THE GENERAL RADIO
EXPERIMENTER

Type 1150-A DIGITAL FREQUENCY METER

NUMERIK DIGITAL INDICATORS

VOLUME 36 No. 4 APRIL, 1962

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GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

A FIVE-DIGIT SOLID-STATE COUNTER FOR FREQUENCY MEASUREMENTS TO 220 kc

The Type 1150-A Digital Frequency Meter is the first of a line of inexpensive, basic counters for laboratory and industrial applications. Like the Type 1130-A Digital Time and Frequency Meter announced a year ago, it is accurate, reliable and easy to operate. Unlike the Type 1130-A, which has memory circuits and a neon-tube columnar readout, the Type 1150-A uses transistors instead of tubes and an in-line readout with alternate counting and display periods.

The counting circuits used are simple, but unconventional by today's practice. Instead of a scale-of-ten derived from a scale-of-sixteen circuit through appropriate feedback, the Type 1150-A is based upon the earlier ring-of-ten counting system.[1] Although the ring circuits require ten bistable elements, instead of four,[2] we have found[3] that modern semiconductors can be used in a simple and economical design. Not only is the overall number of circuit components for a complete decade, including indicators, actually less than that required for the coded scale-of-sixteen circuit, but performance at high counting rates is better, and the circuits can be designed to have tremendous latitude in accommodating variations in transistor characteristics.

Transistors typically operate at relatively low voltages and high currents and are therefore better suited to lighting incandescent lamps than to operating gas-discharge-type indicators. The ring-of-ten circuit is, as a result, directly adaptable to the ten-lamp, end-fire-illuminated NUMERIK indicator (also described in this issue) without interconnecting circuitry. Since the count proceeds around the ring, one flip-flop at a time, in identical reset-set operations, there is no time lost in feedback

[1]See, for instance, V. H. Regener, *Review of Scientific Instruments*, 17, p. 180, 1946.

[2]R. W. Frank and H. T. McAleer, "A Frequency Counter with a Memory and with Built-in Reliability," *General Radio Experimenter*, 35, 5, May, 1961.

[3]A similar approach, for instance, but using complementary techniques, is described by R. A. Stasior, *G. E. Technical Information Series RG1-EGP16*, May 16, 1961.

Figure 1. The Type 1150-A Digital Frequency Meter. Encased in General Radio's multi-purpose cabinet,[4] the instrument is readily mounted in a rack or adapted to table-top use with end frames. The panel is 3½ inches high. The controls and fittings are simple and clearly marked. Frequencies between 10 cps and 220 kc can be counted over preselected time intervals from 0.1 to 10 seconds. Display times can be continuously adjusted from 0.5 to 5 seconds and ∞.

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

mechanisms, and the effects of delays in the transistors are therefore minimized. There is, furthermore, no need to interlock dc levels between various parts of the circuit to maintain adequate margins for reliability. The ring circuits used in this counter are, in fact, so noncritical that they will work with intermixed transistors, ranging in characteristics from the lowest-cost alloy-junction transistors to MADT types!

The fact that incandescent lamps can be lit directly by the collector currents of the counting transistors themselves leads to the utmost simplicity and economy. At the same time, this very simplicity puts a premium on displaying the count according to the conventional count-display time cycle, rather than the continuous regime made possible by the use of auxiliary memory circuits. For ultimate ease of reading and efficiency of counting, the memory system pioneered by the TYPE 1130-A Digital Time and Frequency Meter remains pre-eminent. The need for memory in this less expensive instrument is less, however, because the eye is less fatigued by the blurring that occurs during the counting interval in in-line presentation than by the running-up-and-down appearance of columnar displays.

Five-digit presentation necessarily means, for a full register, a precision of ± 1 part in 10^5, determined by the ± 1 count uncertainty in the last place. The TYPE 1150-A Digital Frequency Meter, like other GR counters, is designed to yield an accuracy figure that takes full advantage of its inherent precision. Even in this simple, inexpensive instrument, this demands the inclusion of an oscillator with a stability over several minutes of at least ½-part per million. This accuracy is necessary because the counter can count a signal of 220-kc frequency for up to 10 seconds. A temperature-controlled quartz crystal, operating at 100 kc, is therefore used as the fundamental reference for the various timing signals required to produce the accurately known time intervals during which the counts accumulate.

MECHANICAL DESIGN

The mechanical design and component layout are simple and efficient, with all circuits easily accessible for maintenance and open for cooling (Figure 2). Ring counting units, input circuits and time-base dividers are on removable, vertical plug-in cards. These cards are arranged at right angles to the front panel and directly behind a large air filter. A small fan expels air from the box and draws cool air in over the vertical circuit cards. With this cooling system a maximum temperature rise at the hottest spot on any of the circuit boards is less than 10°C, thereby insuring reliable operation at high ambient temperatures.

The NUMERIK indicators (see page 10) have a large and efficient heat sink for their incandescent lamps, which prolongs lamp life. In the event of failure, however, any individual lamp can be easily replaced. The group of five NUMERIK indicators are accessible from the front panel of the instrument. A quarter turn of two mounting thumbscrews permits the entire block of indicators to be pulled forward and withdrawn several inches. Eight replacement 330-type lamps are stored in pockets behind the bezel. In order to replace a burned-out lamp, one simply removes two screws holding the backing plate of the indicator and replaces the lamp in the numbered socket. The entire re-

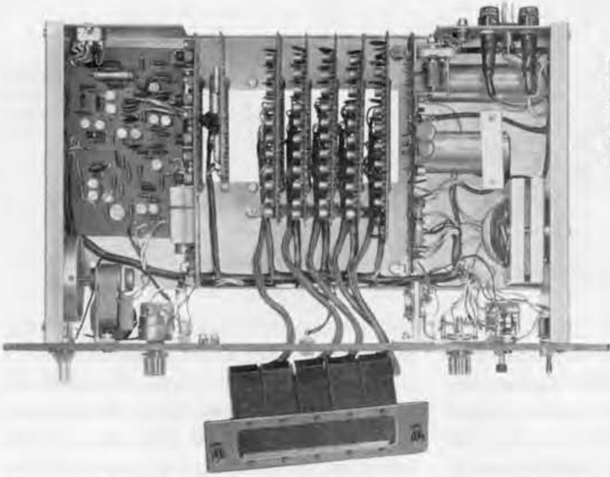


Figure 2. Interior view, showing NUMERIK Indicator assembly detached. The eight spare indicator lamps can be seen behind the panel to the left of the NUMERIK assembly.

placement can be accomplished in about one minute after a defective lamp has been isolated.

When a lamp fails, the entire decade becomes inoperative; no light shows. This fail-safe feature eliminates any possibility of incorrect reading.

A Polaroid filter is used in front of the bank of five indicators to eliminate specular reflection.

GENERAL CIRCUIT DESCRIPTION

The TYPE 1150-A Digital Frequency Meter counts the number of cycles of the input signal in a time interval established by the stable 100-kc crystal oscillator. The block diagram, Figure 3, shows the functional elements of the system.

The signal from the 100-kc crystal oscillator (or from an external 100-kc frequency-standard) is converted to a pulse train to drive a series of precision frequency dividers utilizing unijunction transistors. The output of this divider chain consists of pulses with periods of 0.1, 1, and 10 seconds. These pulses establish the precision gate interval.

In order to understand the program, let us assume that the time-base gate control flip-flop is in the "1" state and that the time-base gate is therefore open. The main-gate control flip-flop is in the "0" state, and the main gate is closed. The next pulse from the time-base divider circuits passes through the time-base gate, complements the main-gate control flip-flop to the "1" state and opens the main gate. When the main gate is open, pulses of the input-signal frequency are admitted to the five ring counting units and totaled. The next pulse from the time-base divider passing through the time-base gate resets the main-gate control flip-flop and closes the main gate. The main gate is therefore open for exactly one period of the time-base signal.

The NUMERIK indicators now begin to display the resultant count. This display interval is determined by the display-time monostable circuit and is adjustable from 0.5 to 5 seconds. When the main-gate control flip-flop closes the main gate, it also sets the time-base gate control flip-flop to the "0" state, closing

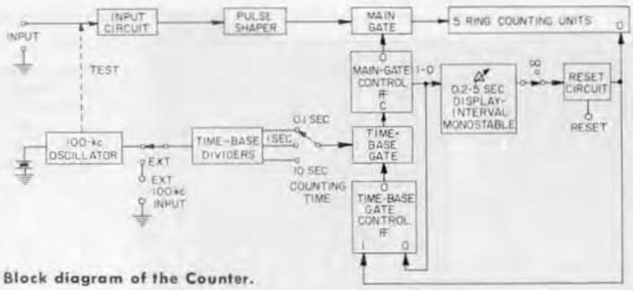


Figure 3. Block diagram of the Counter.

the time-base gate so that no more time-base pulses can pass to the main-gate control flip-flop until the display-time monostable circuit issues its output pulse operating the reset circuit. The reset circuit sets the ring counting circuits to zero, and the end of the zero-setting pulse will set the time-base gate control flip-flop to "1." The process then repeats.

An infinite display time can be obtained if the output of the display-time monostable circuit is opened so that no reset pulse is produced. A switch at one end of the time-interval adjustment range performs this operation and makes possible indefinite display of the results of a single measurement initiated when the manual reset button is pressed.

Provision is also made for manual control of the counting time. When the counting-time switch (Figure 3) is set to a fourth position, the main-gate flip-flop can be controlled from a push-button. The main gate is opened when this button is released and closed when the button is depressed. With manual gating, one can use the counter as a simple totalizing instrument. In the manual position, when the main-gate control flip-flop is set to "0" a normal display and clearing cycle is initiated. A normal display time of 0.5 to 5 seconds can be obtained or the total reading can be retained indefinitely if the display-time switch is set to infinity.

External circuitry can be used to control the gate interval through an auxiliary plug on the rear skirt of the instrument. In addition, this auxiliary plug also provides: (1) the carry pulse from the last of the five decades; (2) means for applying an externally generated reset pulse; (3) a positive pulse corresponding in time to the reset pulse; (4) +20 volts dc; and (5) ground.

RING COUNTING UNITS

The heart of this counter is the ring counting unit. A ring counting system can be considered to be a stepping switch with ten contact positions, as shown in Figure 4. A lamp is connected

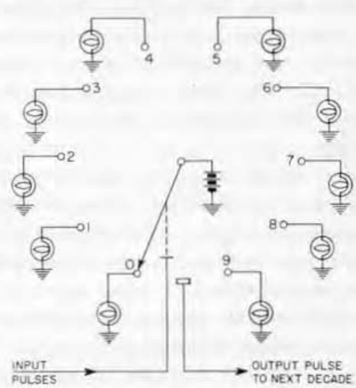


Figure 4. Elementary ring counter.

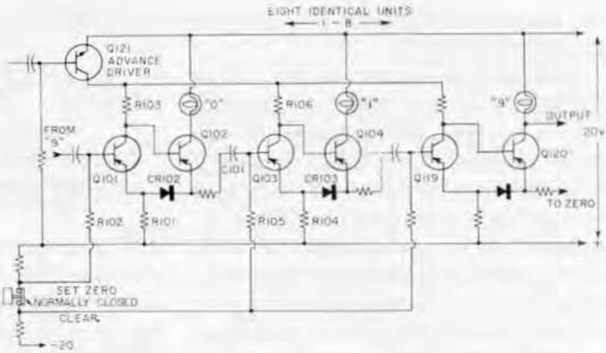


Figure 5. Simplified schematic of one of the ring counting units used in the Type 1150-A Digital Frequency Meter.

to each contact, and the switch rotor is connected to a source of voltage. Each time a pulse is received, the rotor moves from one contact to the next, and the particular lamp that is lighted indicates the number of pulses that have been received. By generating an output pulse each time the rotor moves from "9" to "0," the ring counter functions as a simple decade divider and drives the succeeding unit at one-tenth the rate.

Five ring counting units (RCU's) are used in the TYPE 1150-A Digital Frequency Meter. Twenty-one transistors are required for each decade, two for each of the ten digits, and one more to "move the rotor." Figure 5 is a simplified schematic of one of these five ring counting units. All five are identical in structure. The first unit differs from the other four only in the choice of component values for best high-frequency operation. Each unit consists of a ring of ten bistable circuits, each of which has one "high-current" transistor that drives its associated incandescent lamp in the NUMERIK indicator for that decade.

Referring to Figure 5, let us assume that the decade has been set to its zero state. Q-101 will be OFF and Q-102 ON. Q-102 has its base forward-drive current provided through R-103 and is in saturation, passing 80 milliamperes to light the "0" lamp in the indicator. This 80 milliamperes produces a voltage of −5.5 volts across R-101. The base of Q-101 is returned via R-102, to the set zero buss voltage of about −5.0 volts. The base of Q-101 is, therefore, reverse biased with respect to the emitter, and Q-101 remains OFF. The circuit is stable in this state.

All other pairs in the ring have the opposite stable state. Left-hand transistors, Q-103, etc., are all saturated, and the right-hand transistors, Q-104, etc., are OFF. These are also stable states. Look at Q-103, for example. When it is ON, nearly 1 milliampere of base forward drive flows through R-105, which is connected to the clear buss (at the same potential as the set zero buss). The drop across the 68-ohm resistor R-104 in the common emitter circuit is but 0.07 volt, and practically the full 20-volt collector supply voltage appears across R-106. The very small emitter-to-collector drop of Q-103 is normally below the conduction-knee voltage of Q-104 and keeps it OFF. Complete cutoff of Q-104, even at elevated temperatures and for all possible transistor combinations, is insured by the silicon diode (CR-103 in series with the emitter of Q-104).

The input signal advances the state of the decade by one stage per pulse. A negative pulse is first applied to the base of the advance driver Q-121, turning it OFF. The lamp driver, Q-102, loses base forward drive and goes OFF. The common-emitter voltage changes from −5.5 to zero, and Q-101 goes ON. The positive pulse produced at the common emitter is fed through C-101, turning Q-103 OFF and Q-104, the "1" lamp driver, ON. Each succeeding pulse applied to Q-121 advances the count by one digit. At the count of ten the circuit is switched to the initial conditions, and the negative pulse, as the "9" lamp extinguishes, is fed from the RCU as a carry pulse to the advance driver of the succeeding RCU.

In the simplified schematic of Figure 5 the zero-set system is depicted as a manual switch for simplicity. Opening this switch obviously returns the clear buss to −20 volts, causing all left-hand transistors of the bistable circuits to saturate, and turning the lamp drivers for lamps "1" through "9" OFF. Q-101, on the other hand, loses its forward bias, desaturates, and permits Q-102 to go ON, thereby turning the "0" lamp ON. A fast transistor switch is actually used in the TYPE 1150-A Digital Frequency Meter to accomplish zero setting for all five RCU's.

TIME BASE

The elementary circuit for the 100-kc crystal oscillator is shown in Figure 6. It uses two transistors, an *npn* and a *pnp*, in a modified Pierce circuit. All the open-loop gain (60 db) of this transistor pair is used as negative feedback. Thus, the circuit gain is very stable with respect to variations in temperature, voltage, and transistor parameters, re-

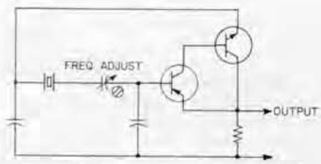


Figure 6. Elementary schematic of crystal time-base oscillator.

sulting in excellent oscillator-frequency stability. The temperature control for the crystal operates as long as the power line is connected, whether or not the panel power switch is on.

APPLICATIONS

The basic counter has many frequency-measurement applications. It can be used to calibrate, and to adjust the calibration of, any signal source lying in the frequency range from a few cycles per second to a maximum counting frequency of 220 kc. A few of its more important applications are: the calibration and setting of oscillators and signal generators, the monitoring of frequencies to 220 kc, and measurements on precision filters and other frequency-selective devices, where high resolution is needed for accurate frequency setting.

Other physical measurements offer a wide range of uses, including the measurement of rotational speed (with a photoelectric or magnetic pickup),[5] and, with appropriate transducers, pressure, temperature, strain, and weight.

With an appropriate transducer, photoelectric or otherwise, the counting of objects on production lines, of particles in liquids, and of similar events that may not be periodic will form an-

[5]A photoelectric pickoff device is now in the final stages of design at General Radio and will soon be available for use with the basic counter and with our stroboscopic equipment line. This unit is a completely self-contained light source and photoelectric cell, which will be powered by the counter or the stroboscope and which will feed its output signal back to the counter or the stroboscope for measurement. A three-connector jack is provided in the rear of the counter to accept this new photoelectric pickoff.

other group of important applications. The simplicity of operation, the accuracy and the reliability of this counter are determining factors in its acceptability in many of these applications.

— R. W. Frank
— J. K. Skilling

CREDITS

The Type 1150-A Digital Frequency Meter was developed by R. W. Frank and J. K. Skilling. H. P. Stratemeyer, Development Engineer, R. A. Mortenson, Design Engineer, H. G. Stirling, Designer, R. A. Chipman, Production Engineer, and William Howard, of Cornell University, have all contributed to the final design.

— Editor

SPECIFICATIONS

Frequency Range: 10 cps to 220 kc.

Input Impedance: AC-coupled approximately 0.5 megohm shunted by less than 100 pf.

Sensitivity: Better than 1 volt, peak-to-peak; for pulse input, duty ratio should be between 0.2 and 0.8.

Display: In-line register, incandescent-lamp-operated.

Display Time: Adjustable from 0.5 to 5 seconds, approximately, or ∞.

Counting Interval: 0.1, 1, 10 seconds, or can be set manually.

Accuracy: ± 1 count ± crystal oscillator stability.

Crystal-Oscillator Stability

Short-Term Stability: Better than ½ part per million.

Cycling: Less than counter resolution.

Temperature: 2½ parts per million for 0 to 50°C ambient.

Warm-up: Within 1 part per million after 15 minutes.

Aging: Less than 1 part per million per week after 4 weeks; decreasing thereafter.

Crystal Frequency Adjustment: The frequency is within 10 parts per million when received. Frequency adjustment provided.

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 45 watts.

Accessories Supplied: Type CAP-22 3-Wire Power Cord; spare fuses; 8 replacement indicator lamps.

Dimensions: Bench model, width 19, height 3⅞, depth 12½ inches (485 by 99 by 320 mm), over-all; rack mount, panel, 19 by 3½ inches (485 by 90 mm); depth, 12¾ inches (325 mm).

Net Weight: 17½ pounds (8 kg), approximately.

Type		*Code Word*	*Price*
1150-AM	Digital Frequency Meter, Bench Mount	OFFER	$915.00
1150-AR	Digital Frequency Meter, Rack Mount	OCCUR	915.00

Patent Applied For.

NEW 3-WIRE POWER CORD

The Type CAP-22 Power Cord (3-wire) is now supplied with all General Radio instruments that use a detachable power cord, replacing the Type CAP-15 formerly supplied. This new design has a hammerhead connector at its power-line end, with both male and female connectors, thus permitting two or more cords to be attached in parallel. Two No. 18 conductors are used. The covering is rubber, and the connector bodies are molded integrally with the cord. This power cord is also available separately, as listed below. Its length is 7 feet, and it is rated at 250 volts, 7 amperes.

Type CAP-22 Power Cord.

Type		*Code Word*	*Price*
CAP-22	Power Cord	TRUCO	$2.25

THE NUMERIK INDICATOR

Selection of the best available readout indicator has been an important part of the development of new in-line-presentation instruments like the one described in this issue.

In the majority of general-purpose applications, and particularly in transistor circuits, the use of incandescent lamp illumination is especially suitable. Transistors operate typically at low voltages, and incandescent lamps adapt easily to these conditions without requiring complicated ancillary circuitry.

After a careful survey of available designs, the products of K.G.M. Electronics, Richmond, England, were judged to have the best combination of these desirable characteristics:

1. Excellent presentation with clear, brilliant readout. The white light is both more pleasing to the eye and actinically more efficient than the orange-red of neon displays.
2. Neat, compact design, with effective means of heat dissipation to insure long lamp life.
3. Use of standard, readily available replacement lamps. Replacement, infrequently required, is easily done.

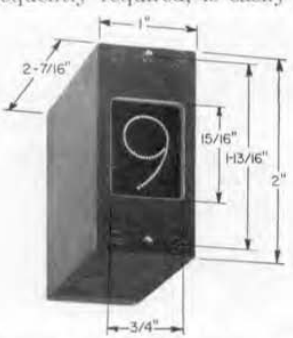


Figure 1. View of the Type IND-0300 NUMERIK Indicator, with dimensions. (Allow additional 1/16" on depth, for common terminal.)


Figure 2. Cutaway view of the Type IND-0300, showing construction.

4. Efficient use of light from low-power lamps.
5. Low parallax. All symbols appear to be nearly in the same plane.
6. Wide viewing angle.
7. Reasonable price.

The TYPE IND NUMERIK Indicators combine ten (or twelve) incandescent bulbs which can be illuminated individually and which, in turn, end-fire illuminate clear plastic strips, as illustrated in Figure 2. Light is introduced at one end of a thin, clear acrylic plate and is conducted with little attenuation along reflective ducting to the display surface where it is translated into a bright display by closely spaced dots scribed in the form of the numeral or symbol. A stack of ten plates is just over 5/16 inch deep.

Light transmission through the acrylic is so good that the bottom symbol of the stack appears to have about the same brightness as the top symbol. Thin sheets of reflective opaque material, which separate the paths through which the light to the display surface is conducted, reduce cross illumination to the point where all symbols except the one illuminated are, for practical purposes, not visible.

Because of the thin stack and excellent light conductivity, the NUMERIK Indi-

Figure 3. Rear view of the Type IND-0300, showing terminals.

cator has the unusually wide viewing angle of 120°.

The units are conveniently mounted behind the panel with only two screws.

To achieve long lamp life, the lamps are mounted in a drilled, solid aluminum block which serves as an efficient heat sink. Further, the sink is joined to the front panel of the instrument by large-cross-section aluminum side blocks. This configuration leads to cool operation and to lamp life averaging 5,000 hours under switching conditions.

Lamps are readily replaced. The removal of two screws at the back of the Indicator frees the lamp block and terminal plate as a unit.

Typical uses of the NUMERIK Indicator are found in annunciators, computers, counters, digital voltmeters and similar instruments, indicator boards for process control, paging systems, programmers, radar, timing systems, and clock displays.

Two types are available from stock: The TYPE IND-0300, which has ten numerals, zero through nine; and the TYPE IND-1801, which has the ten numerals plus a comma on the right side and a decimal point centered on the left side of the numerals. Additional types with letters and other symbols are available on special order.

The NUMERIK Indicators are manufactured for General Radio by K.G.M. Electronics under an agreement that makes General Radio the exclusive distributor for the United States and Canada.

SPECIFICATIONS

Lamps: 14-volt, 80-milliampere, 0.5 candlepower T-1¾ bulb; G.E. #330 or equal. Working life approximately 5000 hours (switching with 10% duty ratio).

Viewing Angle: 120° horizontal; 60° vertical.

Symbol Height: 13/16 inch.

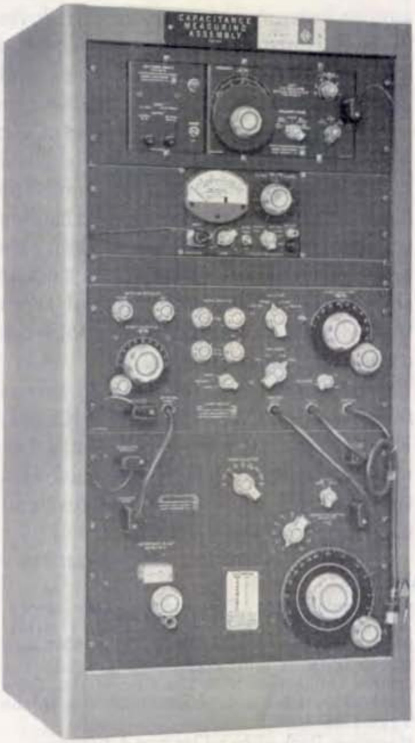
Lamp Holder Block: Solid aluminum heat sink with nylon-filled Bakelite backing block. Nickel-silver contact springs and 11 silver-plated terminals (13 for TYPE IND-1801), one for each lamp and a common ground. The ground connection is to the case of the TYPE IND-0300; it is insulated from the case in the TYPE IND-1801.

Mounting: Back-of-panel by two 4-40 screws.

		TYPE IND-0300	TYPE IND-1801
Window Size:		¾ by 15/16 inch	¾ by 1 1/16 inches
Mounting:		1 13/16 inches, centers	2 3/16 inches, centers
Dimensions:	Width	1 inch	1 inch
	Height	2 inches	2 3/8 inches
	Depth (including terminals)	2½ inches	2 11/16 inches
Net Weight:		4½ ounces	5 ounces
Code Word:		INDAK	INDIG
Prices:	1–19	$32.20	$33.60
	20–49	30.60	32.00
	50–99	28.60	30.00
	100–299	27.20	28.60
	300–999	24.70	26.10
	1,000–4,999	22.00	23.30
	5,000–9,999	18.40	19.60
	10,000–up	16.90	18.10

Patent Applied For.

TYPE 1610-B
CAPACITANCE-MEASURING ASSEMBLIES



View of Type 1610-B Capacitance-Measuring Assembly.

This capacitance-measuring system is now equipped with the TYPE 1210-C Unit RC Oscillator and the new TYPE 1232-A Tuned Amplifier and Null Detector, which replace the TYPE 1302-A Oscillator and the TYPE 1231-BRFA Amplifier and Null Detector used in the TYPE 1610-A Assemblies. Sensitivity is increased over that of previous models, and the detector is continuously tunable from 20 cps to 20 kc, with two additional fixed points, 50 kc and 100 kc. The oscillator frequency is continuously adjustable from 20 cps to 500 kc. The capacitance bridge, TYPE 716-C, remains unchanged.

Prices for the TYPE 1610-B Assemblies are lower than for the TYPE 1610-A, owing to the use of the less expensive but more modern oscillator and detector.

Two models are available: (1) the TYPE 1610-B, which includes the TYPE 716-P4 Guard Circuit, and is suitable for both three-terminal and two-terminal measurements, and (2) the TYPE 1610-B2, which is suitable for two-terminal measurements only. Each is complete in cabinet-type relay rack, with connection cables and power cord.

Type		*Code Word*	*Price*
1610-B	Capacitance-Measuring Assembly	SEDAN	$1740.00
1610-B2	Capacitance-Measuring Assembly (less Guard Circuit)	SABER	1465.00

General Radio Company

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