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IN THIS ISSUE

New Vibration Meter

New Service Laboratory for Canada

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CONTENTS

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Telephone: (Concord) EMerson 9-4400; (Boston) MIssion 6-7400

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THE TYPE 1553-A VIBRATION METER

The new General Radio Vibration Meter, Type 1553-A, is a portable easy-to-use instrument for the quantitative measurement of vibration. With its accelerometer, the Type 1560-P51 Ceramic Vibration Pickup,[1] it is direct reading in acceleration, velocity, displacement, and jerk. Other pickups can also be used, among them velocity-type transducers and special-purpose accelerometers responding to frequencies up to 20 kc. With many of these, the vibration meter can be adjusted to be direct reading.

The excellent performance of this instrument is made possible in large part by its stable, high-gain, wide-band, low-noise amplifier, which can also be used as a sensitive voltmeter for audio and subaudio frequencies and as a calibrated, multi-range preamplifier for analyzers; stroboscopes; tape, graphic level, or direct-reading oscillographic recorders; and oscilloscopes.

The cover photograph shows the external features of the new Type 1553-A Vibration Meter. The instrument is housed in an aluminum Flip-Tilt[2] case, which combines convenience in use with protection during transportation or storage. The pickup, cable, six-inch probe, and probe tips are stored in the cover. The panel layout and readout dials have been designed to avoid ambiguities and to make the instrument simple and easy to use and to read.

[1] E. E. Gross, Jr., "Type 1560-P11 Vibration Pickup System," *General Radio Experimenter*, 34, 11 & 12, November-December, 1960.

[2] H. C. Littlejohn, "The Case of the Well Designed Instrument," *General Radio Experimenter*, 34, 3, March, 1960.

CIRCUITS

The electrical signal from the vibration pickup (accelerometer) is processed by the following electrical systems that make up the indicating instrument: the amplifier, a calibrated attenuator, three ac voltmeters, integrating circuits to convert acceleration signals to velocity or displacement signals, a differentiating circuit to convert acceleration signals to jerk signals, and a calibration circuit for maintaining amplifier gain or for setting amplifier gain to accommodate alternate pickups with different sensitivities. These are indicated graphically in Figure 1.

Amplifiers

Experience gained in the design and building of amplifiers for portable sound-level meters[3,4,5] has been put to direct

[3] E. E. Gross, Jr., "Type 1551-A Sound-Level Meter," *General Radio Experimenter*, 26, 10, March, 1952.

[4] E. E. Gross, Jr., "Improved Performance Plus New Look for the Sound-Level Meter," *General Radio Experimenter*, 32, 17, October, 1958.

[5] E. E. Gross, Jr., "Type 1551-C Sound-Level Meter," *General Radio Experimenter*, 35, 8, August, 1961.

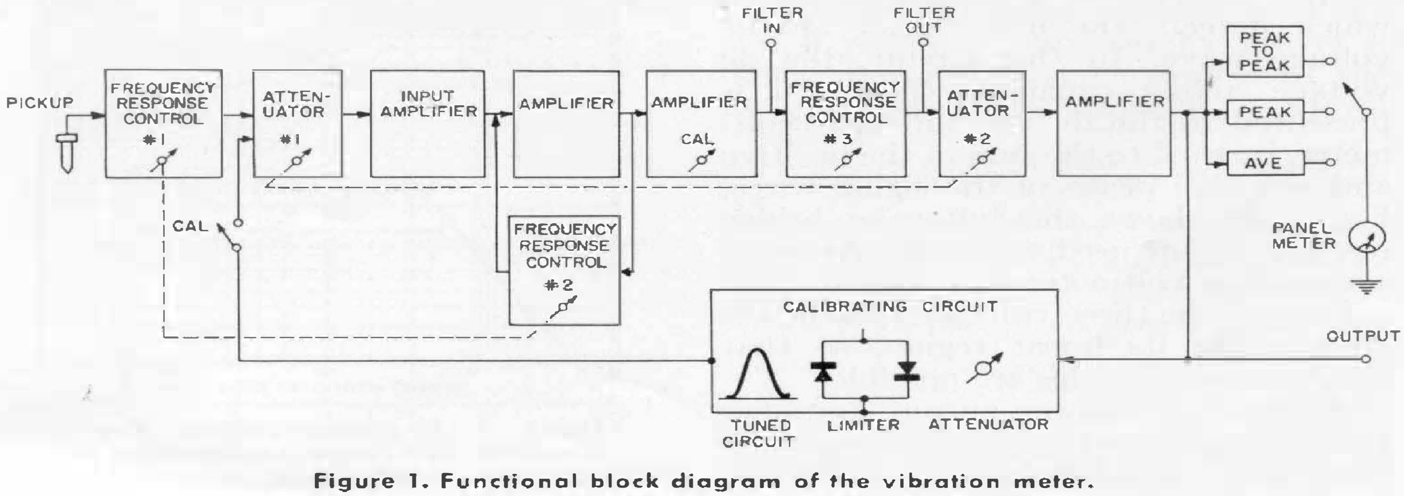

Figure 1. Functional block diagram of the vibration meter.

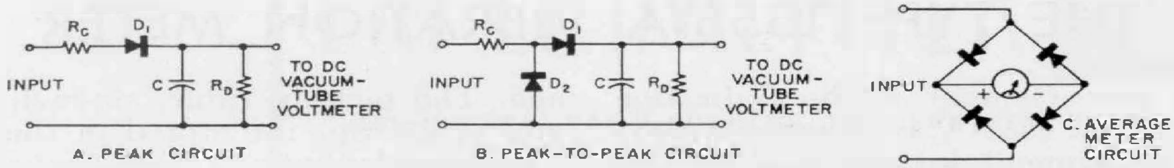

Figure 2. Elementary schematics of the voltmeter circuits.

use in the amplifiers of the TYPE 1553-A Vibration Meter. Similar circuitry as well as resilient mountings and supports for microphonic suppression have been employed. Transistors have been used where characteristics and stability achieved surpassed that previously obtained with vacuum tubes. In some instances, however, the requirements are, even today, better met with vacuum tubes. For example, transistorized versions of the high-impedance low-noise input amplifier are not competitive economically or reliably with vacuum-tube models. In addition, coupling and by-pass capacitors often become prohibitively bulky and expensive when low-impedance transistor amplifiers replace tube amplifiers that must have flat response to 2 cps or lower.

Voltmeters

The three voltmeter circuits with responses, respectively, of peak, peak-to-peak, and average are shown in Figure 2. The peak-indicating circuit (Figure 2a) is the well known combination of a diode rectifier, a capacitor and a dc voltmeter system. The peak-to-peak reading circuit (Figure 2b) is obtained by the addition of a second diode D_2 which detects the other peak of the voltage wave. In this circuit, the dc voltage across capacitor C, which is presented to the dc vacuum-tube voltmeter, is equal to the sum of the positive and negative peaks of the signal wave. Figure 2c shows the full-wave bridge rectifier circuit used to obtain the average reading voltmeter.

Each of the three voltmeter circuits is operated in its linear region, so that common meter scales are possible.

An emitter-follower output amplifier and silicon-junction diodes make it possible to maintain a high ratio (10^5) of $\frac{R_D}{R_C}$ (see Figures 2a and 2b) to provide true peak and peak-to-peak responses, even for very complex wave forms.[6,7] The sensitivity of the average-reading meter circuit is adjusted to be 10 db

[6] Arnold P. G. Peterson, "Response of Peak Voltmeter to Random Noise," *General Radio Experimenter*, 31, 7, December, 1956.

[7] L. L. Beranek, *Acoustic Measurements*, John Wiley & Sons, New York, 1949, pp 475-479.

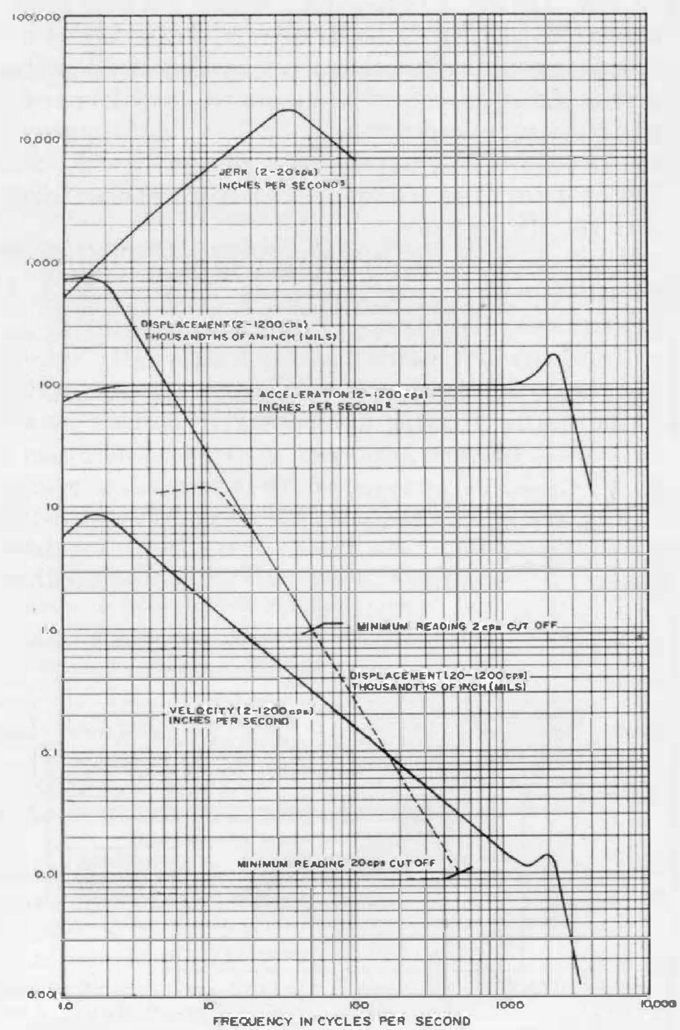

Figure 3. Frequency-response characteristics for a constant acceleration of 100 in./sec^2.

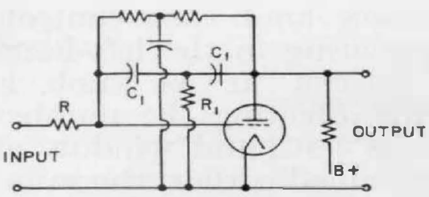

Figure 4. Schematic of improved integrating circuit.

greater than the sensitivity of the peak-to-peak reading, so that for a sine wave the same current flows through the indicating meter for average and peak-to-peak voltmeter selection. This change in sensitivity is automatically indicated in the window showing the meter full-scale reading.

Integrating Circuits

The frequency-response characteristics available in the TYPE 1553-A Vibration Meter with the TYPE 1560-P51 Pickup are shown in Figure 3. These curves show the readings obtained on the vibration meter as a function of frequency for a constant acceleration of 100 inches per second per second. Over their specified frequency ranges all responses are well within 10% of their respective design objectives. It is worth noting that the high sensitivity and good low-frequency response for velocity and displacement measurements have been achieved by an integrating circuit that performs the desired frequency-response shaping without the losses inherent in conventional integrating circuits. The circuit (Figure 4) is a modification of the familiar Miller-type integrator.[8] The grid-plate capacitor of the Miller circuit is replaced here by a form of parallel-T tuned circuit. Advantages of the new circuit are illustrated in Figure 5 which shows the low-frequency portion of the displacement response of the TYPE 1553-A and the computed response for two *RC* or Miller-type integrators. At f_1, the minimum desired response frequency, both responses are within 5% of the true displacement response. The difference in maximum responses (A) represents the saving in gain requirements for equivalent sensitivity on displacement afforded by the new circuit. This reduced gain requirement also means one can obtain higher sensitivity with no increase in noise level. A further improvement in noise level accrues from the new circuit because its response falls off just below its normal operating range of f_1 to nf_1.

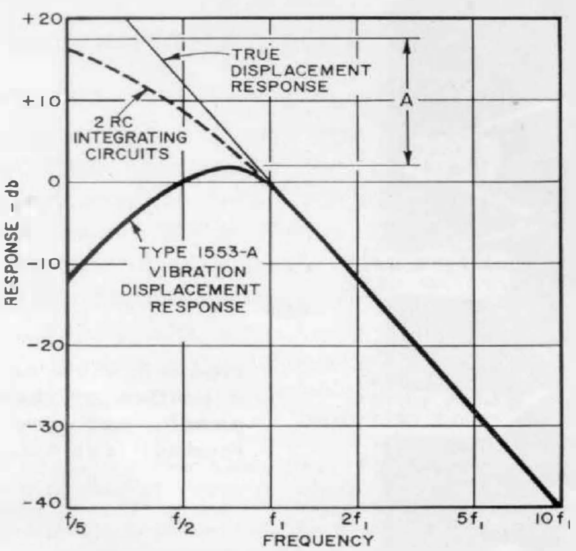

Figure 5. Low-frequency displacement response.

JERK RESPONSE

Jerk,[9,10,11,12] the time rate of change of acceleration, is the response obtained when the output of an accelerometer is differentiated. Jerk is a measure of any sudden change in acceleration of a body. It is this sudden change that is related to the riding quality of automobiles or elevators. It is important in load tie-down in railroad cars, trucks, and aircraft. Low frequencies (usually 1 to 20 cps) are of interest in jerk measurements. The rated response of the TYPE 1553-A for jerk measurement is 2 to 20 cps. The actual response, obtained by use of a differentiator of design* similar to the integrator described above, is, as shown

[8] *Reference Data for Radio Engineers — Fourth Edition*, International Telephone & Telegraph Corp., New York, 1957.

[9] *Ride and Vibration Data*, Special Pub. Dept. (SPC) Society of Automotive Engineers, New York, 1950.

[10] T. A. Pearls and C. W. Kissenger, "A Jerkmeter for Ballistocardiography," *NBS Report No. 4132*, Washington, D. C., June, 1955.

[11] Donald P. Eckman, *Industrial Instrumentation*, Wiley & Sons, New York 1951, p 213.

[12] Arnold P. G. Peterson and E. E. Gross, Jr., *Handbook of Noise Measurement (Fourth Edition)*, General Radio Company, 1960.

*Here the parallel-T circuit is used below its null frequency while the integrator operates above the null frequency of the parallel-T network.

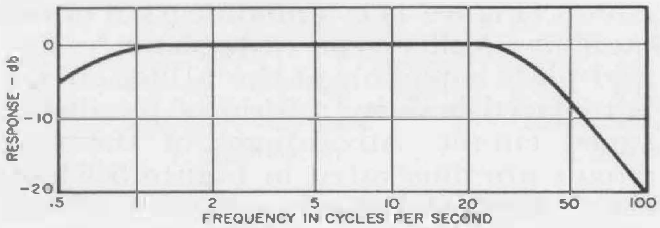

Figure 6. Response to constant jerk signal as a function of frequency.

in Figure 6, very good from 1 to 25 cps. A welcome by-product of this type of differentiator is the very good high-frequency cut-off.

READOUT SYSTEM

The information available from the TYPE 1553-A is indicated in a simple unconfusing manner. Figure 7 shows the appearance of the two main readout dials. The meter full-scale sensitivity always appears in the left-hand window, while the appropriate units always appear in the right-hand window. Any one of three panel controls can change the setting of the meter full-scale dial, each independently of the other two. As one might expect the SCALE SELECTOR knob controls this dial over a wide range of meter sensitivities (ten 10-db steps). In addition to pointing to the measurement characteristic and changing the units appearing in the right-hand window the FUNCTION knob also controls the number appearing in the left-hand window. The METER READS knob is the third control affecting the number appearing in this left-hand window of Figure 7. As explained earlier, the number is decreased by 3 to 1 when the knob is turned from PEAK to AVE.

CALIBRATION

Internal calibration of the vibration meter is accomplished by a method similar to that employed to calibrate the General Radio Sound-Level Meter.[1] A feedback system from output to input containing a tuned circuit, a calibrated attenuator, and limiters is adjusted to produce a 100-cycle oscillation at a level indicated on the meter when the gain of the instrument is correct. The attenuator is calibrated for pickup sensitivities of 30 to 150 mv/g. A precise setting of the meter indication in the CAL position is not required because the meter indication multiplies any change in amplifier gain, i.e. the meter reading changes approximately ten percent for each one percent change in gain. Complete system calibration including the pickup at 100 cps can readily be made with the TYPE 1557-A Vibration Calibrator.[13]

[13]E. E. Gross, Jr., "Little Dithers," *General Radio Experimenter*, 34, 11 & 12, November-December, 1960.

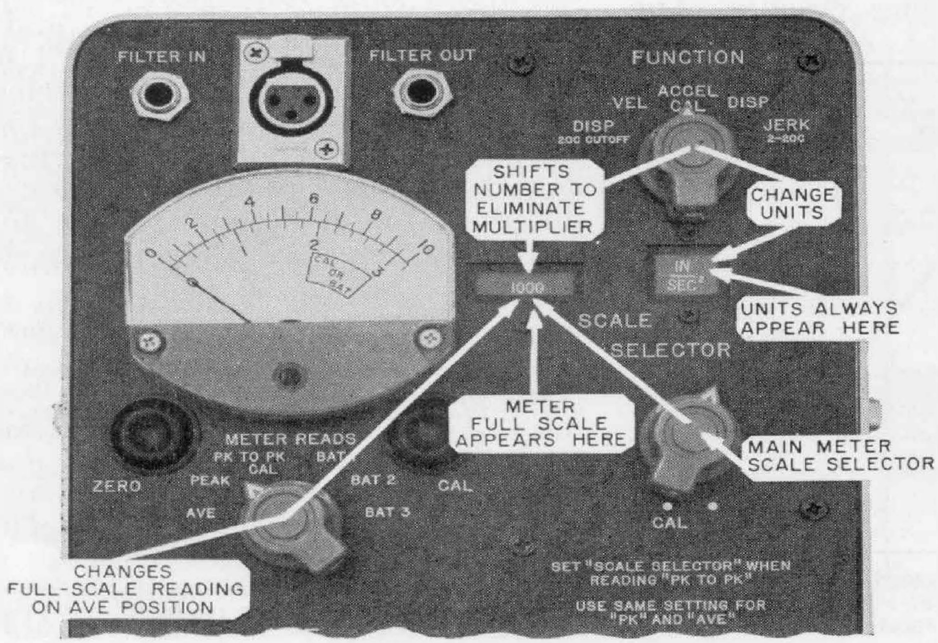

Figure 7. View of a portion of the panel showing readout system.

TABLE

TYPE 1553-A VIBRATION METER
MEASURED QUANTITIES AND MINIMUM SIGNALS

QUANTITY	MINIMUM READING PEAK TO PEAK	MINIMUM READING AVERAGE	MINIMUM SIGNAL μv rms	FREQUENCY RANGE CPS
Jerk	30 in/sec^3	10 in/sec^3	5.5	2-20
Acceleration	0.3 in/sec^2	0.1 in/sec^2	10	2-1200
Velocity	0.03 in/sec	0.01 in/sec	13	2-1200
Displacement	0.003 in	0.001 in	8.2	2-1200
Displacement	0.00003 in	0.00001 in	8.2	20-1200

SENSITIVITY AND NOISE LEVEL

Table 1 lists the effective sensitivity of the TYPE 1553-A for each measured quantity. In each case the minimum reading is 1/10 full scale. The minimum signal is the rms input voltage required to produce the minimum readings. The internal noise level of the TYPE 1553-A causes a meter reading of less than 3%, and so the signal-to-noise ratio exceeds 10 db at the minimum reading tabulated. On acceleration, which is the response one would choose when using the instrument as a voltmeter or preamplifier for auxiliary equipment, the maximum full-scale sensitivity is 100 μv rms. This is true for the 2-to-20,000 cps bandwidth as well as the 2-to-1200 cps bandwidth shown.

AUXILIARY EQUIPMENT

Analyzers

The output from the TYPE 1553-A Vibration Meter can be fed to the TYPE 1554-A Sound and Vibration Analyzer[14] when spectrum analysis of the vibration waveform is required. The combination of these two instruments permits one to obtain detailed frequency and amplitude information for all four of the vibration quantities measured with the TYPE 1553-A. Frequency analysis is necessary in many mechanical design problems and in most vibration control problems.

For shock measurements the TYPE 1556-B[15] Impact Noise Analyzer can be operated from the vibration meter output. The storage feature of the impact noise analyzer makes it possible to measure the peak value of a single shock on impact, while the time-average measuring circuit provides a measure of the shock duration.

Strobotac

The 5-volt output from the vibration meter is adequate to trigger the TYPE 1531-A Strobotac® Electronic Stroboscope,[16] so that the strobe light is synchronized with a signal from the vibration being studied.

SUMMARY

The TYPE 1553-A Vibration Meter is a small, battery-operated, portable, complex but easily operated instrument for measuring one or more of four quantities of a vibratory motion. It is normally supplied with a rugged piezo-ceramic accelerometer pickup that has a very good low-frequency response. Excellent high-frequency performance permits the use of many small high-impedance accelerometers for measurements up to 20 kc. Efforts to keep the operation simple have resulted in a direct readout system in which the meter full scale and proper units are always correctly displayed — no multipliers. A

[14] J. J. Faran, "A New Analyzer for Sound and Vibration," *General Radio Experimenter*, 33, 12, December, 1959.

[15] Arnold P. G. Peterson, "The Impact Noise Analyzer," *General Radio Experimenter*, 35, 9, September, 1961.

[16] M. J. Fitzmorris, C. J. Lahanas, and W. R. Thurston, "New Eyes for Industry," *General Radio Experimenter*, 34, 9, September, 1960.

true peak-to-peak meter circuit is employed and frequency-response shaping circuits are designed to give maximum sensitivity with low noise.

— E. E. Gross, Jr.

CREDITS

The Type 1553-A Vibration Meter was developed by E. E. Gross, author of the foregoing article. Two who contributed to the packaging and general appearance of the instrument are George Clemow, who designed the direct read-out system, and Henry Sterling, who was responsible for the general mechanical design of the instrument. The project was under the direction of Dr. A. P. G. Peterson.

— Editor

SPECIFICATIONS

Ranges

Acceleration: 0.3 to 300,000 in./sec² peak-to-peak, 0.1 to 100,000 in./sec² average.

Velocity: 0.03 to 30,000 in./sec peak-to-peak, 0.01 to 10,000 in./sec average.

Displacement: 0.003 to 300 in. (peak-to-peak), 0.001 to 300 in. (average) from 2 to 1200 cps; 0.00003 to 30 in. (peak-to-peak), 0.00001 to 10 in. (average) from 20 to 1200 cps.

Jerk: 30 to 300,000 in./sec³ (peak-to-peak), 10 to 300,000 in./sec³ (average).

Frequency Range: Amplifier response, 2-20,000 cps; with Type 1560-P51 Pickup, 2 to 1200 cps for acceleration, velocity, and displacement, 2 to 20 cps for jerk.

Accuracy: ±10% of full scale.

Input Impedance: 25 megohms.

Voltage at Output Jack: 5 volts rms behind 75 kΩ for full-scale deflection.

Attenuators: A 10-step attenuator changes the meter scale range by a factor of 100,000 to 1. Window readout indicates full-scale values and units.

Calibration: Internal.

Allowable Pickup Sensitivity for Direct Reading: 30 to 150 mv/g.

Terminals: A panel jack is provided for plugging in headphones, Type 1554-A Sound and Vibration Analyzer, Type 1556-B Impact Noise Analyzer, Type 1531-A Strobotac® Electronic Stroboscope, or oscilloscope.

Tube and Transistor Complement: Two CK512AX, five CK6418, one 2N520A, one 2N525, and one 2N377A.

Batteries: 3 size D cells and one 67-volt battery (Burgess Type XX45 or equivalent) supplied. Typical battery life, 7 days at 8 hours per day.

Accessory Supplied: Type 1560-P51 Vibration Pickup.

Case: Flip-tilt aluminum case; pickup and probe store inside.

Dimensions: Width 8, height 9¼, depth 7½ inches (205 by 235 by 195 mm), over-all (case closed).

Net Weight: 10½ lb (4.8 kg).

Type		*Code Word*	*Price*
1553-A†	Vibration Meter	WAGER	$675.00
1560-P51	Replacement Pickup*	VIBRO	80.00
	Set of Replacement Batteries	WAGERADBAT	4.10
1560-P35	Permanent-Magnet Clamp	MAGNO	6.50

*Give instrument and serial number when ordering. †U.S. Patent Nos. 2,966,257 and D187,740.

GENERAL RADIO SERVICE LABORATORY OPENED IN TORONTO

For the convenience of our Canadian customers, a new Service Laboratory was opened November 1 at the General Radio Canadian Office, 99 Floral Parkway, Toronto 15, Ontario. This Laboratory provides complete repair and calibration facilities for General Radio products. For customers who wish to make their own repairs, a stock of replacement parts is available.

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