DELTA

Ballantine 320

INSTRUCTIONS FOR THE MODEL 320 TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER

BALLANTINE ELECTRONIC INSTRUMENTS

BALLANTINE LABORATORIES - BOONTON - N. J.

BALLANTINE LABORATORIES - BOONTON - N. J.

INSTRUCTIONS FOR THE

MODEL 320

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER

CONTENTS

1. SPECIFICATIONS

MODEL 320 TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER

Voltage Range

100 microvolts to 320 volts rms in 13 ranges, in steps of 10 db (total range of 130 db).

Frequency Range

5 to 500,000 cps

Crest Factor Range

1 to 5 (0 to 14 db) for full scale readings; 1 to 15.8 (0 to 24 db) for bottom scale readings.

Accuracy

Sine waves: 3% from 15 to 150,000 cps; 5% from 5 to 15 cps and from 150,000 to 500,000 cps.

Non-sinusoidal waves: 3% if all component frequencies lie in the range from 15 to 150,000 cps; 5% for all other conditions within the allowable frequency and crest factor ranges.

All accuracy figures apply to *any point on the meter scale* and for all ranges.

Stability of Calibrating Source

0.5% for line voltage variations of 105-125 volts and for long term usage.

Input Impedance

10 megohms, shunted by approximately $25\mu\mu f$ to 10 millivolts, and by approximately $8\mu\mu f$ above 10 millivolts.

Meter Scales

Logarithmic voltage scales reading from 1 to 3.2 and from 3.1 to 10; auxiliary scale in decibels from 0 to 10.

Output Characteristics

Main Amplifier Output (binding posts): maximum voltage gain of 90 db ± 1 db balanced to ground, decreasing in 10 db steps to -30 db.

Monitor Output (jack): maximum voltage gain of 84 db ± 1 db single ended, in phase with the input, decreasing in 10 db steps to -36 db.

Mean Square Output (jack): negative dc output voltage of 0.2v corresponding to full scale meter deflection.

Power Supply

105-125 volts or 210-250 volts, 50-420 cps, 75 watts.

Tubes

4 — 5654; 2 — 6U8; 1 — 12AV7; 1 — 0A2; 1 — 0B2; 1 — 5651; 1 — 5Y3GT.
All tubes are supplied.

Dimensions

$14\frac{3}{8}''$ wide, $10\frac{1}{8}''$ high, $12\frac{3}{8}''$ deep. Portable construction.

Weight

Instrument alone, 21 pounds; Packed for shipping, 40 pounds.

2. GENERAL DESCRIPTION AND APPLICATIONS

The Ballantine True Root Mean Square Voltmeter Model 320 is an amplifier-detector type instrument designed primarily for the measurement of the true root mean square value (effective value) of voltages as may be found in ac systems operating at power, audio, and ultrasonic frequencies. It must not be confused with a wide selection of electronic voltmeters of the average and peak responding types which although stated to read rms voltage do so only when the wave form is sinusoidal.

Essentially the Model 320 comprises a high impedance attenuator followed by a degeneratively stabilized amplifier which feeds a specially developed square law detector. The latter unit is a refinement of a type of segmented function generator well established in analogue computer practice; and in conjunction with a full-wave rectifier it provides a precise wide band, wide dynamic range, bilateral squaring action which is unaffected by normal variations in ambient temperature, is instantly responding, and cannot burn out. Vacuum tubes are not employed in the detector and hence no variations in its characteristics arise as a result of aging effects or changes in contact potentials.

Current from the detector passes to a logarithmically graded moving coil meter, which retains the logarithmic voltage scale and associated linear decibel scale which are characteristic of other well-known Ballantine voltmeters. The two voltage scales are read with an accuracy unaffected by the position on the scale of the value observed, and this advantage is enhanced by a large meter so that a condition of high resolution exists whereby 1 mm of pointer deflection corresponds to 1% in reading at any point. The zero of the decibel scale is referred to 1 volt, although special models having a reference of 0 dbm or some other commonly used power reference can be supplied. An auxiliary dial marked in db decade steps and coupled to the range selector switch supplements the meter db scale so as to facilitate db measurements made over a wide range when they are preferred to voltage readings.

The response time of the instrument is determined solely by the meter, and is of the order of 2 seconds.

Incorporated within the Model 320 is a constant voltage source, the Model 430 Calibrator Unit, which by a simple switching procedure is applied to check calibration accuracy of the voltmeter without requiring any external equipment for the purpose. This calibrator augments the reliability of the voltmeter in insuring that its accuracy can be maintained at all times close to the high standards achieved during adjustment in Ballantine's Calibration Department.

To extend the limits of rms voltage measurements possible with the Model 320 beyond the 100 microvolt to 320 volt range, Ballantine Laboratories offers the Model 220A Decade Amplifier and the Models 620 and 1320 Multipliers. To permit accurate wide-band measurements of rms current and power dissipation, the Model 600 series of shunt resistors ranging from 0.01 ohm to 1000 ohm is available for use with the Model 320.

A switch is available which disconnects the detector from the amplifier and brings out to the panel binding posts a balanced to ground low impedance output, capable of moderately high output voltages. Another panel connection provides for amplified signal monitoring simultaneously with metering, with phones or oscilloscope. A third panel output also leaves the detector operative, but disconnects the meter in such a way that a mean-square output is available for recording devices.

Some applications for which the Model 320 is especially suited are:

- General RMS Voltage Measurement in Grounded Circuits
- Noise Figure Determination in Tubes, Transistors, Networks, and Resistors
- "White" Noise Tests on Audio Equipment and Noise Level Checks in Carrier Systems
- Adequate Implementation of Sections 2.1, 3.2, "I.R.E. Standards on Methods of Measuring Noise in Sound Recording and Reproducing, 1953"
- Mean Square Sound Pressure Measurements and Acoustic Studies with Suitable Microphones
- As Audio Output Power Meter with Appropriate Load Impedance
- Precise Measurement of Total Harmonic Distortion in Conjunction with A Fundamental Suppression Filter
- Measurement of Intermodulation Distortion and Products
- Measuring Average Power in Periodic Pulse Trains in Combination with a Known Load Resistor
- Measuring Exciting Currents and Losses of Transformers, Coils, Magnetic Amplifiers and Other Non-Linear Devices
- Accurate Determination of RMS Ripple Voltage
- Vibration Testing — Tube Microphonics

3. OPERATION

3.1. POWER CONNECTION AND WARM UP — The Model 320 is supplied with tubes and fuse and is ready to operate as received. Connect the power cord to a source of 105-125 volts, or 210-250 volts, however the instrument is originally specified, at any frequency between 50 and 420 cps. See section 6.1.3. for instructions regarding line voltage conversion. If desired connect the instrument ground to power system ground by means of the green lead from the line plug. Turn on the ON-OFF switch. The red pilot light should glow when power is on.

Allow a 5 minute warm up period before use, unless the instrument has not been in service for many months, in which case allow a warm up period of at least 30 minutes.

IT IS IMPORTANT THAT AIR BE ALLOWED TO CIRCULATE FREELY AT THE REAR OF THE INSTRUMENT, AND THAT NO SOURCES OF HEAT BE PLACED AGAINST THE BACK OF THE INSTRUMENT CASE.

For all measurements described in Section 3, the METER-AMP switch is set at METER.

3.2. RANGE SELECTION — The thirteen position range selector switch on the panel provides the user of the instrument with the following information when the meter is indicating:

a) the setting of the switch indicates the RMS VOLTS FULL SCALE corresponding to full scale meter deflection,

b) the choice of VOLTS scale of the meter is indicated,

c) the number of db to be added to the reading of the DECIBELS scale of the meter is indicated.

The thirteen positions span the voltage range of 100 microvolts to 320 volts in steps of exactly 10 db, or a factor of 3.162. The meter permits a slight amount of overlap between ranges.

Preliminary to taking measurements or making and removing connections to the INPUT terminals, the range selector switch should be rotated to the extreme clockwise position in order to afford maximum protection to the instrument in case of overload or transient surge.

3.2.1. Db Scale and Dial — In the interests of general utility the 0 of the meter DECIBELS scale has been set arbitrarily at the bottom scale points 1 and 3.16 on the VOLTS scales, with 10 db therefore corresponding to the top scale points 3.16 and 10, respectively. To correlate db readings from range to range of the instrument when db readings are used in preference to volts readings, a db indication for each position of the range switch appears in red numerals through an aperture below the range switch knob. This indication, e.g., −30, added algebraically to the db reading of the meter, gives the signal level with respect to a reference voltage of 1 volt, or 1 milliwatt in 1000 ohms, designated by DBV.

The DBV level thus obtained may in turn be converted to any other desired standard level by the addition or subtraction of a constant db conversion, for all ranges. Table I gives the conversion for three standard references.

To simplify further such conversions and other computations involving decibels the DB Conversion Slide Rule will be found useful. It is available free of charge on application to Ballantine Laboratories, Inc.

3.2.2. Input Impedance — The impedance measurable across the INPUT terminals with the instrument in operation is not invariant, but changes with the position of the range selector switch. In all cases it is sufficiently high that loading disturbances generally are quite small.

For ranges up to and including 10 MV FULL SCALE the impedance is 10 megohms shunted by approximately 25 $\mu\mu$f. Above this point the impedance is 10 megohms shunted by approximately 8 $\mu\mu$f. There is, in addition, a decrease in the shunt resistance and,

TABLE I

Reference level	Conversion from 1 v, 1 mw in 1000 ohms (DBV)
.775v, 1mw in 600 ohms (dbm)	Add 2.2 db
1.732v, 6mw in 500 ohms	Subtract 4.8 db
1.897v, 6mw in 600 ohms	Subtract 5.6 db

to a lesser extent, an increase in capacitance with increasing frequency as the upper frequency limit of the instrument is approached.

Should it be desired to measure the input impedance accurately, a resonance method employing impedance substitution is recommended. The instrument should be on, with the CAL-USE switch at USE, and care should be taken not to exceed the FULL SCALE VOLTS figure for the range being measured.

3.2.3. Noise Level — The noise level of the instrument referred to its input with the INPUT terminals short-circuited through a low resistance is of the order of 10 to 14 μv rms, and consists of wide-band random thermal and flicker noise and harmonics of the power supply frequency. The signal-to-noise ratio for low scale readings on the 320 μV FULL SCALE range is approximately 20 db. On all other ranges the minimum ratio is at least 30 db at bottom scale and 40 db at full scale. The error of rms indication from this source is less than +1% on the 320 μV FULL SCALE range and is negligible for all other ranges.

3.3. USE OF CALIBRATOR

— The following calibration procedure should be performed after the initial warm up period. It should not be necessary to repeat the calibration except in extreme cases of line voltage variation, ambient temperature change, and tube and component deterioration or replacement. The following instructions are summarized for quick reference on the meter face.

1. Set the range selector switch to either 3.2MV, 100MV, 3.2V or 100V FULL SCALE. The choice of range is solely a matter of convenience in consideration of the adjacency of ranges being used for measurements. It is not necessary to remove the signal from, or short circuit, the INPUT terminals.
2. Switch the USE-CAL switch to CAL, and adjust the CAL ADJ control for a meter reading of exactly 10 on the red DECIBELS scale.
3. Set the range selector switch to the next higher (clock-wise) range, and adjust the meter screw for a meter reading of exactly 0 db.
4. Keeping the USE-CAL switch on CAL, repeat steps 1, 2, and 3 until no further adjustments are necessary. Then switch to USE.

The stability of the calibrating source is 0.5% for line voltage variations of 105-125 v and for long-term usage.

Even though the amplified calibrating signal may be made available at the AMP OUT and MONITOR OUT outputs (see Sections 4.1 and 4.2), the voltage level at these points is influenced by variations in amplifier performance and therefore cannot be considered as a stable source unless a variation of several per cent is tolerated.

Similarly, the MEAN SQUARE output (as described in Section 4.3) is calibrated to within a possible error of 2% by the above procedure.

A 1 volt rms signal is available within the instrument from the calibrator. See section 5.5.

3.4. USE OF THE METER SCREW

— Aside from the adjustment required as a part of the calibration procedure, and even though the calibration procedure insures measurement within the specified limits of error, it is occasionally advantageous to effect a further adjustment of the meter screw either for more convenient operation or in some cases for improved accuracy.

With the USE-CAL switch at USE and with a signal applied to the INPUT terminals such that a meter reading of exactly 10 on the red DECIBEL scale is obtained, setting the range switch to the next higher range (clock-wise) should, but will not necessarily, produce a reading of exactly 0 db, even if the calibration procedure has been previously performed. The discrepancy should not exceed 0.2 db, and should approach this figure only if the crest factor of the signal is high. If it is desired to preserve continuity of results with best accuracy during a particular series of measurements for which the signal wave form does not vary greatly, the meter screw may be adjusted to give precise overlap. The CAL ADJ control should not be used for this purpose.

Do not attempt to obtain a 0 db meter reading by means of the meter screw if no signal is applied to the INPUT terminals.

3.5. RMS VOLTAGE MEASUREMENTS

— Connect the signal to the INPUT terminals. The left terminal G is grounded to the instrument case; therefore, above-ground (either ac or dc) measurements may be made only at the user's own risk of the shock hazard and instrument loading effects thereby incurred.

The nature of the signal source, its voltage and impedance level, will determine the input cable requirements. A short length of a low-loss, low capacitance shielded cable terminated in a shielded plug is recommended.

3.5.1. Sinusoidal Wave Forms — The rms voltage value of a sine wave signal is given by the reading of the meter on one of the two VOLTS scales, with reference to the range switch for the appropriate VOLTS scale and multiplying factor to be used.

Maximum instrument error for any point on the meter and on any voltage range is ±3% for signals between 15 cps and 150,000 cps and ±5% for signals between 5 cps and 15 cps and between 150,000 cps and 500,000 cps. The instrument may be used for reduced accuracy relative measurements for signal frequencies up to several megacycles per second; however, signals below 3 cps may suffer distortion and their application is not recommended. The 3 db frequencies of the instrument are approximately 1½ cps and 1½ mc.

3.5.2. Non-Sinusoidal Wave Forms With Crest Factors of 5 or Less (0 to 14 db) — Crest factor, also known as peak factor, is defined for a periodic wave form containing no dc component as the ratio of the peak (instantaneous) amplitude to the rms amplitude (IRE Standard Definition of Pulse Crest Factor, in 51 IRE 20 S 1).

The rms value of a non-sine wave signal with crest factor of 5 or less is given directly by the reading of the meter with reference to the range switch for the appropriate voltage scale and multiplying factor to be used. Maximum instrument error for any point on the meter and on any voltage range is ±3% for signals the frequency components of which lie entirely within the band of 15 to 150,000 cps. Should any frequency components lie outside this band, but entirely within the band of 5 to 500,000 cps, the maximum error approaches ±5%. See Section 3.5.4.

Since the crest factor of random noise, either narrow or wide band, does not for all practical purposes exceed 5, the true rms value of a random noise signal can be measured with the Model 320, subject to the above frequency restrictions. Should noise frequencies extend beyond 500kc error is necessarily incurred, although such error is kept small if the noise frequencies can be restricted to approximately 1 mc.

3.5.3. Non-Sinusoidal Wave Forms With Crest Factors between 15.8 and 5 (14 to 24 db) — The limit of linear and accurate response of the amplifiers and square law detector occurs at a peak voltage five times the rms voltage corresponding to full scale meter deflection. Therefore, should the crest factor of a signal be greater than 5 (but less than 15.8) it is required that the rms value of the signal be less, or be attenuated to be less, than a full scale reading.

The maximum permissible fraction of full scale volts is given by 5 ÷ Crest Factor. Thus, a signal with a crest factor of 10, for example, can be correctly measured only if it is attenuated by networks external to the instrument to give a reading no higher than half of full scale (1.58 or 5 on the VOLTS scales). The amount of such attenuation must be accurately known if the rms voltage is to be accurately determined.

Within this restriction, the maximum instrument errors are the same as for non-sinusoidal wave forms with crest factors of 5 or less. To minimize errors the meter screw adjustment of section 3.4. should be effected.

3.5.4. Effects of Frequency Components Not within Instrument Bandwidth — It is to be expected that in many cases the signal will contain frequency components lying outside the band of 5 to 500,000 cps. Since the true rms value E of the non-sinusoidal voltage signal as a function of the rms values of its sine wave harmonic components E_1, E_2, E_3, . . . is given by

$$E = (E_1^2 + E_2^2 + E_3^2 + \dots)^{1/2},$$

the error caused by the complete omission of, say, all components above E_k is calculable if suitable information relating to the signal is known. Such information may be obtained by harmonic analysis, either analytical, graphical, or experimental, or by true rms measurements encompassing a wider frequency band. In the practical case of measurement with the Model 320, however, the error will approach but never attain this theoretical figure, since outside the specified frequency band the instrument response falls off gradually, and frequency components lying in these immediate regions are attenuated but not completely omitted.

3.5.5. AC Overload Characteristics — The maximum ac signal voltage overload which may be applied to the instrument is determined by damage likely to occur to the input attenuator and the first amplifier tube. For ranges to 10 MV FULL SCALE, 1 volt rms may be applied continuously to the input terminals without damage to the instrument. For the next three ranges, to 320 MV FULL SCALE, 32 volts rms may be safely applied. For the remainder of the ranges, to 320 V FULL SCALE, the limit is 1000 volts rms or 1600 volts peak. To exceed these ratings does not necessarily cause instrument damage, particularly if the overload is quickly removed. Therefore after an overload the calibration should be checked. See Section 3.3.

It is not possible for a signal voltage overload to damage the meter itself except in the case of a severe overload periodically repeated and continued over a long time.

3.5.6 DC Component of Input Signal — The rms voltage as measured by the Model 320 does not include the effect of any direct voltage component present in the input signal. Should independent means be available for measurement of the direct component, the complete rms value may be calculated, as

$$E_{rms\ complete} = (E_{dc}^2 + E_{rms\ ac}^2)^{1/2}$$

The maximum dc voltage which may be applied to the INPUT terminals is 1000 volts. For dc voltages exceeding 1000 volts, an external blocking capacitor must be used. Plastic film capacitors are particularly recommended for this service because of their very high leakage resistance.

3.6. RMS VOLTAGE MEASUREMENTS BELOW 100 MICROVOLTS

— In order to increase the sensitivity of the Model 320 beyond 100 microvolts, preamplification must be provided. The amplifier used for this purpose must have an rms noise level, referred to its input, considerably below the rms signal level if accuracy is not to be sacrificed. The effect of noise on rms value is given by

$$E_{rms} = (E_{rms\ signal}^2 + E_{rms\ noise}^2)^{1/2}$$

It will generally be found that a sufficiently low noise level cannot be obtained except by restriction of bandwidth or reduction of input resistance, or both. Therefore, to obtain the ultimate sensitivity the preamplifier should have the following characteristics: high gain, narrow bandwidth, and input resistance no higher than necessary.

The Ballantine Model 220A Decade Amplifier is suggested for this application, especially when the amplifier is followed by appropriate frequency selective networks. Information concerning these networks may be obtained by application to Ballantine Laboratories, Inc.

3.7. RMS VOLTAGE MEASUREMENTS ABOVE 320 VOLTS

— In order to extend rms voltage measurements to higher levels an external multiplier (voltage divider) must be used.

3.7.1. Model 1320 Multiplier — The Ballantine Model 1320 Multiplier has been designed for use with the Model 320 to permit high voltage measurements from grounded sources. The voltage is limited to 15,000 volts peak. The input impedance of the Model 1320 is approximately 40 megohms, shunted by approximately 3 $\mu\mu$f.

To use the multiplier, plug it firmly into the INPUT terminals of the Model 320, taking care that the G terminal of the multiplier projects to the left, and connect the high voltage signal to the insulated terminal. The multiplier ratio is 100 to 1. Therefore to measure 1000 volts full scale, set the voltmeter range to 10 V FULL SCALE; set to 32 V FULL SCALE to measure 3200 volts; and set to 100 V FULL SCALE to measure 10,000 volts. The additional measurement error which the multiplier may contribute is $\pm 2\%$, from 5 to 500,000 cps.

The Model 1320 Multiplier may also be used to increase the input impedance of the voltmeter for lower voltage wide band measurements, down to 3.2 volts full scale as obtained with the range switch set at 32 MV FULL SCALE. The multiplier cannot be used on the four sensitive voltmeter ranges above 1000 cps without additional error.

3.7.2. Model 620 Extra High Voltage Multiplier — For very high voltages the Ballantine Model 620 Extra High Voltage Multiplier is available. It provides a voltage step down of 10,000 to 1 with an accuracy of $\pm 2\%$ and will withstand peaks of 60,000 volts. The input capacitance of the Model 620 is 3.8 $\mu\mu$f and when it is used in conjunction with the Model 320 voltmeter measurements may be made over a frequency range of 60 to 500,000 cps for any voltage between 1 volt and an upper limit given by 60 kilovolts rms divided by the crest factor of the wave. If sine waves are being measured, for example, the upper limit is then 42.5 kilovolts rms.

3.8. RMS CURRENT MEASUREMENTS

—The Model 320 may be used with resistances of known value for making rms current measurements, preferably at circuit points adjacent to ground. The Ballantine Model 600 series of precision wirewound resistors is recommended for this service. These resistors are available in the values of .01 .1, 1, 10, 100, and 1000 ohms, and are supplied in plug-in form for insertion across the INPUT terminals of the Model 320. With these resistors rms currents of from 0.1 microampere to 10 amperes can be measured to the same frequency and crest factor specifications as for rms voltage measurements.

3.9. POWER DISSIPATION MEASUREMENTS

— Measurements of true ac power dissipation in a known resistive load can be made with the Model 320 by connecting the INPUT terminals to the resistive load, i.e., measuring the rms voltage across the load, and computing the dissipated power from the observed voltage reading by means of

$$P = \frac{E_{rms}^2}{R_{load}}.$$

The possible range of power measurements is 130 db, which for 600 ohms corresponds to 16.7 micromicrowatts to 167 watts, or −77.8 dbm to +52.2 dbm. The DECIBELS scale of the meter in conjunction with the db range switch indicator may be used for direct reading power measurements, convertible to any desired power reference level as described in Section 3.2.1.

4. OPERATION OF AUXILIARY FUNCTIONS

4.1. MAIN AMPLIFIER OUTPUT—With the METER-AMP switch at AMP, the square law detector and meter are disconnected from the instrument, and the balanced to ground output signal from the output transformer is connected to the red AMP OUT terminals. Ac ground is connected to the black AMP OUT terminal, and this terminal may be connected to dc ground GND by means of the shorting link provided for this purpose.

The balanced output corresponding to a full scale meter reading is approximately 10 volts rms. Thus with the range selector switch set on the most sensitive range, 320 μV FULL SCALE, the voltage gain from the INPUT terminals to the AMP OUT terminals is 90 db $\pm$1 db, from 5 to 500,000 cps. Each successive position of the range selector switch reduces this gain by 10 db, to –30 db.

Maximum balanced output is at least 50 volts peak with 50 volts rms from 15 to 150,000 cps and 10 volts rms from 5 to 15 and from 150,000 to 500,000 cps. However, to insure rated output at all frequencies the balanced load should not be less than 10,000 ohms, or 5000 ohms each side of ground, with maximum capacitive loading of 50 $\mu\mu$f. The 3 db frequencies are approximately 1½ cps and 1½ mc.

The ac source impedance for the balanced output is very approximately 300 ohms. Dc source resistance is approximately 120 ohms.

Should it be desired to elevate the balanced output circuit to some dc potential, as may be convenient when the instrument is being used as a preamplifier for a balanced power output device, the shorting link between the black AMP OUT terminal and GND may be removed, and a dc potential not to exceed 300 volts positive or 100 volts negative may be connected to the black AMP OUT terminal.

Grounding either of the red AMP OUT terminals is not recommended for wide band operation.

4.2. MONITOR OUTPUT — Insertion of a phone plug into the MONITOR OUT panel jack provides a voltage signal which may be used for simultaneous monitoring, viewing, listening, or other inspection of the signal being measured by the instrument. The output from this point is in phase with the signal input to the instrument, and is approximately 5 volts rms when the meter is indicating full scale. Thus with the range selector switch set on the most sensitive range, 320 μV FULL SCALE, the voltage gain from the INPUT terminals to the MONITOR output is 84 db $\pm$1 db from 5 to 500,000 cps. Each successive position of the range selector switch reduces this gain by 10 db, to –36 db.

The MONITOR output is completely independent of the metering and other output functions of the instrument, and its service in no way disturbs these functions. It is recommended, nevertheless, that systems fed from this output be shielded from the source being measured (or vice versa) especially when low levels and/or high frequencies are being encountered.

Rated output is 5 volts rms, 25 volts peak. However, to insure rated output at all frequencies the load should not be less than 20,000 ohms, with 30 $\mu\mu$f maximum capacitive loading. Ac source impedance is approximately 50 ohms resistive except at the lowest frequencies when it is determined by the 15μf output coupling capacitor. Dc source resistance is 100,000 ohms.

4.3. MEAN SQUARE OUTPUT — With the METER-AMP switch kept at METER, the insertion of a phone plug into the MEAN SQUARE OUT panel jack disconnects the meter from the detector circuit, substitutes a 1000 ohm resistor shunted by 100 μf, and brings out a negative unidirectional voltage proportional to the mean square of the signal applied to the INPUT terminals of the instrument. The dc output to a high resistance load is –0.2 volts corresponding to full scale meter deflection and –.02 volts corresponding to bottom scale deflection, which permits a crest factor of 5. The dc output may be increased to a maximum of –5 volts at the expense of decreased crest factor margin and reduced accuracy.

Recording this voltage on a strip chart with time or frequency as the independent variable will give a curve the area beneath which determines energy or any other integrated quantity. The General Radio Type 715 DC Amplifier and the 5 ma Esterline-Angus recorder are suggested for this service.

The response time of the MEAN SQUARE output to reach 90% of its final amplitude is approximately 0.25 seconds. If it is desired to reduce this response time, either the 100μf condenser C27 may be reduced, at the expense of raising the low frequency limit of the instrument in proportion to the ratio of the old and new capacitance values, or else the 1000 ohm resistor R55 may be shunted or decreased at the expense of reduced voltage output. If it is desired to increase the response time, C27 must be increased in proportion. A voltage rating of at least 6 volts is required, and tantalum capacitors are recommended. It is left to the user to effect such modifications.

The 1000 ohm resistor R55 may be removed entirely if it is desired to use as the load on the MEAN SQUARE output a current-sensitive device having a resistance of 1000 ohms or less. The dc output current corresponding to full scale meter deflection is –200 microamperes. Currents up to a maximum of –5 ma may be drawn. However, for the output to be accurate the load resistance must be decreased such that the load voltage does not exceed –0.2 volts. An external meter may be used in some remote location, or a meter with a special scale calibration may be used instead of the meter in the instrument.

CAUTION: When connecting the MEAN SQUARE output jack to an external circuit involving sources of dc potential such sources should be disconnected during the process of inserting or removing the plug otherwise the meter may suffer permanent damage.

5. CIRCUIT DESCRIPTION

A block diagram, the full circuit diagram, parts list, and chassis plan are included at the end of this instruction book.

5.1. AMPLIFIERS — Four separate stabilized amplifiers serve the Model 320.

Amplifier A consists of three capacitance coupled pentode stages. The first stage is especially designed for low noise, hum, microphonics, and other forms of interference. Voltage gain is 52 db, and is controlled primarily by the resistors R10, 18, 25, 26, 27, and 28.

Amplifier B is also of three stages: two capacitance coupled pentode stages direct coupled to a triode cathode follower. Voltage gain is 32 db, and is controlled primarily by R33 and R43.

The phase inverter is composed of a pentode stage direct coupled to a triode cathode follower. Voltage gain is exactly unity, and is controlled primarily by R39 and R40. The phase inverter and the second and output stages of amplifier B comprise a balanced system, the output of which is capacitively coupled to a unity ratio wide band transformer.

The monitor amplifier consists of two triode stages series-connected, the so-called super cathode follower. Voltage gain is slightly less than unity.

All amplifiers employ generous amounts of over-all and local feedback to minimize distortion and changes of gain due to tube deterioration, tube replacement, and variations in line voltage. All tubes are operated well below their dissipation ratings to insure long life.

5.2. ATTENUATORS — Two separate wide band capacitance compensated resistance attenuators serve the instrument.

The input attenuator presents 10 megohms resistance to the input signal, which it attenuates in the ratios of $10^{3/2}$, 10^3, and $10^{9/2}$. The capacitance compensation C2 and C3 is carefully adjusted during factory calibration, and should not be readjusted except as described in Section 6.3.1.

The mid-section attenuator, interposed between amplifiers A and B, allows attenuation ratios of $10^{1/2}$, 10 and $10^{3/2}$. Both attenuators are set by the range selector switch, according to the schedule of Table II.

5.3. SQUARE LAW DETECTOR AND METER — A detector to be used for accurate true rms measurements is necessarily a square law device over a wide dynamic range of inputs and frequencies. Of the very few intrinsic square law devices the thermocouple approaches the ideal characteristic most closely, but there are severe practical difficulties associated with its application. In another class are those approximate square law devices such as certain selected vacuum tubes, or various metallic rectifiers and varistors used in combination with linear resistors to modify their higher power laws. Such devices require careful selection, adjustment, and controls (including temperature) to achieve a moderate degree of approximation.

TABLE II

Range switch FULL SCALE	Input Att. Ratio	Mid. Sect. Att. Ratio	Total Att. Ratio
320 μV	1	1	1
1 MV	1	$10^{1/2}$	$10^{1/2}$
3.2 MV	1	10	10
10 MV	1	$10^{3/2}$	$10^{3/2}$
32 MV	$10^{3/2}$	$10^{1/2}$	10^2
100 MV	$10^{3/2}$	10	$10^{5/2}$
320 MV	$10^{3/2}$	$10^{3/2}$	10^3
1 V	10^3	$10^{1/2}$	$10^{7/2}$
3.2 V	10^3	10	10^4
10 V	10^3	$10^{3/2}$	$10^{9/2}$
32 V	$10^{9/2}$	$10^{1/2}$	10^5
100 V	$10^{9/2}$	10	$10^{11/2}$
320 V	$10^{9/2}$	$10^{3/2}$	10^6

Conversely, a square law characteristic can be synthesized from linear resistors in combination with voltage biased diodes, such that the parabolic characteristic is approximated by a continuous sequence of linear segments. The degree of approximation may be made as good as desired through the use of an increasing number of segments, and the dynamic range is limited only by the quality of the diode switches.

The Model 320 employs a detector of this last, the segmented approximation type, utilizing high back resistance germanium diodes in a unique circuit* wherein the effects of crystal imperfections are minimized. Nine linear segments are used, yielding a controlled squaring error of less than one percent over most of the fifty to one dynamic range of input voltage (twenty-five hundred to one current response).

The detector accepts positive voltage signals from a full wave rectifier at the secondary of the balanced amplifier output transformer, and responds in a current instantly proportional to the square of the input voltage. This current is passed through a logarithmic meter with 200μa full scale sensitivity, by-passed to the alternating component of the current. By calibrating the meter in terms proportional to the square root of its current, the root-mean-squaring operation has been accomplished.

Detector response corresponding to full scale meter deflection is controlled by R56, the CAL ADJ control, which sets the detector bias supply voltage. See Section 3.3.

The logarithmic meter used in this instrument, as in all Ballantine Sensitive Voltmeters, gives indications **at all on-scale points with the same high accuracy as at full scale.** This is a distinct advantage over the usual crowded scale of the typical rms indicator.

5.4. POWER SUPPLY — All plate and screen supply voltages, with one exception, are taken from a single gas tube regulated power supply, with suitable filtering and decoupling as needed. The exception is the common supply for the balanced output cathode followers, which is taken from a high voltage point preceding the regulator tubes.

A stable bias supply for the square law detector is effected by means of a Type 5651 reference tube used as a regulator.

Dc heaters are used for the first two stages of amplifier A. A separate metallic rectifier is used for this purpose.

Ac line voltage is normally 115 volts nominal, 50 to 420 cps. For easy conversion to 230 volts nominal, see Section 6.1.3.

5.5. CALIBRATOR: MODEL 430* — The Model 430 Calibrator Unit is a plug-in stabilizer, or regulator, unit consisting entirely of passive elements. It is designed to accept an input of 5.75 to 6.85 volts, 50 to 420 cps, derived from the ac heater supply, and it delivers an output of 1 volt rms ±0.5% to a high resistance load. For use in the Model 320 the output is attenuated to 3.162 mv. However, the 1 volt output is also available from a socket pin for any user application. The Model 430 may be put to use as a separate entity from the Model 320 Voltmeter.

The circuitry consists of a transformer-driven lamp bridge regulator with most of the bridge output balanced out, leaving only a component which is practically constant for moderate excursions of input voltage.

*Patent pending.

6. SERVICE AND MAINTENANCE

Limited servicing of this instrument by the user is feasible providing the procedures outlined below are followed.

However, it cannot be too strongly emphasized that the instructions given, especially in sections 6.2.1., and 6.3.1. below, merely outline a method of effecting a relatively crude adjustment to remedy any significant irregularities which may possibly develop in the voltmeter after extensive usage. Even with such basic servicing instruments as are mentioned the work should be entrusted only to technicians having the highest skill and experience in measuring the frequency response of networks. A refined and comprehensive method of recalibration is beyond the scope of this handbook and cannot be effected without specialized test equipment having an accuracy of the order ten times greater than specified for the instrument being checked. Such equipment and personnel trained in its use are available in the Calibration Department of Ballantine Laboratories, Inc., so that if trouble develops which cannot be corrected except by the replacement of special components, or if the user is not equipped with the necessary test equipment, it is recommended that the instrument be returned to Ballantine Laboratories, Inc., for servicing. Before returning the instrument, please describe the trouble to us by letter.

6.1. GENERAL INSTRUCTIONS

6.1.1. Replacement of Fuse and Pilot Light — The fuse is a 3AG cartridge type, 1 amp for 115 volt line operation and ½ amp for 230 volt line operation, and is located adjacent to the power cord entrance to the instrument. It is accessible without removal of the instrument from its case. A spare fuse is supplied.

The pilot light, Type 47, is made accessible by unscrewing the red plastic cap on the panel.

6.1.2. Removal of Instrument from Case — To remove the instrument from its case it is necessary merely to stand the instrument in its normal position and unscrew the two large knurled thumb screws located on the back of the case. After a few revolutions the front of the case, attached to the panel, will disengage the body of the case and the instrument may be withdrawn.

To return the instrument to its case, slide it into the case as far as possible, taking care to pull the power cord through its entrance hole. Engage the front and rear sections of the case and tighten the two knurled thumb screws to complete the engagement.

6.1.3. Line Voltage Conversion — The line voltage for which the instrument is connected on leaving the factory is indicated on a decal adjacent to the power cord entrance and fuse. If it is desired to convert from 115 volt to 230 volt operation, or vice versa, the proper connections of the primary windings of the power transformer must be made to the numbered terminals on the line filter housing, in the right rear corner of the chassis.

TABLE III

TUBE	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V1 5654	0	4v	0	5.75v	60v	130v	4v		
V2 5654	0	2v	0	5.75v	90v	110v	2v		
V3 5654	0	1.75v	75vdc *	75vdc *	110v	90v	1.75v		
V4 5654	0	3.5v	*	*	110v	110v	3.5v		
V5 6U8	300v	0	110v	75vdc *	75vdc *	108v	2.75v	110v	108v
V6 6U8	300v	0	110v	75vdc *	75vdc *	108v	2.75v	110v	108v
V7 12AV7	170v	**	70v	75vdc *	75vdc *	68v	0	2.5v	75vdc *
V8 OB2	255v	150v	—	150v	255v	—	150v		
V9 0A2	150v	0	—	0	150v	—	0		
V10 5651	87v	0	—	0	87v	—	0		
V11 5Y3GT	350v	—	—	350vac	350vac	—	350v	—	
Model 430 Cal. Unit	0	—	75vdc *	75vdc *	1vac	3.16mvac	—	—	

All voltages positive dc unless otherwise indicated.
* Ac heater voltages to ground are indefinite, varying from 0 to 6.3 volt. Heater voltage is 6.3vac.
** Excessive loading error.

In the following, the colors refer to the colors and color tracers of the power transformer primary leads, and the numbers refer to terminals.

For 115 volt operation connect black and black-red to 1, and connect black-yellow and black-green to 2.

For 230 volt operation connect black to 1, black-green to 2, and black-yellow and black-red to 3.

Connections should be made by soldering.

6.2. AMPLIFIERS

— A complete circuit diagram, parts list, and chassis plan are included at the end of this instruction book.

In case of malfunction, as evidenced by insufficient or even absence of amplifier response, instability, high noise or hum level, intermittent operation or other disturbances, the first step in servicing is to check all tubes. 6AK5's may be used in place of the premium 5654, if necessary. It is recommended that the two 6U8 output tubes be selected to give approximately the same dc voltages on the triode cathodes.

With all tubes operating normally, the operating voltages at the tube points should be measured and checked against Table III. Dc measurements should be made with an instrument of at least 10,000 ohms per volt sensitivity.

If the source of trouble is still undetected, it becomes necessary to use such auxiliary test equipment as a wide band oscillator, auxiliary vacuum tube voltmeter, and oscilloscope, and trace a signal through the instrument. An investigation of this caliber requires experience in instrument servicing, and consideration should be given to the economy of returning the instrument to Ballantine Laboratories, Inc., for servicing.

The nominal main amplifier output voltage to ground corresponding to full scale meter deflection is 5 volts rms. In the event that with sufficient input voltage to the amplifier, as is applied in the course of the calibration procedure, this output cannot be achieved, and the CAL ADJ control does not have sufficient adjustment to attain a full scale deflection, it is possible as a temporary measure only to secure a slight increase in amplification by shunting either or both of the feedback resistors R10 and R33 by other resistance of value high compared to R10 and R33. As soon as possible, however, the basic cause of the amplifier deterioration should be determined. See also Section 6.4.

6.2.1. Frequency Response Adjustment

— With the range selector switch set at 320 μV FULL SCALE, the response of the instrument to high frequency signals is determined primarily by the amplifiers. An internal adjustment, in the form of the variable inductor L1, is provided to allow the amplifier response above 100kc to be accurately set at the factory for minimum high frequency error. Should this adjustment be disturbed, and if it is not desired to return the instrument to the factory for the most accurate adjustment, it may be made by providing the instrument with a sinusoidal signal of 100 to 320 μv, 150 to 500kc, monitoring this signal with another wide band voltmeter such as the Ballantine Model 310A or 314, and setting L1 for minimum error. L1 is located on the long terminal board at the side of the chassis adjacent to V3, and may be adjusted from either the top or bottom.

There are no adjustments for low frequency response. Should trouble be encountered, it is good practice to check all coupling and cathode by-pass condensers.

6.3. ATTENUATORS

— The input and midsection attenuators should not require servicing for the life of the instrument, since they are made entirely of specially selected stable resistors and capacitors. It is possible, however, for the input attenuator to be damaged by the inadvertent application of voltages in excess of 1000 volts to the input terminals.

To service the input attenuator, first set the range switch in the 320 μV FULL SCALE position, then remove the range selector switch knob, the metal escutcheon plate (four screws), and the db dial. The attenuator assembly, now exposed, is held in place by four screws, one on each side of the switch shaft and one on each side of the input terminals. Removing these screws and unsoldering the output connection at the top of the assembly will permit the whole assembly to be withdrawn straight out from the panel. The ground connection will also pull out, and may then be unsoldered if desired.

6.3.1. Frequency Response Adjustment

— At sufficiently high frequencies the attenuation ratio of the input attenuator is determined by capacitance, and receives very careful factory adjustment. Should the settings of the capacitance trimmers C2 and C3 be disturbed it is necessary that they be reset. If it is not feasible to return the instrument to the factory for the most accurate adjustments, they may be made with the assistance of a wide band oscillator monitored with a wide band voltmeter such as the Ballantine Model 310A or 314.

C2 and C3 are located on the left and right sides, respectively, of the attenuator assembly, above the input terminals. They are exposed after removal of the range selector switch knob and the metal escutcheon plate; do not remove the db dial.

To adjust C3 set the range selector switch on any range 1 V FULL SCALE or greater (−10 db or greater on the db dial), and apply to the instrument a monitored sinusoidal signal anywhere in the range

150kc to 500kc to give some meter deflection. Using a fiber or similar insulated screw driver, adjust C3 for minimum error.

To adjust C2 set the range selector switch on either 32, 100, or 320 MV FULL SCALE (–40, –30, or –20 on db dial) and apply to the instrument a monitored sinusoidal signal anywhere in the range 150 kc to 500 kc to give some meter deflection. Adjust C2 for minimum error.

An adjustment of C3 always requires a readjustment of C2, but not vice versa.

6.4. SQUARE LAW DETECTOR AND METER — If it is ascertained that the amplifier is in order, and yet with an output of 5 volts rms each side of ground from the output transformer a full scale meter deflection cannot be obtained, then the detector circuit may be suspected.

The dc voltage of the 5651 reference tube, approximately 87 volts, is reduced by the CAL ADJ control R56 to no less than approximately 64 volts, as required, before being applied as the detector bias supply. This can be checked by measurements on R56.

If with both bias and signal properly applied to the detector a meter deflection cannot be obtained, determine if the rated output is available from the MEAN SQUARE output. If it is available, either the meter or its by-pass C27 is defective.

If neither a meter deflection nor mean square output is obtained, nothing remains but to check the crystal diodes used in the detector, beginning with CR2 and CR3.

One end of each diode must be unsoldered and checked, after cooling, for back resistance of the order of 1 megohm, and forward resistance of several hundred ohms.

The detector components are on a square terminal board vertically mounted at the rear of the instrument, facing the back of the case.

6.4.1. Electrical Overlap Adjustment — Should it be found that in the course of the calibration procedure, Section 3.3., full scale deflection can be easily attained but the range of adjustment of the meter screw is inadequate to make the bottom scale adjustment, then the electrical overlap adjustment R73 must be reset. To do this, follow the calibration procedure but use instead of the meter the MEAN SQUARE output, as measured by a suitable sensitive high resistance dc voltmeter. Thus, adjust the CAL ADJ control for exactly –0.2v output, and then after setting to the next higher range adjust R73 for exactly –.02v output. Repeat this process several times, then go through the usual calibrating procedure with the meter.

R73 is the only control mounted on the detector terminal board, and is accessible through a ventilation hole on the back of the case.

6.5. POWER SUPPLY — Should it be noted that the amplifiers or detector are inoperative because of the absence of dc supply voltage, a check of the power supply is indicated. A possible source of trouble aside from tube failure is the failure of the electrolytic condensers used for filtering and decoupling. This may be revealed by simple ohmmeter checks of resistance to ground.

Unduly high susceptibility of the instrument to transient signals and line voltage transients can often be eliminated by replacing the 0A2 and 0B2 regulator tubes.

6.6. MODEL 430 CALIBRATOR UNIT — — It is not recommended that the user attempt to service this unit. If it is known to be malfunctioning it should be removed from the instrument and returned to Ballantine Laboratories, Inc. It is not necessary to send the complete instrument.

The unit is removed by unscrewing the two screws holding the mounting tags at the base of the unit to the chassis, and pulling out the unit. Extreme care should be taken in handling this unit and in packing it for shipment.

7. WARRANTY

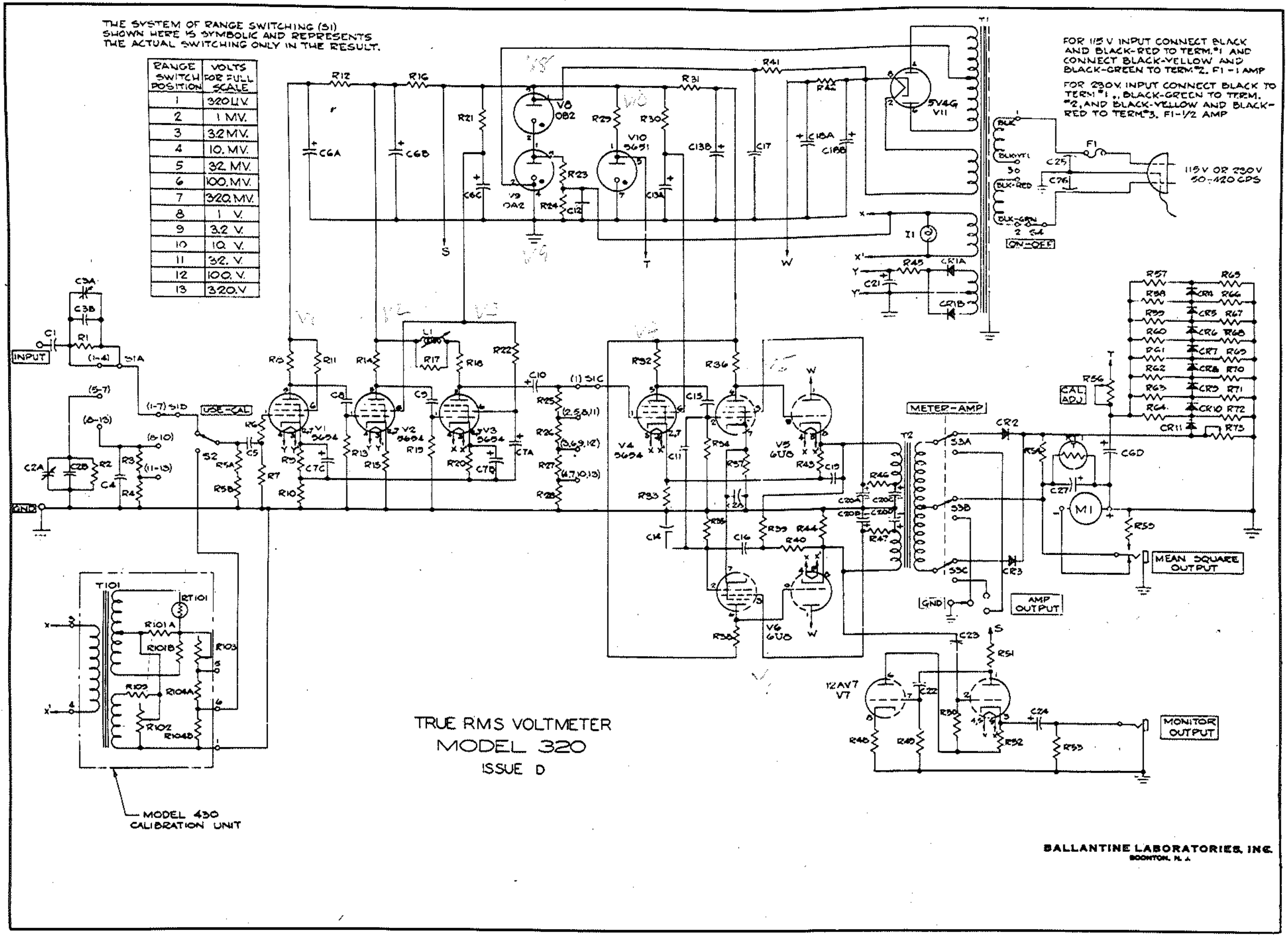
We warrant each instrument or part thereof sold by us to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except tubes, which shall within one year after shipment to the original purchaser prove upon our examination to have become defective.

8. SHIPPING INSTRUCTIONS

If it should become necessary to return the instrument or any part thereof for servicing, make certain that at least 4 inches of padding material surround the instrument. Ship via Railway Express, and send under separate cover a full description of the trouble.

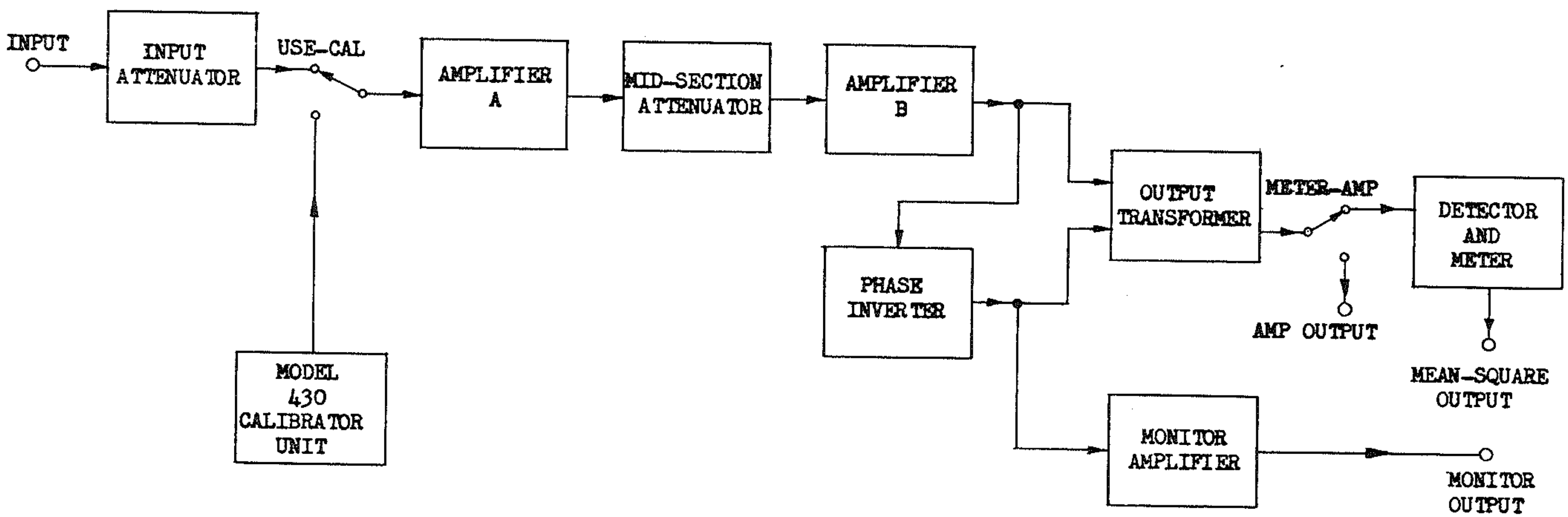
THE SYSTEM OF RANGE SWITCHING (S1) SHOWN HERE IS SYMBOLIC AND REPRESENTS THE ACTUAL SWITCHING ONLY IN THE RESULT.

RANGE SWITCH POSITION	VOLTS FOR FULL SCALE
1	320 µV.
2	1 MV.
3	3.2 MV.
4	10. MV.
5	32. MV.
6	100. MV.
7	320. MV.
8	1 V.
9	3.2 V.
10	10. V.
11	32. V.
12	100. V.
13	320. V



TRUE RMS VOLTMETER
MODEL 320
ISSUE D

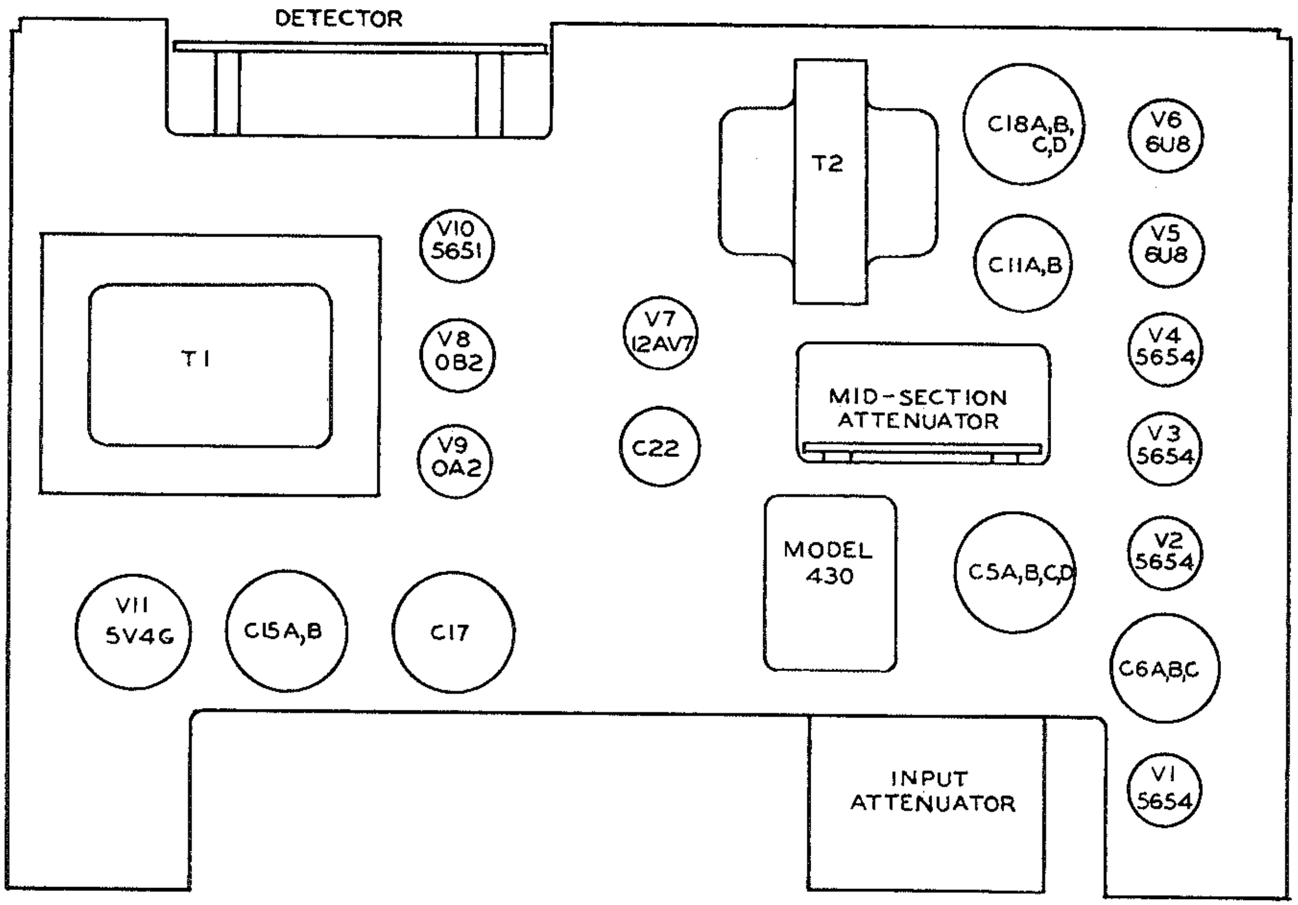
BALLANTINE LABORATORIES, INC.
BOONTON, N. J.



BLOCK DIAGRAM

MODEL 320 ELECTRONIC VOLTMETER

JRH 7-20-54



CHASSIS LAYOUT

MODEL 320 ELECTRONIC VOLTMETER

RET 6-16-54

REPLACEMENT PARTS LIST

REFER TO MODEL 320 SCHEMATIC DIAGRAM, ISSUE A

B. L. Part #	Circuit Symbol	RESISTORS	Manufacturer
1463	R1	10 megohms, Type CP-1, 1%,	Wilkor
1384	R2	338,000 ohms, Type CA-H-1/2, 1%,	Phaostron
1650	R3	9,700 ohms, Type N20, 1%,	Corning
1651	R4	316 ohms, Type N20, 1%,	Corning
1087	R5A	22 megohms, Type EB, 5%,	Allen-Bradley
1087	R5B	22 megohms, Type EB, 5%,	Allen-Bradley
1090	R6	510 ohms, Type EB, 10%,	Allen-Bradley
1470	R7	13 megohms, Type CP-1, 1%,	Wilkor
1554	R8	50,000 ohms, Type L-1/2, 1%,	Elec. of Col.
1054	R9	2,000 ohms, Type EB, 5%,	Allen-Bradley
1369	R10	20 ohms, Type CP-1/2, 1%,	Wilkor
1090	R11	510 ohms, Type EB, 10%,	Allen-Bradley
1040	R12	20,000 ohms, Type EB, 5%,	Allen-Bradley
1007	R13	2 megohms, Type EB, 5%,	Allen-Bradley
1321	R14	15,000 ohms, Type CP-1/2, 1%,	Wilkor
1063	R15	300 ohms, Type EB, 5%,	Allen-Bradley
1266	R16	6,800 ohms, Type GB, 5%,	Allen-Bradley
1044	R17	10,000 ohms, Type EB, 5%,	Allen-Bradley
1321	R18	15,000 ohms, Type CP-1/2, 1%,	Wilkor
1007	R19	2 megohms, Type EB, 5%,	Allen-Bradley
1063	R20	300 ohms, Type EB, 5%,	Allen-Bradley
1032	R21	47,000 ohms, Type EB, 5%,	Allen-Bradley
1042	R22	15,000 ohms, Type EB, 5%,	Allen-Bradley
1016	R23	470,000 ohms, Type EB, 10%,	Allen-Bradley
1016	R24	470,000 ohms, Type EB, 10%,	Allen-Bradley
1652	R25	15,000 ohms, Type N25, 1%,	Corning
1653	R26	4,700 ohms, Type N20, 1%,	Corning
1657	R27	1,500 ohms, Type N20, 1%,	Corning
1655	R28	694 ohms, Type N20, 1%,	Corning
1253	R29	30,000 ohms, Type GB, 5%,	Allen-Bradley
1020	R30	300,000 ohms, Type EB, 5%,	Allen-Bradley
1267	R31	7,500 ohms, Type GB, 5%,	Allen-Bradley
1311	R32	50,000 ohms, Type CP-1/2, 1%,	Wilkor
1710	R33	250 ohms, Type RS-2, 1%,	Dale
1007	R34	2 megohms, Type EB, 5%,	Allen-Bradley
1007	R35	2 megohms, Type EB, 5%,	Allen-Bradley
1321	R36	15,000 ohms, Type CP-1/2, 1%,	Wilkor
1063	R37	300 ohms, Type EB, 5%,	Allen-Bradley
1321	R38	15,000 ohms, Type CP-1/2, 1%,	Wilkor

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 320 SCHEMATIC DIAGRAM, ISSUE A

B. L. Part #	Circuit Symbol	RESISTORS	Manufacturer
1063	R37	300 ohms, Type EB, 5%,	Allen-Bradley
1321	R38	15,000 ohms, Type CP-1/2, 1%,	Wilkor
1365	R39	19,000 ohms, Type CP-1/2, 1%,	Wilkor
1320	R40	20,000 ohms, Type CP-1/2, 1%,	Wilkor
1627	R41	(2x) 1,500 ohms, Type 28E, 5%,	Sprague
1208	R42	(2x) 2,000 ohms, Type HB, 5%	Allen-Bradley
1711	R43	10,000 ohms, Type RS-5, 1%,	Dale
1203	R44	10,000 ohms, Type HB, 5%,	Allen-Bradley
1582	R45	2.4 ohms, Type BW-1/2,	I.R.C
1063	R46	300 ohms, Type EB, 5%,	Allen-Bradley
1063	R47	300 ohms, Type EB, 5%,	Allen-Bradley
1086	R48	1,500 ohms, Type EB, 5%,	Allen-Bradley
1007	R49	2 megohms, Type EB, 5%,	Allen-Bradley
1007	R50	2 megohms, Type EB, 5%,	Allen-Bradley
1311	R51	50,000 ohms, Type CP-1/2, 1%,	Wilkor
1086	R52	1,500 ohms, Type EB, 5%,	Allen-Bradley
1026	R53	100,000 ohms, Type EB, 5%,	Allen-Bradley
1311	R54	50,000 ohms, Type CP-1/2, 1%,	Wilkor
1338	R55	1,000 ohms, Type CP-1/2, 1%,	Wilkor
1819	R56	10,000 ohms, Type 43-10K Pot.,	Clarostat
1370	R57	34,300 ohms, Type DC-1/2, 1%,	Electra
1371	R58	129,000 ohms, Type DC-1/2, 1%,	Electra
1372	R59	311,000 ohms, Type DC-1/2, 1%,	Electra
1373	R60	694,000 ohms, Type DC-1/2, 1%,	Electra
1374	R61	1.55 megohms, Type DC-1/2, 1%,	Electra
1375	R62	3.48 megohms, Type DC-1/2, 1%,	Electra
1464	R63	7.23 megohms, Type DC-1, 1%,	Electra
1465	R64	10.4 megohms, Type DC-1, 1%,	Electra
1376	R65	6,450 ohms, Type DC-1/2, 1%,	Electra
1377	R66	13,700 ohms, Type DC-1/2, 1%,	Electra
1378	R67	18,700 ohms, Type DC-1/2, 1%,	Electra
1379	R68	31,100 ohms, Type DC-1/2, 1%,	Electra
1380	R69	46,000 ohms, Type DC-1/2, 1%,	Electra
1381	R70	68,000 ohms, Type DC-1/2, 1%,	Electra
1382	R71	94,400 ohms, Type DC-1/2, 1%,	Electra
1383	R72	78,500 ohms, Type DC-1/2, 1%,	Electra
1911	R73	500,000 ohms, Type Q Pot.,	I.R.C.

REPLACEMENT PARTS LIST

REFER TO MODEL 320 SCHEMATIC DIAGRAM, ISSUE A

B. L. Part #	Circuit Symbol	CONDENSERS		Manufacturer
2129	C1	.033 uf,	Type 73P33010, 1000 v,	Sprague
2429	C2	7-45 uuf,	Type TS2A-N500,	Erie
2433	C3	0.75-1.5 uuf,	Type 3MB11-160-203,	E. F. Johnson
2229	C4A	1,500 uuf,	Type CM-20-152,	El-Menco
2529	C4B	75 uuf,	Type GP1K-750, 500 v,	Erie
2529	C4C	75 uuf,	Type GP1K-750, 500 v,	Erie
2130	C5	.047 uf,	Type 620G, 200 v,	Good-All
2024	C6A	40 uf,	Type DFP, 300 v,	Sprague
2024	C6B	40 uf,	Type DFP, 300 v,	Sprague
2024	C6C	40 uf,	Type DFP, 300 v,	Sprague
2024	C6D	20 uf,	Type DFP, 150 v,	Sprague
2025	C7A	10 uf,	Type DFP, 300 v,	Sprague
2025	C7B	150 uf,	Type DFP, 6 v,	Sprague
2025	C7C	5 uf,	Type DFP, 6 v,	Sprague
2163	C8	.22 uf,	Type 615G-22402, 200 v,	Good-All
2103	C9	.01 uf,	Type 67P10304, 400 v,	Sprague
2067	C10	12 uf,	Type BR-1225, 250 v,	Cornell-Dubilier
2530	C11	47 uuf,	Type GP1K, 500 v,	Erie
2103	C12	.01 uf,	Type 67P10304, 400 v,	Sprague
2004	C13A	15 uf,	Type DFP, 300 v,	Sprague
2004	C13B	15 uf,	Type DFP, 300 v,	Sprague
2527	C14	220 uuf,	Type GP2K, 500 v,	Erie
2103	C15	.01 uf,	Type 67P10304, 400 v,	Sprague
2109	C16	.047 uf,	Type 67P47302, 200 v,	Sprague
2110	C17	.047 uf,	Type 67P47304, 400 v,	Sprague
2026	C18A	30 uf,	Type DFP, 500 v,	Sprague
2026	C18B	10 uf,	Type DFP, 500 v,	Sprague
2525	C19	10 uuf,	Type GP1K, 500 v,	Erie
2027	C20A	200 uf,	Type DFP, 150 v,	Sprague
2027	C20B	200 uf,	Type TVA-2428, 150 v,	Sprague
2068	C20C	20 uf,	Type TVA-2428, 150 v,	Sprague
2068	C20D	20 uf,	Type DFP, 150 v,	Sprague
2020	C21	3,000 uf,	Type DFP, 10 v,	Sprague
2110	C22	.047 uf,	Type 67P47304, 400 v,	Sprague
2103	C23	.01 uf,	Type 67P10304, 400 v,	Sprague
2002	C24	15 uf,	Type DFP, 300 v,	Sprague
2164	C25	.01 uf,	Type FIF 103, 600 v,	Tobe
2164	C26	.01 uf,	Type FIF 103, 600 v,	Tobe
2060	C27	100 uf,	Type BRH-501, 50 v,	Cornell-Dubilier

REPLACEMENT PARTS LIST

REFER TO MODEL 320 SCHEMATIC DIAGRAM, ISSUE A

B. L. Part #	Circuit Symbol	OTHER COMPONENTS	Manufacturer
3004	L1	.7-3 mh Adjustable Coil,	Ballantine
3037	T1	Power Transformer,	Ballantine
3038	T2	Output Transformer,	Ballantine
3400	F1	1 amp. fuse, Type 3AG,	Littelfuse
3451	L1	Pilot Light, Type 47,	General Electric
3164	M1	Indicating Meter,	Ballantine
3231	S1	Range Selector Switch, Type L,	Ballantine
3232	S2	CAL-USE Switch, Type F,	Ballantine
3233	S3	Meter-Amp Switch, Type F,	Ballantine
3234	S4	ON-OFF Switch, Type 20994LH,	Arrow, Hart & Hegeman
3126	V1, 2, 3, 4	Type 5654 Tube,	General Electric
3121	V5, 6	Type 6U8 Tube,	RCA or Tung-Sol
3127	V7	Type 12AV7 Tube,	RCA or General Elec.
3128	V8	Type 0B2 Tube,	RCA
3106	V9	Type 0A2 Tube,	RCA
3117	V10	Type 5651 Tube,	Raytheon
3137	V11	Type 5V4G Tube,	RCA
3077	CR1A	Selenium Rectifier, Type QlClSlF,	Radio Receptor
3077	CR1B	Selenium Rectifier, Type QlClSlF,	Radio Receptor
3130	CR2, 3	Crystal diodes, Type 1N58A,	Sylvania
3119	CR4, 5, 6, 7, 8, 9, 10, 11	Crystal diodes, Type 1N54,	Ballantine

BALLANTINE LABORATORIES - BOONTON - N.J.

BALLANTINE LABORATORIES - BOONTON - N.J.