

8. BALANCED OR DIFFERENTIAL MEASUREMENTS (Continued...)

(b) DIFFERENTIAL D.C. MEASUREMENTS

When low frequencies or signals with both A.C. and D.C. components are to be measured differentially, the mode of operation is almost identical to A.C. measurements.

Connect a lead from the COMMON terminal to the nearest D.C. potential of the signal being measured e.g. if it is swinging about ground then it should be connected to ground or chassis, if it is say, a switching signal between the anodes of two valves then it should be taken to the +ve rail with a maximum limit of +400V D.C. to which the common terminal can be taken. The display signal in the D.C. differential mode can be measured directly as calibration remains constant.

NOTE Almost infinite COMMON MODE REJECTION can be made with Model bwd 502, by connecting the COMMON Black terminal to the signal to be rejected where it is a low impedance source and can drive a .47uF capacitor and a 1MΩ resistor in parallel. However, if this is not possible the following limitations must be considered.

Differential rejection will only operate if the Common Mode signal to be rejected is less than X500 the Attenuator setting e.g. with the Attenuator set at 1V/cm the common signal must not be greater than 500V (A.C., p-p or D.C.) or the input amplifier will be overloaded and the signal will be distorted. If the common mode signal is 240V A.C. the peak to peak voltage is approximately 700V and the attenuator should not be used below $\frac{700}{500}$ = 1.4Vcm the nearest actual setting being 2V p-p/cm.

The accuracy of the input attenuator resistors also controls the rejection ratio and other than the 20 and 50mV settings, may reduce the rejection to only 20-1 which means, in the case of a 240V A.C. signal, a 35V p-p signal could still appear with the required signal superimposed on it, at 2V p-p/cm, unless the COMMON TERMINAL is also connected to the 240V supply as mentioned in the previous paragraph.

Provided the limits and methods of connection indicated above are observed when making differential measurements far more information can be extracted from a circuit than with normal oscilloscope operation, with only one signal lead and one side grounded.

9. ISOLATED MEASUREMENTS A.C. or D.C.

With the isolated ground of Model bwd 502 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 0.47 uF 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 D.C. or 250V A.C.

10. CURRENT MEASUREMENTS A.C. or D.C.

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. Simpler still, at low currents, place a 1Ω resistor across the vertical input terminals and the attenuator then reads mA and AMPS directly.

If this resistor is placed in series between a source and a load, the oscilloscope will read the current flowing, either A.C. or D.C. in mA or AMPS, e.g. 0.1V on the attenuator = 0.1A., 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.

11. MEASUREMENTS WITH AN EXTERNAL HORIZONTAL INPUT.

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

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

Remove the CAL. 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 C.R.T. or transferred to a rulled graph paper. A.C. signals will show phase displays or Lissajous figures. With the vertical input switched to D.C. less than 1^{o} phase shift exists up to 5KHz and 5^{o} at 20KHz between X and Y inputs.

The balanced input also permits algebraic subtractions to be incorporated in this type of display, e.g. +3V applied to the +ve input and +1V to the negative input will produce only +2V deflection of the C.R.T.

For further details of experiments in the educational field a loose leaf book is being made available describing a wide range of experiments in the fields of Physics, Electricity, Chemistry, etc. using Model bwd 502 together with Model bwd 602 and the 600 series accessories. Write direct to B.W.D. Electronics Pty. Ltd., for information.

12. CIRCUIT DESCRIPTION

NOTE: As the circuit is isolated from ground, all measurements must be made with respect to the COMMON line and not to the chassis frame.

VERTICAL AMPLIFIER

The balanced inputs via the +ve and -ve input Terminals are connected to the A.C. - D.C. slide switch S1A and B. In the D.C. position, C1 and C9 are shorted out, but in the A.C. position they block D.C. and very low frequency signals. From S1 the signal passes through the dual attenuator, S2A and B, attenuates the +input in a 1 - 10 - 100 ratio, and S2C and D similarly attenuates the negative input.

The intermediate steps are obtained by varying the gain of the Input Amplifier by switching R16, RV1 and RV2 in sequence by S2E.

The Amplifier is a 3-stage balanced circuit employing a double triode input stage driving transistor amplifiers Q1 and 2, which in turn drives a hybrid cascade output stage consisting of Q3 and 4 and V2. V1A and B function as an impedance convertor and gain control stage, the max. gain is only x2. Cross neutralising is employed to compensate for capacitive coupling that occurs in the valve, attenuator and input terminals, etc. RV3A ATTEN. BAL. control adjusts the cathode potentials of V1A and B to eliminate trace movement when S2E selects different steps. The VDR in the cathode circuit stabilises the amplifier gain against mains changes.

Q1 and Q2 are directly coupled to V1A and B anodes. Degeneration in the emitter circuit stabilises the gain and RV4 CALIBRATE Control enables the sensitivity to be varied from approximately 15mV to 25mV p-p/cm. Vertical shift is applied to the collector loads by RV3B and R24 and 27 buildout resistors.

The hybrid Output Stage provides the large output swing necessary to drive the C.R.T. plates Q 3 and 4 current drivers, drive the cathodes of V2A and B with an overall characteristic similar to that of a pentode stage.

High Frequency compensation is controlled by C24 and C25 in parallel and RV5 and C23 in series. Trigger take off is from V2A anode via R36 and C26 to the INT-EXT selector switch S3A.

TRIGGER CIRCUIT

Three trigger sources can be applied to the trigger circuit. Internal Trigger from the vertical amplifier, External Trigger via R58 and C42 or the Mechanical Trigger pulse, also via R58, C42, which is generated when R65 is shorted out, producing a negative pulse which feeds through C43.

S3A selects the INT-EXT trigger source which is coupled through C44 to Q5 phase splitter. The required output phase is selected by S4B and + and - switch and then coupled to Q6 emitter follower driver stage through C46. Two controls in the emitter circuit adjust the trigger level. RV12 TRIGGER LEVEL Control varies the emitter voltage and hence the trigger point of the following Schmitt Trigger pair Q7 and Q8. When it is rotated fully clockwise to the PRESET position, the pick-up arm of the potentiometer disconnects from the track and the divider R70 and RV13 take over to control the trigger level.

TRIGGER CIRCUIT (Continued...)

Q7 and Q8 generate a precise amplitude square or pulse wave from any amplitude input. When S5 is closed the action is as follows: with Q7 conducting, its collector will bottom and Q8 will be cut off by the voltage divider action across R74, R76. A negative going input signal will cut off Q7, its anode will rise pulling Q8 base positive, so turning Q8 on, producing a negative trigger pulse at the collector. As the emitters are coupled together, the current through Q8 will now hold Q7 off until its base rises above the common emitter potential and the switching action is reversed. When S5 is opened, C48 together with C49 or C50 as selected by S6C, couple the emitters of Q7 and 8 forming an emitter coupled bi-stable circuit, which will free run at a time constant determined by the capacitors and the emitter impedances. As the capacitors reduce as the Time Base speed increases, the free running rate of the AUTO trigger also increases maintaining a fairly constant trace brightness with no input signal.

TIME BASE CIRCUIT

The Time Base sawtooth generator consists of Q9 and Q10 bi-stable trigger, V3A Miller sawtooth generator and V3B cathode follower with associated clamping diodes D6, 7, 8, 9, 10, and 11,. The function is as follows:

Assuming Q9 is conducting, Q10 will be cut off, its collector will rise and D9 will be conducting pulling the grid of V3A positive. The anode of V3A will be at approximately +60V and coupled through B2, R99, R100 and C58, the grid of V3B will be at approximately -1V causing D11 to conduct and through R102 and 3 attempting to pull D9 out of conduction. In this direct coupled quiescent state, the trace will be ready for a trigger input pulse from Q8 via C51. A negative pulse on Q9 base will cause the collector to rise taking Q10 base positive, this causes current to flow through Q10 into the emitter resistor R88, biasing Q9 off further and a rapid cumulative action occurs in which Q9 cuts off and Q10 saturates. When D9 reverse biases V3A is left with its grid at -0.5V approximately and connected through the timing resistor R97 or R96 and 95 to a negative potential which will pull V3A towards cut off.

However, the timing capacitor C59 - C63 as selected by S6B is also connected to V3A grid and via the D.C. coupling of B2, R99 and C58 and R100 and V3B back to the anode of V3A.

As V3A grid attempts to fall and charge the timing capacitor, the anode will rise. This rise is communicated back to its own control grid via the D.C. coupling, V3B and the selected timing capacitor.

TIME BASE CIRCUIT (Continued..)

The result of this negative feedback is to linearise the charging rate of the timing capacitor and to produce a positive going waveform at the anode of V3A and via the D.C. coupling to V3B grid it appears at low impedance at the cathode of V3B. When the potential at the junction of R102 and R103 reaches approximately -4V, D10 conducts and charges C57 and C52, 53, 54 or 82 as selected by S6D, it also takes the base of Q9 positive to its emitter potential and continues positively until Q9 conducts, its collector falls and cuts off Q10 and at the same time transfers the emitter current from Q10 to Q9. D9 conducts pulling the grid of V3A positively and its anode falls, rapidly discharging the timing capacitor until V3B cathode falls sufficiently to cause D11 to conduct to pull D9 back to a quiescent condition and stabilise the valve condition ready for the next trigger pulse, which will initiate the next trace once the hold off capacitor C57, C52-4 and C82 has discharged sufficiently through R81.

C.R.T. Blanking by the Time Base circuit is accomplished by directly coupling the output of Q9 collector to the C.R.T. blanking electrodes. Q9 is a high voltage transistor whose collector load is connected to the +290 rail via R85, R86 and C55, it is, however, clamped at +62V via D1 to which the C.R.T. A1 electrode is also clamped and causes the blanking electrode to be driven between +62 and +20V approximately during the return trace to blank the C.R.T.

HORIZONTAL AMPLIFIER

Two pentodes V4 and 5 are employed to drive the horizontal display, these have been used to obtain high linearity at high gain with good frequency response. The Time Base output from V3B cathode is divided down through R101 and R104 to feed to V4 grid. Horizontal shift voltage is supplied to the bottom of the divider from RV16A HORZ. SHIFT control.

HORZ. GAIN control RV16B between the cathodes of V4 and 5 controls the degeneration and hence the stage gain and operates between min and max limits set by RV17 and 18. High frequency compensation is provided by C66 and C67. TB output at rear panel is connected to V4 cathode for a low impedance drive.

When the Time Base VERNIER is turned anticlock to T. B. OFF, S7A opens to disable the Time Base circuit and S7B apens RV17 min. gain control to increase the range of the Horizontal Amplifier from 5-1 to approximately 10-1.

C.R.T. AND SUPPLIES

Type 13/27 C.R.T. requires approximately equal + and - E.H.T. supplies for correct operation. The negative supply is a voltage doubler consisting of D4 and 5 with C28 and 29 and C31 and 32 capacitors. A second stage of filtering R43 and C30 reduces ripple to a low level. RV10 INTENSITY control varies the impedance of the divider between grid and cathode and so varies the potential between them.

C.R.T. AND SUPPLIES (Continued)

'Z' modulation is coupled through C34 to the C.R.T. grid. Focus potentials for RV9 are obtained from the E.H.T. divider R47, RV9, R48, RV10 and R49. All other electrode voltages are internally preset, RV6 Astigmatism control and RV8. Geometry control, together with R45 and 46 divider to the deflection plate shield, are adjusted for optimum focus and patern geometry.

The PDA supply, like the negative E.H.T. supply, is a voltage doubler rectified by D2 and D3 and C35 and 36 coupling capacitor and filter. D3 is returned to the +290V rail to add this potential to the PDA voltage.

POWER SUPPLIES

Two secondary windings provide the main D.C. supplies, + and - 64V is obtained from the 51V winding by half wave rectifying, followed by three stages of filtering for the various circuits. The +285V rail is obtained by doubling the 82V winding and adding it to the +64V supply. All valve heaters are taken to a 6.3V rail with RV19 across to cancel hum at highest gain settings.

CALIBRATOR

The 550V A.C. supply is coupled through C41 and R57 to B1 neon which roughly clamps the wave at ±60V. The signal is further divided down by R56 and Q11 which is operating as a 6to 8V zener diode using the base emitter function. The resultant square wave is taken through R55 to RV11 where 1V p-p square wave is obtained.

13. ADJUSTMENTS AND MAINTENANCE

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

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

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

NOTE: Voltages unless otherwise stated are shown with respect to the COMMON line - measurement cannot be made by using the instrument frame as a meter connection.

Valve replacement will not affect the calibration of this instrument, however, V1 needs to be reasonably balanced so that the Attenuator Balance control does not have to be frequently reset. If a replacement valve does not provide the required degree of balance try inter-changing the 6DJ8 with V2 output stage. Other valves require no selection.

bwd-502 ALIGNMENT PROCEDURE

With instrument functioning and trace aligned to graticule, check the following details prior to alignment with TRIGGER LEVEL set to AUTO and TB to 1mSec.

1. ATTEN. to 0.02, centre trace with shift. Turn to .1V recentre with ATTEN. BAL. Preset in centre of Shift Knob, repeat if necessary to eliminate trace movement.

2. Check operation of T.B. VERNIER on each T.B. range.

3. Turn VERNIER to T.B. OFF, spot should move ±5cm with HORIZONTAL SHIFT control.

4. General check of controls.

   (a) Intensity: Linear control over intensity range.

   (b) Focus: Approx. centre with movement either side.

   (c)1 Horz. Gain: Trace should expand equally either side of centre.

   (d) Vert. Shift: Trace should move completely off screen above and below centre.

   (e) Trigger Level: With Atten. at 0.2V and CAL signal fed into +ve Input check AUTO, Level Select and PRESET operation.

   (f) A.C. - D.C. Switch: Set up as for (e) change from A.C. to D.C., trace will move down on D.C. and display a partly differentiated wave on A.C.

   (g) + - Switch: Set up as for (e) Trigger point should change over as indicated by switch.

   (h) Horz. Input & Gain: Feed CAL signal into Horz Input socket with T.B. VERNIER turned to T.B. OFF. HORZ. GAIN should vary display from 2 mm to over 2 cm.

C.R.T. TRACE ALIGNMENT

If a 1000 Hz square wave signal is available, feed this into the VERT. AMPLIFIER and adjust waveform to fill the screen. T.B. to 1mSec. VERNIER to 2. If a square wave is not available use the CAL waveform. T.B. to 10mSec. VERNIER to 2.

RV6 on LH side rear of board is adjusted in conjection with the FOCUS control to obtain the best resolution over the entire screen area.

RV8 adjusts the pattern geometry and should be set to display vertical and horizontal lines with minimum of pincushion or barrel distortion. RV6 may need slight readjustment after RV8 has been set as some interaction occurs.

ATTENUATOR ALIGNMENT

Test Equipment required 1kHz square wave generator with better than 1% amplitude accuracy.

1. Set ATTENUATOR to 0.02V, feed in 100mV p-p (1% accuracy) square wave.

2. Set RV4, Vertical Amplifier Calibrate Control to display 5cm deflection.

3. Switch to 0.05V, increase input to 200mV p-p, set RV1 to display 4cm deflection.

4. Switch to 1V, increase input to 500mV p-p, set RV2 to display 5cm deflection.

5. Neutralising Adjustment

   Test Equipment required 1kHz square wave generator with better than 1uSec rise time and variable output from 50mV to 20V p-p (bwd Models 602 and 112 are suitable.)

   The Instrument should be inverted and a 4" to 5" wide metal plate placed across chassis side rails covering attenuator assembly. Set attenuator to 0.02V p-p, T.B. to 100uSec, VERNIER to 5. Input 1kHz 100mV amplitude between RED & BLACK terminals.

   Adjust C20 screw trimmer (located under P/C Board close to V1) for optimum square wave shape. Change input to BLUE & BLACK terminals and adjust C19 for optimum square wave. Repeat operation.

   Now check 0.05 and 0.1V position - slight undershoot may be apparent in 0.1V position, which if checked differentially between RED & BLUE input may produce a slight overshoot, however when C19 and C20 are correctly set negligible change in wave shape will occur at different attenuator settings.

6. Remove screening plate over attenuator and turn switch to 0.2V position. 1kHz square wave between + RED & BLACK terminals. Adjust C4 for optimum square wave. Turn attenuator to 2V increase input signal and set C5 for optimum square wave.

   Change input leads to BLUE & BLACK terminals. Attenuator 0.2V, adjust C12 for square wave and again reset input at 2V and adjust C13 for square wave shape.

   Test Equipment required Capacitance meter reading 0 to 100pf.

7. Input Capacitance. Connect capacitance meter across RED/BLACK input terminals - note reading at 0.1V attenuator setting. Turn to 0.2V, set C3 to produce the same reading. Repeat at 2V and adjust C2. Input capacitance should be approx. 35pf. Connect to BLUE-BLACK terminals, again note reading at 0.1V. Set C11 at 0.2V and C10 at 2V to obtain the same reading (35pf approx.)

VERTICAL AMPLIFIER ALIGNMENT

Test equipment required. 100 kHz square wave generator less than 50 nano Sec rise time.

1. Attenuator to 0.02V, input to RED &BLACK terminals, signal input 100 mV p-p T.B. range 1μSec, VERNIER set to 2.

   Adjust C25 (underside of P/C board) and RV5 (forward of V2) for optimum square wave with minimum over or undershoot.

2. Check bandwidth, 6 cms deflection below 50 KHz should drop to not less than 4.2 cm at 3MHz.

TIME BASE ALIGNMENT

Test Equipment required: Crystal controlled oscillator and frequency divider with 1, 10 and 100 μ Sec 1, 10 and 100mSec output.

Feed in 1mSec pulse (1kHz), T.B. to 1mSec, VERNIER to CAL.

Adjust RV 17 (Centre front of P/C board) for a trace 10.5cm long.

Now adjust RV15 (front RH side) for 1 pulse/cm.

Turn T.B. to 100μSec and check at 100 μSec (10kHz)

Turn T.B. to 10 μSec and check at 10 μSec (100kHz) Adjust by C65 (centre of P/C board) to set calibration.

Turn T.B. to 1 μSec and check at 1 μSec (1 MHz) adjust by C63 (on T.B. range switch) for accurate calibration.

HORZ. EXPENSION

T.B. to 1mSec, VERNIER to 1. Feed 1 kHz square wave in, adjust VERNIER or input frequency to display 1 waveform/cm. Turn HORZ. GAIN fully clockwise, adjust RV18 (centre front) to display 1 waveform/5cm.

HORIZONTAL AMPLIFIER CHECK

Switch to Horizontal Input. Feed sine wave at 1kHz into the HORZ. INPUT socket, adjust for 6cm deflection, amplitude should not fall below 4.2 cm at 200kHz.

Sensitivity:	Min gain approx. 5V p-p/cm. Max. gain greater than 0.5V p-p/cm.
Calibrator:	ATTEN. to 0.2V, input D.C., feed in Cal waveform. Adjust RV11 (EHT board) for 5 cm deflection.

REPLACEMENT PARTS

Spares are normally available directly from the manufacturer, B.W.D. ELECTRONICS PTY. LTD. 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 components.

As the policy of B.W.D. ELECTRONICS PTY. LTD., is one of continuing research and development, the company reserves the right to supply the latest equipment and made amendments to circuits and parts without notice.

14. ACCESSORIES FOR MODE 502 OSCILLOSCOPES

Demodulator Probe	Type P10	(100Kc's to 100 Mc's 30V p-p max.)
High Impedance Probe	Type P21	(10MΩ and 12 pf)
Screened leads with prods	Type P30	(complete with prod and crocodile clip)
4mm plugs	Various Colours	
Leather carrying case.		
Instrument Trolley	Type T/15	(Available with or without accessory drawer)

Accessories for demonstration work refer to sheet 600 accessories and data sheet on Model 602 Combination Generator/Power Supply Instrument.

MODIFICATIONS:

ISS. 4
S1B CORRECTED
R100 WAS 1MΩ
R122, C84 ADDED

ISS. 5 1/67
RV2 WAS 2·2K
⊕ NOTE ADDED
C64, C71 WAS 100/64
Q11 WAS BC107
Q9 SELECTED (Vco 75V)
C8 WAS 560 C16 WAS 680

ISS. 6
B2 added. R62 was 120K Ω, RV10 was 250K
& PARALLEL R.S. REMOVED
C86 ADDED B1 REMOVED
C44 RELOCATED
R117 REMOVED

ISSUE 7 R 57 REMOVED

C55 33pF REMOVED.
R86 10K "
D17 22v. ZENER ADD.
R86 NOW 2·2MΩ FROM D17 TO "0V."
79 was between Q9.6. and common line

SWITCHES

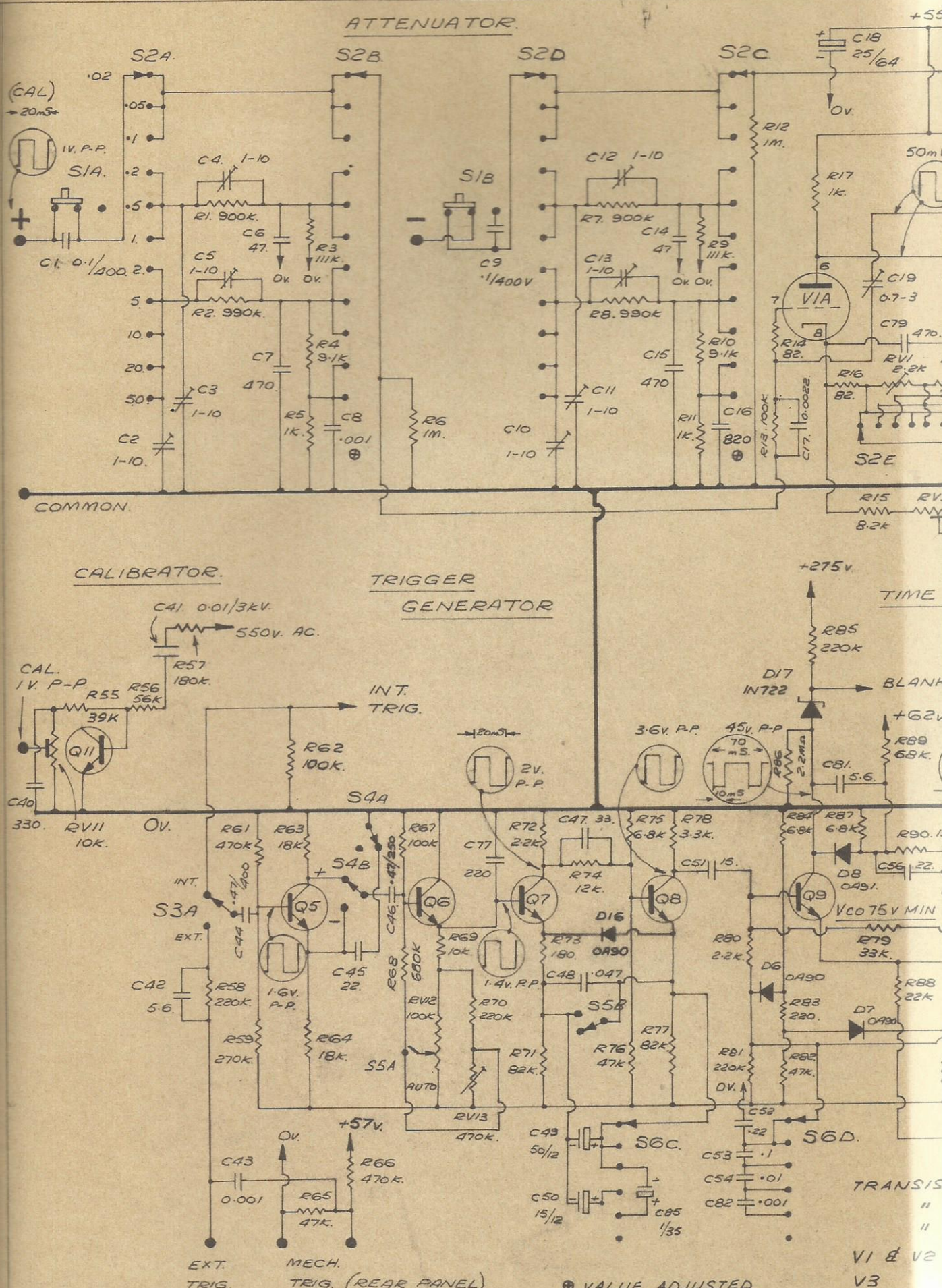
S1A&B.	AC - DC INPUT.
S2A-E.	ATTENUATOR.
S3.	TRIG. INT - EXT.
S4A&B.	" + OR −
S5. A&B	" AUTO — SELECT (REAR RV12)
S6A-D.	TIME - BASE RANGE.
S7A&B.	INT - EXT. T.B. (REAR RV14)
S8A&B.	AC ON - OFF (REAR RV10)

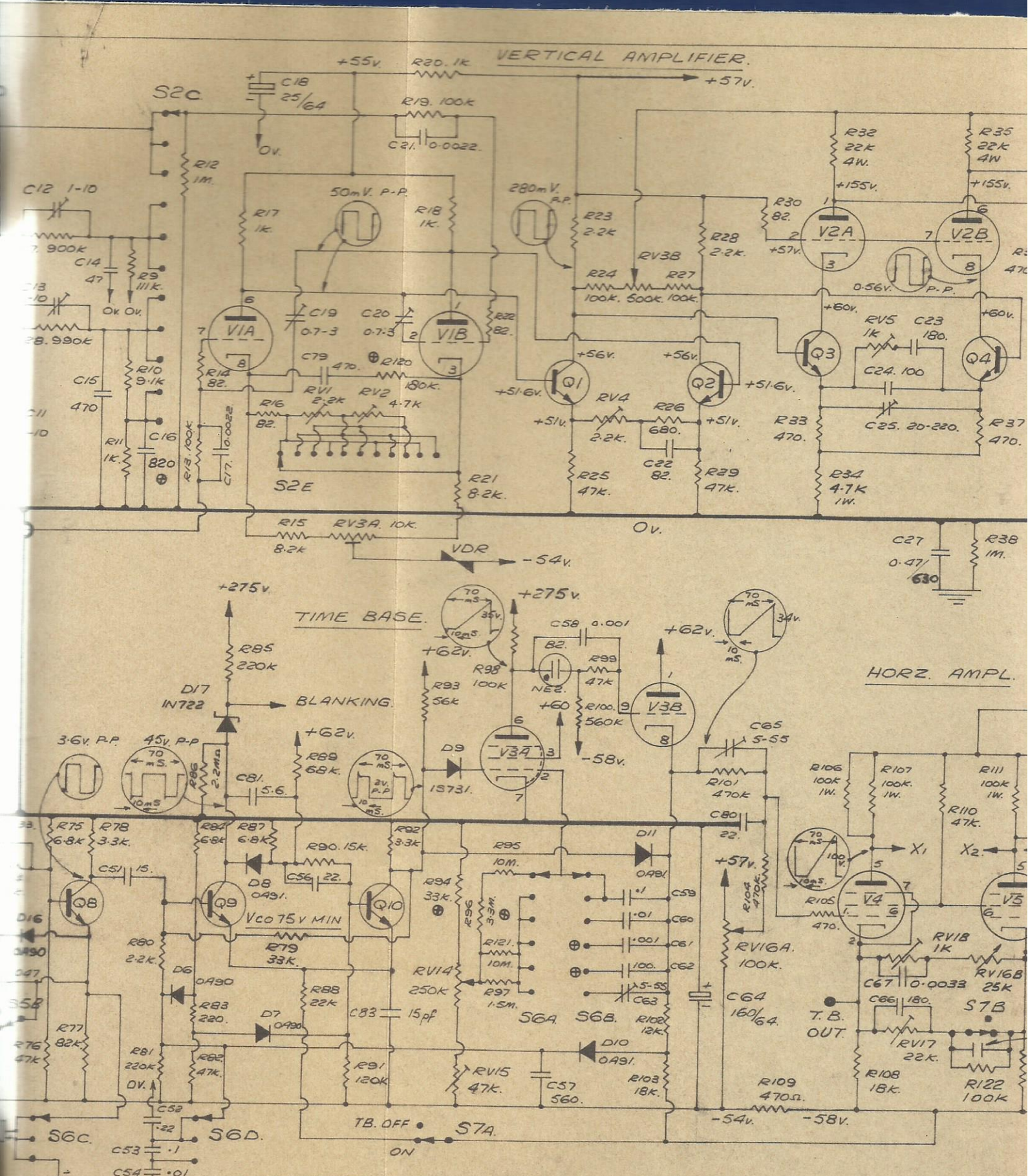
CONTROLS.

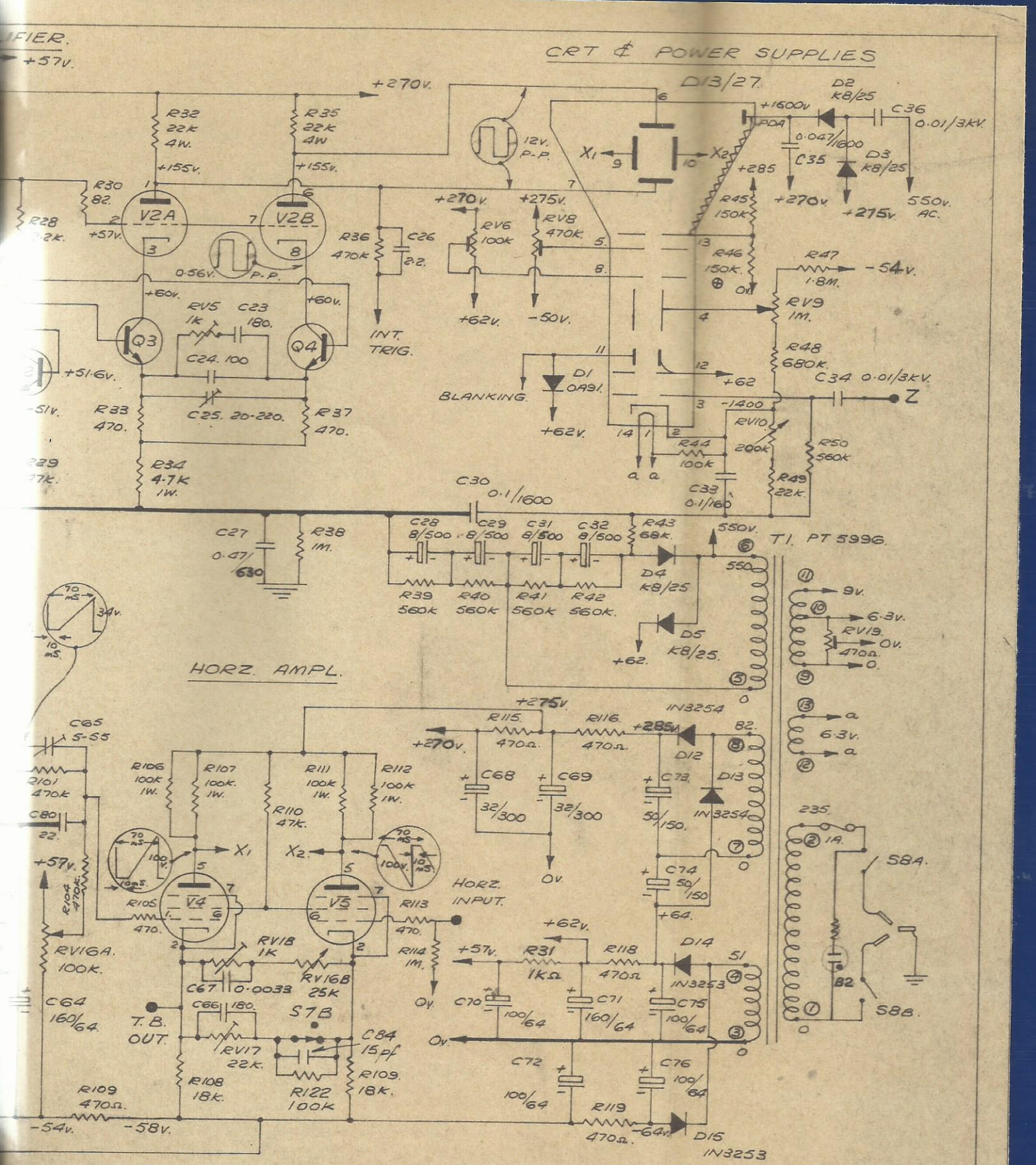
RV1.	SET 50mV. CAL.
RV2.	" 100mV. "
* RV3A.	ATTEN. BALANCE. (PANEL PRESET.)
* RV3B.	VERT. SHIFT.
RV4.	CALIBRATE VERT. AMP.
RV5.	H.F. SQUARE - WAVE SHAPE.
RV6.	ASTIGMATISM P/S.
RV7.	NOT USED.
RV8.	TRACE GEOMETRY.
* RV9.	" FOCUS.
* RV10.	" INTENSITY.
RV11.	1V. CALIBRATE P/S.
* RV12.	TRIGGER LEVEL CONTROL.
RV13.	" " PRESET.
* RV14.	T.B. VERNIER.
RV15.	" " P/S.
* RV16A.	HORZ. SHIFT.
* RV16B.	" GAIN.
RV17.	" " X1 P/S.
RV18.	" " X5 P/S.
RV19.	HUM BALANCE.

* FRONT PANEL CONTROLS.

TYPICAL WAVEFORMS SHOWN ARE WITH CAL. W/F. INPUT, VERTICAL ATTENUATOR AT 0·5V./cm. AND TIME BASE AT 1mS/cm.


ATTENUATOR.
S2A.
S2B.
S2D
S2C
S2E
S1A.
S1B
(CAL)
20mS
1V. P-P.
.02
.05
.1
.2
.5
1.
2.
5.
10.
20.
50.
C1. 0·1/400.
C2 1-10.
C3 1-10
C4. 1-10
R1. 900k.
C5 1-10
R2. 990k.
C6 47.
R3 111k.
C7 470.
R4 9·1k.
R5 1k.
C8 ·001
R6 1m.
C9 ·1/400V
C10 1-10
C11 1-10
C12 1-10
R7. 900k
C13 1-10
R8. 990k
C14 47
R9 111k.
C15 470
R10 9·1k
R11 1k.
C16 820
R12 1M.
R13. 100k
C17. 0·0022.
C18 25/64
0v.
R17 1k.
V1A
R14 82.
C19 0·7-3
C79 470.
RV1 2·2k
R16 82.
R15 8·2k
COMMON.
CALIBRATOR.
TRIGGER GENERATOR
TIME
+275v.
C41. 0·01/3kV.
550v. AC.
R57 180k.
CAL. 1V P-P
R55 39K
R56 56k
Q11
C40 330.
RV11 10k.
INT. TRIG.
R62 100k.
20mS
2V. P-P.
3·6V. P.P.
45v. P-P
70 mS.
10mS
R86 2·2M
C81. 5·6.
R85 220k
D17 IN722
BLANK
+62v
R89 68k.
S4A
S4B
S3A
INT.
EXT.
R61 470k
R63 18k
R67 100k
C77 220
R72 2·2k
C47. 33.
R75 6·8k
R78 3·3k.
R84 6·8k
R87 6·8k
R90.
D8 OA91.
C56 22.
C51 15.
Q5
Q6
Q7
Q8
Q9
D16
R73 180.
OA90
Vco 75v MIN
R79 33k.
R80 2·2k.
D6 OA90
R83 220.
D7 OA90
R88 22k
C42 5·6.
R58 220k.
R59 270k.
R64 18k.
R68 680k
RV12 100k.
R70 220k
R71 82k.
R76 47k.
R77 82k.
R81 220k
R82 47k.
S5A
S5B
AUTO
RV13 470k.
C48 ·047
C49 50/12
C50 15/12
C85 1/35
S6C.
S6D.
C52 ·22
C53 ·1
C54 ·01
C82 ·001
+57v.
C43 0·001
R65 47k.
R66 470k.
EXT. TRIG.
MECH. TRIG. (REAR PANEL)
⊕ VALUE ADJUSTED ON TEST
TRANSIS
V1 & V2
V3
V4 &
NOTE: ALL VOLTAGES & WAVEFORMS MEASURED WITH RESPECT TO COMMON.


VERTICAL AMPLIFIER.
+55v.
R20. 1k
+57v.
C18 25/64
R19. 100k
C21. 0·0022.
S2C
0v.
R12 1M.
C12 1-10
50mV. P-P.
280mV. P-P.
R17 1k.
R18 1k.
R23 2·2k
R28 2·2k.
RV3B
R24 100k.
R27 500k. 100k.
R30 82.
R32 22k 4W.
R35 22k 4W
+155v.
V2A
V2B
+57v.
0·56v. P-P.
C14 47
R9 111k.
C19 0·7-3
C20 0·7-3
R22 82.
V1A
V1B
C79 470.
R120 180k.
+56v.
+51·6v.
Q1
Q2
Q3
Q4
+60v.
RV5 1k
C23 180.
C24. 100
C25. 20-220.
R33 470.
R37 470.
R34 4·7k 1W.
R10 9·1k
C15 470
C16 820
R11 1k.
R13 100k
C17. 0·0022
R14 82.
R16 82.
RV1 2·2k
RV2 4·7k
RV4 2·2k.
R26 680.
C22 82.
+51v.
R25 47k.
R29 47k.
R21 8·2k.
S2E
R15 8·2k
RV3A. 10k.
VDR
-54v.
0v.
C27 0·47/630
R38 1M.
TIME BASE.
+275v.
R85 220k
D17 IN722
BLANKING.
+62v.
R93 56k
R98 100k
C58 0·001
B2.
NE2.
R99 47k
R100. 560k
+60
-58v.
V3A
V3B
C65 5-55
R101 470k
C80 22.
HORZ. AMPL.
R106 100k 1W.
R107 100k. 1W.
R111 100k 1W.
R110 47k.
X1
X2
V4
V5
RV18 1k
RV16B 25k
C67 0·0033
C66 180.
S7B
T. B. OUT.
RV17 22k.
R108 18k.
R122 100k
R109 470Ω.
3·6v. P-P.
45v. P-P.
C81. 5·6.
R89 68k.
D9 IS731.
3v. P-P.
R75 6·8k
R78 3·3k.
R84 6·8k
R87 6·8k
R92 3·3k
R90. 15k.
C56 22.
D8 OA91.
C51 15.
Q8
Q9
Q10
VCO 75v MIN
R79 33k.
R80 2·2k
D6 OA90
R88 22k
R83 220.
D7 OA90
R77 82k.
R76 47k
R81 220k
R82 47k.
0v.
C52 ·22
C53 ·1
C54 ·01
C82 ·001
C85 1/35
R95 10M.
D11 OA91
R94 33k.
296
3·3M.
C59 ·1
C60 ·01
C61 ·001
C62 100.
C63 5-55
R121. 10M.
R97 1·5M.
RV14 250k
C83 15pf
S6A.
S6B.
R102 12k.
D10 OA91.
R103 18k.
RV15 47k.
C57 560.
R91 120k
S6C.
S6D.
TB. OFF
ON
S7A.
R104 470k.
RV16A. 100k.
C64 160/64.
+57v.
-54v.
-58v.
TRANSISTORS Q1-Q4 2N3694
" Q5-Q10 BC107
" Q11 2N3565
V1 & V2 6DJ8
V3 6BL8
V4 & V5 6AU6
VALUE ADJUSTED ON TEST
ISSUE 7
7/67
MODEL 502.
SCALE —
DRAWN J.B. 11/66
TRACED D.C. 11/66
BWD ELECTRON
MODE
5"



MODEL	502.	BWD ELECTRONICS PTY. LTD. MELBOURNE AUSTRALIA.	DRG. NO.
SCALE	—	MODEL b.w.d. 502 5" OSCILLOSCOPE.	620.
DRAWN	J.B. 11/66		
TRACED	D.C. 11/66		