TECHNICAL MANUAL

MODEL 520-A

EXTENDED-RANGE VOLTMETER

DESCRIPTION:

The WAVEFORMS Model 520-A Extended-Range Voltmeter is an amplifier-rectifier type sensitive voltmeter, with a frequency range of 10 cycles to 2 megacyles and 12 voltage ranges from 0.001 volt to 300 volts full scale, making possible useful readings as low as 100 microvolts. The meter is also calibrated in decibels, with a reference level of 1 milliwatt in 600 ohms.

The 520-A may be used as a sensitive voltmeter for investigations of circuit operation, network characteristics, sources of noise or erratic operation in high-gain amplifiers, and in any applications where high sensitivity and accurate calibration are required. As a null detector or indicator, where high accuracy is not required, it may be used at frequencies as high as 4 megacycles, with some loss in sensitivity, and at frequencies lower than 10 cycles.

In addition to its applications as a voltmeter, the 520-A may also be used as an amplifier, with a gain of 1,000, adjustable in 10-db steps. High-impedance loads will not affect the meter reading, so that the instrument may be used simultaneously as a voltmeter and an amplifier. Distortion of the output signal is quite low, so that the 520-A may be used as an oscilloscope preamplifier or wherever a convenient, wideband, adjustable amplifier is required. In these applications its frequency response is useful from well below 10 cycles to about 4 megacycles.

For better detection of small increments of voltage, or for more accurate reset-ability, the 520-A may be obtained with a mirror scale at slight extra cost. A buff-background scale is also available instead of the usual white scale, for less eyestrain under circumstances in which the meter face must be observed for long periods of time. Standard meters may be modified with these special scales at any time before or after delivery.

SPECIFICATIONS:

Voltage Ranges:

Volts full scale	0.001	0.003	0.01	0.03	0.1	0.3	1	3	10	30	100	300
Dbm*	-60	-50	-40	-30	-20	-10	0	+10	+20	+30	+40	+50

Frequency Range: 10 cycles per second to 2 megacycles per second.

Accuracy: ±3% of full scale, 20 cycles to 1 megacycle.
±5% of full scale, 10 cycles to 2 megacycles.

Stability: ±1% for line voltage changes from 105 to 130 volts.

Meter Calibration: The meter circuit is an average-reading type, calibrated in RMS values for sine-wave input. There are two linear voltage scales, 0 to 1 and 0 to 3; the db scale is calibrated from -12 to +2.

Input Impedance: 10 megohms shunted by 24 micromicrofarads; less than 10% change due to range switching.

Characteristics As An Amplifier:

Gain: 1,000 (60 db) from input to output terminals at 0.001 volt setting of range switch.

Frequency Response: Useful from below 10 cycles to about 4 megacycles; uniform within ±5% from 10 cycles to 2 megacycles.

Maximum Output Voltage: 1 volt RMS. Output voltage is approximately equal to meter reading, where full-scale deflection corresponds to 1 volt output.

Output Impedance: Approximately 600 ohms.

Load Impedance: Greater than 100,000 ohms, for no effect on meter reading. Lower load impedances may affect the meter reading, but will not increase distortion. Load capacitance may affect amplifier high-frequency performance.

Meter Overload Protection: The meter movement is completely protected against overload.

Power Supply: 105-130 volts (117 volts nominal), 40 watts, 50-400 cycles.

Dimensions: 6-½" high, 4-¼" wide, 7-½" deep overall.

Weight: 6-½ pounds.

(*Reference level: 1 milliwatt in 600 ohms. These db values are the level in dbm which will cause the meter to indicate 0 db.)

CONTROLS AND CONNECTIONS:

Power Switch: A toggle switch on the right of the instrument panel. The meter illumination serves as the pilot light, indicating when power is on.

Range Switch: Located in the center of the instrument panel. The VOLTS indications give the voltage at the input terminals which will cause full-scale deflection of the meter; the DB indications are the level in dbm (reference level: 1 milliwatt in 600 ohms) which will cause the meter to indicate 0 db.

Input Terminals: Two binding posts, spaced 3/4" center-to-center, at the left of the instrument panel. The lower binding post is connected to the 520-A chassis.

Fuse: A 0.5-ampere "slo-blo" fuse is located on the back of the instrument.

OPERATION:

Voltage Measurements: After the 520-A has been connected to the 117-volt line and the power turned on, it should be allowed to warm up briefly. Set the range switch to the desired voltage range and connect the instrument to the voltage to be measured. If in doubt as to the magnitude of the voltage to be measured, set the range switch to the highest (300 volt) range, connect the instrument across the unknown voltage, and reduce the range switch settings until the voltage is conveniently measurable. (Although the circuit provides complete overload protection for the meter movement, it is still good practice to minimize shocks to the movement caused by slamming the pointer against the stop.)

CAUTION: The maximum d-c plus peak a-c voltage applied to the input terminals of the 520-A should not exceed 600 volts.

With the meter in operation and with the input terminals shorted the meter reading may differ from zero by as much as 1% of full scale due to residual noise in the first amplifier stage. Since this signal adds to a voltage being measured only as the square root of the sum of the squares it will not affect the meter accuracy and should not be directly subtracted from the meter reading. This effect will be most noticeable on the 0.001, 0.1 and 10 volt ranges.

In measuring other than sinusoidal voltages, it should be kept in mind that the 520-A is an average reading device, which is calibrated in terms of RMS values for sinusoidal input. This type of circuit gives readings which are quite close to the true RMS values, even when the harmonic content is comparatively high. The error by which the reading of the 520-A may differ from the true RMS value due to the presence of harmonics is indicated in the table below. Corresponding figures for peak reading meters are also shown.

% HARMONIC CONTENT	MODEL 520-A AVERAGE METER	PEAK METER
0	0% error	0% error
10% 2nd	-0.5% "	-10% to +10% "
20% 2nd	-2% to 0% "	-22% to +18% "
50% 2nd	-10% to -2% "	-32% to +34% "
10% 3rd	-4% to +4% "	-10% to +10% "
20% 3rd	-8% to +6% "	-22% to +18% "
50% 3rd	-20% to +4% "	-4% to +34% "

For greatest accuracy, readings should be taken on the upper two-thirds of the meter scale.

DB Measurements: Measurements of decibels are made in the same way as are voltage measurements. The setting of the range switch indicates the number of db to be added to the meter reading in db. Thus, if the range switch is set at -20 db and and the meter reads -5 db then the indicated level is (-20) + (-5) = -25 db (referred to 1 milliwatt in 600 ohms).

Db measurements may also be made using other reference levels, or the ratio of two voltages may be measured directly in decibels by reading the two voltages on the decibel scales and subtracting one reading from the other. It should be realized, in such cases, that the decibel is actually a power measurement, and is defined as ten times the common logarithm of the ratio of two powers:

$$Db = 10 \log_{10} \frac{P_1}{P_2} = 20 \log_{10} \frac{E_1}{E_2}.$$

The expression for voltage ratios holds only if the two voltages are measured across equal impedances. If the impedances differ, then the number of db is given by

$$Db = 20 \log_{10} \frac{E_1}{E_2} + 10 \log_{10} \frac{R_2}{R_1},$$

where R_1 and R_2 are the resistive parts of the impedances associated with E_1 and E_2.

Use As An Amplifier: The 520-A may be used as an amplifier simply by connecting the desired load (oscilloscope, high impedance headphones, etc.) to the output jack and connecting the 520-A input terminals to the signal source. Load impedances greater than 100,000 ohms will not affect the meter calibration, so that the 520-A may be used as an amplifier and a voltmeter simultaneously. Load impedances lower than 100,000 ohms may affect meter calibration, but will not adversely affect amplifier operation. Highly reactive loads may impair amplifier performance at extreme frequencies.

Gain of the amplifier outside the frequency range of 10 cycles to 2 megacycles will be somewhat affected by the range-switch position. In most switch positions, high-frequency response is down about 3 db of the mid-frequency value out to about 4 megacycles.

Notes: Because of the high gain and high input impedance of the 520-A, stray-field pickup will cause a meter reading with open terminals on the most sensitive ranges. The pick up may provide enough signal to force the needle off scale, but will not cause damage. Similarly, if measurements are being made across a high-impedance source, hum or other pickup may adversely affect results. These effects can be avoided by shielding the input leads and the input connector. However, it should be noted that this shielding will increase the capacitive loading of the source, which may affect operation of the circuit being investigated.

Operation of the 520-A in the presence of very strong electromagnetic fields may result in additional errors. A check measurement of a known voltage will usually indicate whether such a disturbance is being experienced, and this precaution is advisable in areas where trouble from this source may be anticipated, as in the vicinity of high-power radio transmitters.

Since the 520-A contains a power supply which itself may generate significant hum fields, it should not be placed in very close proximity to high-impedance, high-gain circuits which are being investigated.

Under some circumstances, difficulties due to hum pickup may be reduced by experimenting with the power-plug orientation of the 520-A and of the other instruments and equipment in the setup being worked on. This effect is a function of the power-line connections in the area and of the power-supply characteristics of the other equipment involved.

MAINTENANCE

Circuit Description: The 520-A contains two feedback pairs connected in cascade. An attenuator which operates in steps of 40 db is connected between the input terminals and the first tube, while the attenuator which controls intermediate voltage ranges is located between the two feedback pairs. Both are operated from the same switch shaft. The meter rectifier uses a full-wave circuit, with crystal rectifiers; feedback is taken from the meter to the cathode of the first tube of the second feedback pair. The amplifier output connection is located between the meter and the feedback cathode, so that this feedback is effective in reducing the distortion due to the rectifier characteristics which would otherwise appear in the output.

Tube and Crystal Replacement: Any standard 6AK5 may be used for replacement purposes. However, it is desirable to select the input tube for minimum hum and noise.

Any crystal rectifier similar or superior to the Tung Sol TS-1 diodes may be used in the meter rectifier circuit.

Removal of the 520-A From Its Case: The 520-A is held in its case by the two screws on the rear of the instrument. When these screws are removed, the chassis may be withdrawn from its cover.

CAUTION: Performance of the 520-A is affected by the position of some of the leads in the instrument. Care should be taken not to disturb any of the wiring, or the position of any component.

Calibration: Calibration of the 520-A may be accomplished with the aid of a low-distortion signal source, such as the WAVEFORMS Model 510-B or Model 512 oscillators, and an accurate meter. Apply a voltage which will give full-scale deflection, e.g., 1 volt with the meter set to the 1-volt scale, to the input terminals of the 520-A. Adjust the calibration potentiometer, which is located at the rear of the terminal board on the toggle switch side of the instrument, until the meter reads full scale. Without changing the input voltage, check to see that the meter reads correctly on the next higher scales, e.g., on the 3-volt and 10-volt scales.

If the meter cannot be calibrated by this procedure, and all tubes and crystals check OK when out of the circuit, the instrument should be returned to the factory for servicing and calibration.

GUARANTEE:

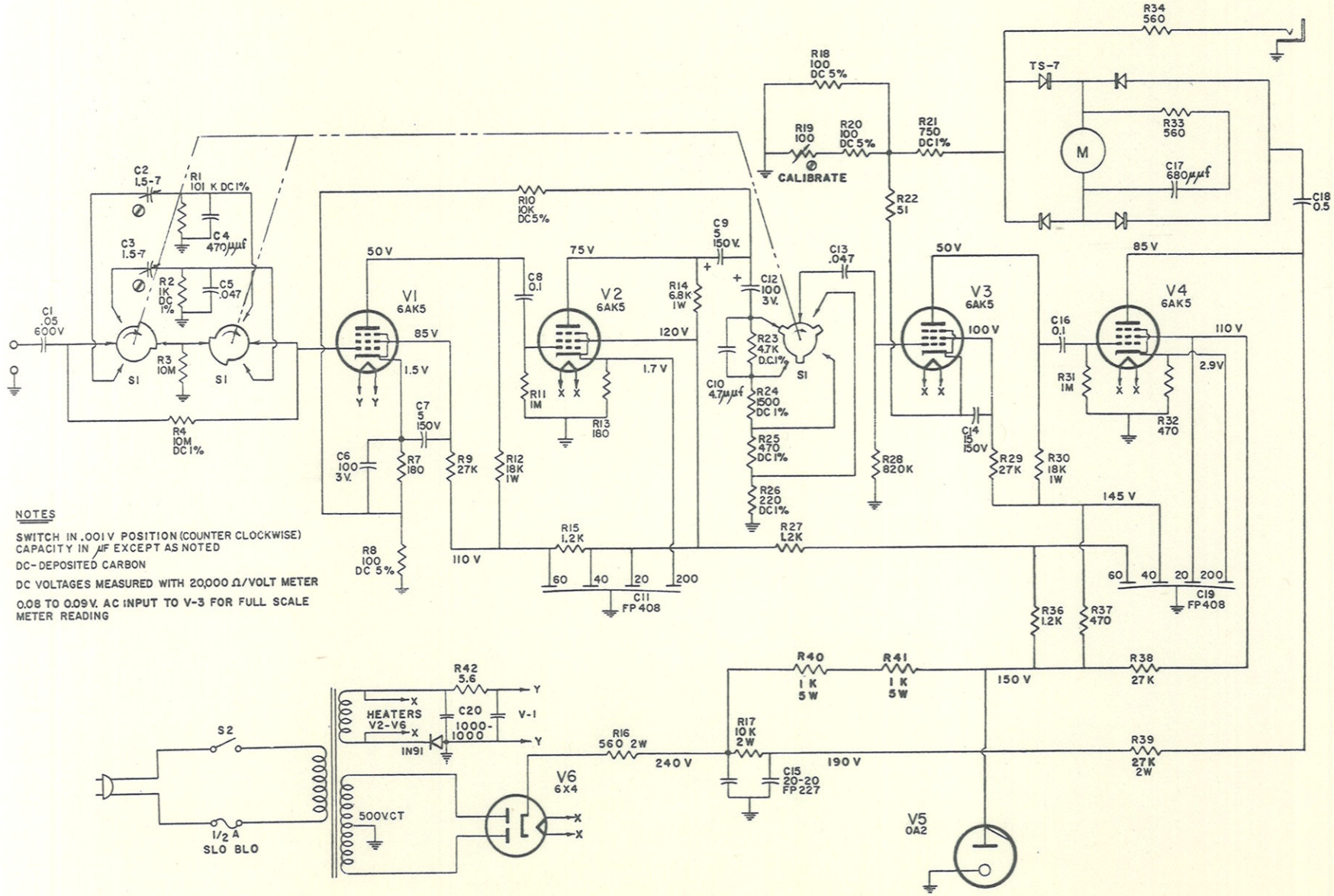
This instrument was carefully tested, inspected, and packed, and left our factory in perfect operating condition. It should be inspected and tested as soon as it is received. If damage is discovered, a claim should be filed with the carrier at once, and WAVEFORMS should be notified.

WAVEFORMS, Inc., unconditionally guarantees its instruments to be free of defects in materials and workmanship. Our liability under this guarantee is limited to the repair and adjustment of any instrument returned to the factory for that purpose within one year of the date it was delivered to the purchaser, and to the replacement of any defective parts except tubes, crystal diodes, and fuses. Tubes are subject to the standard RETMA guarantee. Equipment returned to us for servicing must be carefully packed and shipped with transportation charges prepaid.

If any difficulty should develop with this instrument, please notify us, giving details of the difficulty, and include the type and serial number of the instrument. We shall immediately reply, giving service information or shipping instructions.

If the difficulty proves to have been caused by misuse or abuse of the instrument, or if the guarantee has expired, we shall make an estimate of the repair charges and request your approval before work is begun. If the amount involved is under ten dollars, repairs will be made immediately, without waiting for your express approval.

IF WE CAN BE OF ANY ASSISTANCE, PLEASE CALL ON US



NOTES

SWITCH IN .001V POSITION (COUNTER CLOCKWISE)
CAPACITY IN μF EXCEPT AS NOTED

DC- DEPOSITED CARBON

DC VOLTAGES MEASURED WITH 20,000 Ω/VOLT METER

0.08 TO 0.09 V. AC INPUT TO V-3 FOR FULL SCALE METER READING

WAVEFORMS, INC.

MODEL 520-A SENSITIVE AMPLIFIER-VOLTMETER

SERIAL NOS. AFTER 4200