the GENERAL RADIO
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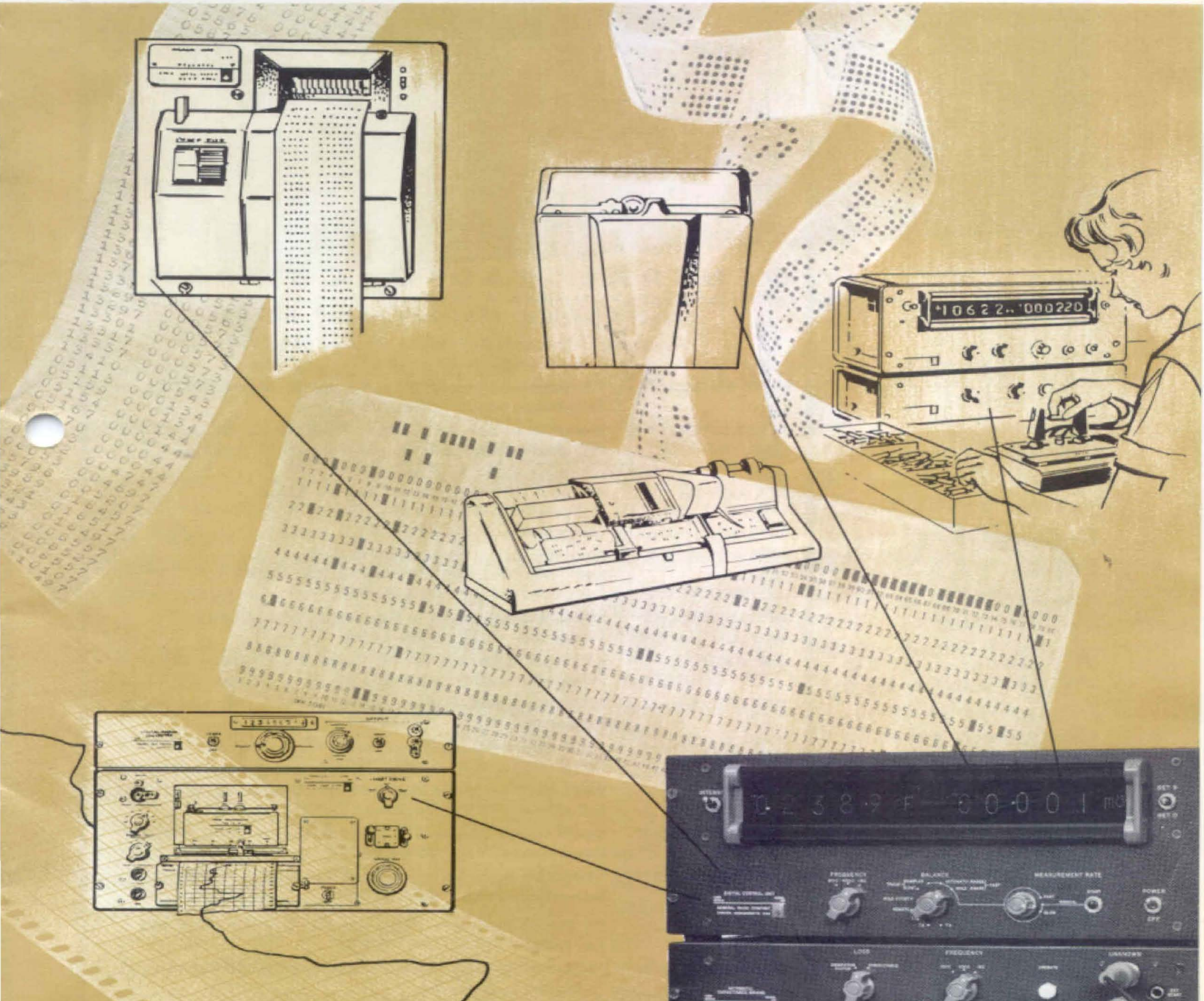
50th ANNIVERSARY

VOLUME 39 NO 4 APRIL 1965



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THE AUTOMATIC CAPACITANCE BRIDGE
COAXIAL MICROWAVE NEWS
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Figure 1. Type 1680-A Automatic Capacitance Bridge Assembly.

THE AUTOMATIC CAPACITANCE BRIDGE

The ideal measuring instrument is one that requires only that the unknown be connected to its terminals and which thereupon indicates the measured value, with not so much as a single control being manipulated. A few such automatic instruments have been developed; many more are sure to come. General Radio's first entry in a projected series of automatic digital instruments is the Type 1680-A Automatic Capacitance Bridge, which selects range, balances capacitance and loss simultaneously, generates coded digital output data, and displays the measured values, complete with decimal points and units, on illuminated indicators — all in a half second or so. This new bridge not only permits a dramatic speedup in the measurement of capacitors, but also couples easily into systems for automatic, error-free recording of data.

The exceptional speed and self-balancing capability of the automatic bridge are not bought at the expense of accuracy or capacitance range. Basic accuracy is ±0.1%, and the capacitance range for useful measurements is 1 picofarad to 1000 microfarads (see Specifications). Dissipation-factor range is 0.0001 to 1.0, and the bridge also measures parallel conductance from 0.1 nanomho to 1 mho.

HOW IT WORKS

The bridge circuit is a transformer ratio-arm bridge, in which balance is achieved by the adjustment of the voltage impressed on the standard capacitor. The method by which this voltage is automatically adjusted to produce balance is shown in Figure 2. Any unbalance current from the bridge is separated into real and imaginary components by two phase-sensitive de-

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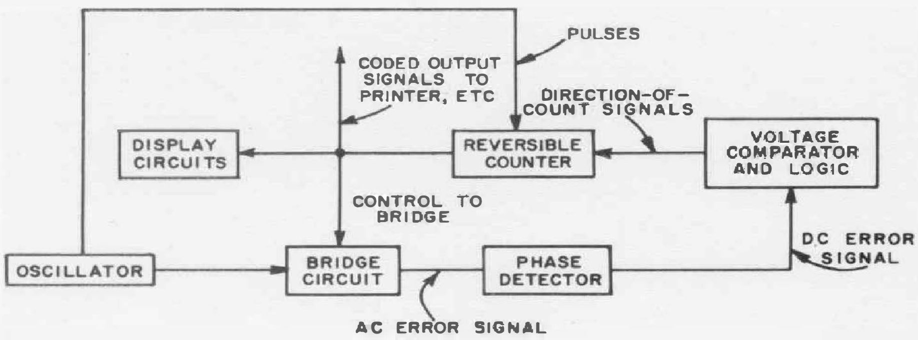

Figure 2. Elementary block diagram of the automatic bridge.

tectors. The dc output from each detector controls the direction in which a reversible counting decade counts pulses derived from the bridge generator. If, for instance, the capacitance value indicated by the counting decade is too high, the dc output from the phase detector will cause counts to be subtracted from the decade. The coded output of each counting decade is, in turn, fed back through a digital-to-analog converter to change the voltage on the bridge standard until balance is reached.

To minimize balancing time, as well as to afford the greatest versatility of operation, four operating modes are provided. The optimum mode depends on the kind of measurements being made and on how much each component differs in value from the next.

In the two FAST modes, the initial value is set to 02000, and the pulses are counted first in the *most* significant digit until it is balanced, then in the next most significant, and so on until the least significant digit is balanced. The balance speed in these modes is essentially independent of the value of the unknown.

The AUTOMATIC RANGE mode is used for highest-resolution measurements of capacitors that vary widely in value from one to the next. For such measurements, this is the fastest mode. The bridge quickly selects the right range and the balance sequence starts at the most significant digit and works to the least.

The HOLD RANGE mode is identical to the AUTOMATIC RANGE mode except that the bridge will not shift to a lower range and thus displays a series of measured values in a form for easy comparison. Operating in this mode, the bridge would not, for instance, indicate two successive measurements as 1263.1 nF and 13.107 nF. Instead, the second measurement would be made on the same range as the first, for a reading of 0013.1 nF. Although the bridge will not change to a lower range, it will go to a higher one, so that a correct answer will always be indicated.

In the two CONTINUOUS modes, the pulse count starts at the least significant digit of the counter, so that balance time depends on the difference

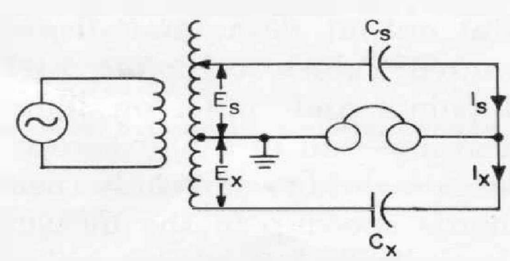

Figure 3. Simplified schematic diagram of transformer ratio-arm bridge.

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between the last value measured and the true value of the unknown.

In the continuous-tracking (TRACK CONT) mode, the balance begins at the previous measured value and proceeds from the least significant figure to the most, as with a conventional counter. The bridge then follows changes in capacitance as they occur, always indicating the current capacitance value. This mode is used if the application involves small changes in the capacitance being measured, as, for instance, in temperature-coefficient testing.

In the TRACK SAMPLED mode, the bridge, instead of automatically following changes in capacitance, makes measurements only on command of the operator. Balance starts at the previous value and proceeds from the least significant figure to the most, and this mode is thus especially useful in the testing of many capacitors of the same nominal value.

The Transformer Ratio-Arm Bridge

The transformer ratio-arm bridge (see Figure 3) has enjoyed recent favor in commercial designs and is used in the most accurate capacitance bridges available today.[1] The chief advantage of this type of bridge is that a precisely known turns ratio can be used to extend the usefulness of a single high-precision standard component over a very wide range. This turns ratio, moreover, is unaffected by age, temperature, or voltage variation.

To balance the bridge, the voltage on the standard capacitor is adjusted so that the current through the standard arms equals the current flowing through the unknown arm. Under this condition, the detector current is zero and the detector indicates a null. At balance, therefore:

$$E_s j\omega C_s = E_x j\omega C_x$$

or

$$C_x = \frac{E_s}{E_x} C_s.$$

The ratio transformer in the TYPE 1680-A Bridge is a high-permeability toroid with 1-, 10-, 100-, and 1000-turn windings. The internal standards, which basically determine the accuracy and stability of any bridge, are a 0.1-μF polystyrene and silvered-mica capacitor, with a temperature coefficient of only a few parts per million/°C, for capacitance measurements at 1 kc/s and 400 c/s; a 1-μF precision polystyrene capacitor for 120-cycle capacitance measurements; and, as conductance standards, several precision resistors wound on flat card forms to an initial tolerance of better than ±0.01% and sealed against atmospheric effects.

The Phase Detector

Since the detector signal is zero at balance, the phase-detector characteristics do not affect accuracy. They do, however, affect speed of balance. The TYPE 1680-A Bridge uses a sampling, or keyed, phase detector,[2] which arrives at its final output value within only one period of the signal frequency. The principle of operation is shown in Figure 4. The phase detector stores the instantaneous value of the input signal at a particular point in the ac cycle. So that the detector can sample the value of the in-phase component, a

[1] J. F. Hersh, "Accuracy, Precision, and Convenience for Capacitance Measurements," *General Radio Experimenter*, August–September 1962.

[2] K. E. Schreiner, "High-Performance Demodulations for Servo Mechanisms," *Proceedings of the National Electronics Conference*, 1946, Vol 2, p 393–403.

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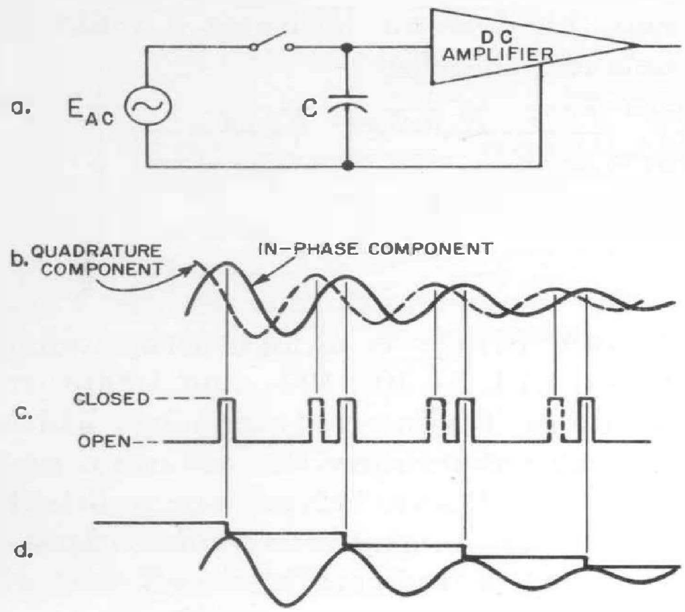

Figure 4. The sampled phase detector. a. Elementary block diagram. b. The error signal, E_{AC}, resolved into in-phase and quadrature components. c. The switch closes when the signal component reaches its peak value. d. The resulting dc output closely follows the peak value of the signal component as the error signal approaches zero.

switch is closed briefly when this component reaches its peak amplitude, and this peak value is stored in a storage capacitor. The quadrature component is zero at this time and thus does not affect the voltage. The dc output of this type of detector follows the instantaneous value very closely and supplies the necessary up-to-date information to the logic circuits.

The Reversible Counter

There are two reversible decade counters, one for capacitance balance, one for loss. Each consists of four complementary flip-flops coupled together by gates that can arrange the circuit for either forward or reverse counting. The digital logic[3] by which the four flip-flops are used to generate a scale of 10 is shown in Figure 5. A 1-2-4-2 coded output is supplied at a rear-panel connector to drive auxiliary output devices, such as printers, tape-punches, etc.

Voltage-Adjusting Network

To balance the bridge to a null, the voltage on the standard capacitor must be adjusted precisely in steps as small as the least significant digit, which is

[3] Patent applied for.

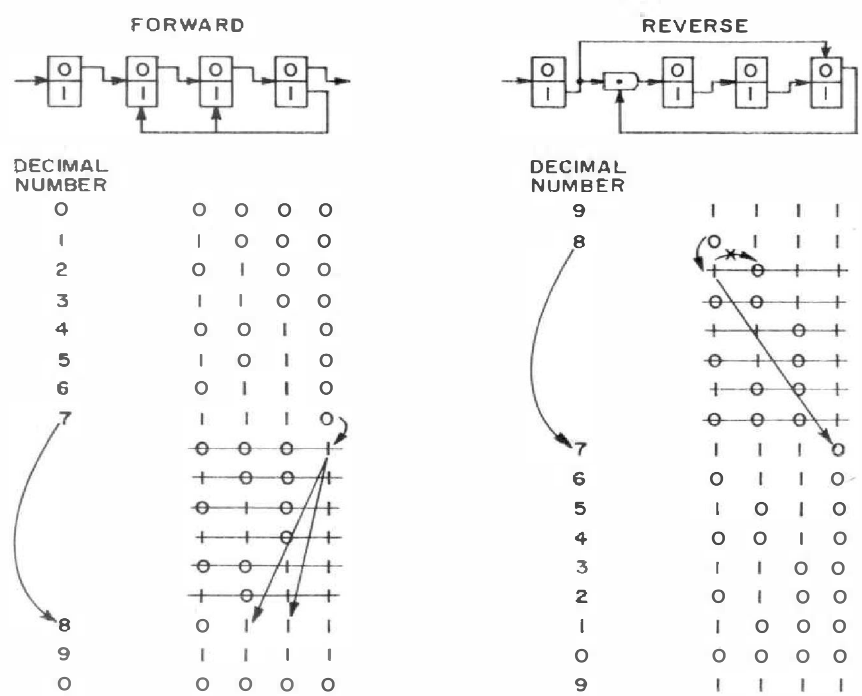

Figure 5. (*Left*) Feedback system for converting 16 states of four flip-flops into a scale of 10. Carry pulses are generated during transitions from state 1 to state 0, feedback pulses during transitions from state 0 to state 1. The crossed-out states do not occur but are bypassed by the feedback reset operations.
(*Right*) In the reverse direction, carry pulses are generated during transitions from state 0 to state 1. After state 8, the carry pulse from the first flip-flop does not reach the second flip-flop because of the gate, but it is used to set the fourth flip-flop to the zero state.

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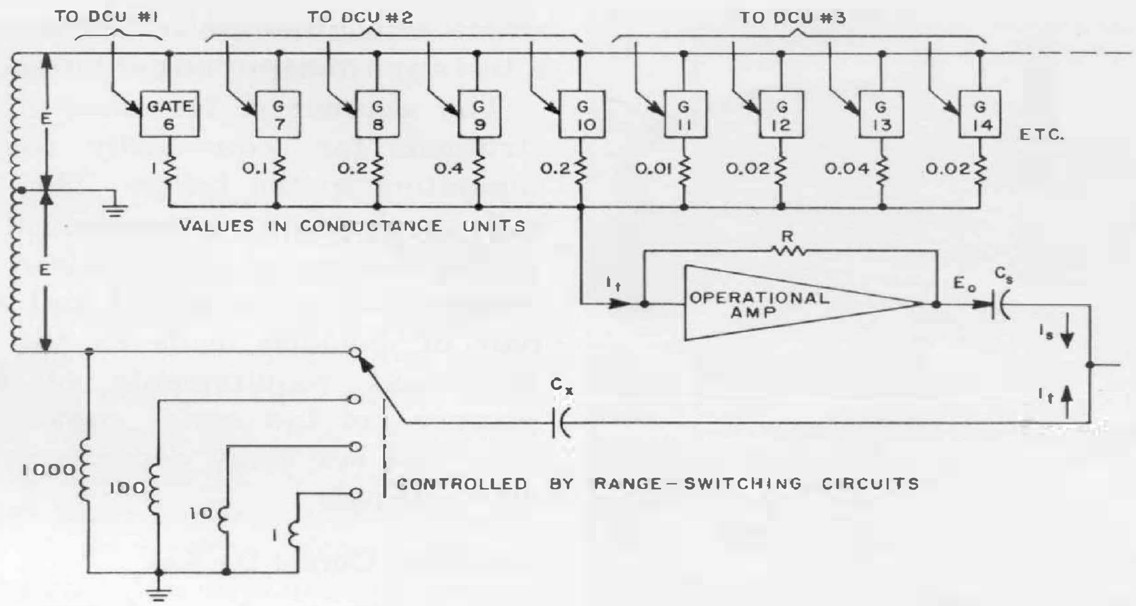

Figure 6. Resistive current-adding network used to control voltage on standard capacitor.

0.01% of full scale. Figure 6 illustrates the principle of the resistive current-adding network used for this purpose. The bridge voltage E is applied through transistor gating circuits to a series of weighted conductances. There are four conductances for each full counting decade, weighted in a 1-2-4-2 series to match the decade output code. If, for example, the unknown capacitor is 1.37 μF, the counting decades will continue to operate until the transistor gating circuits connect conductances weighted 1, 0.2, 0.1, 0.01, 0.02, and 0.04 (a total of 1.37) to the bridge transformer. When this condition is reached, a current of 1.37 units flows to the input of an operational amplifier and feedback resistor, which converts the current into 1.37 units of voltage to balance the bridge.

The transistor gating circuits do not significantly affect accuracy. With the high-gain operational amplifier, the digital-to-analog conversion accuracy is determined by the resistors to within a few parts per million.

Accuracy

The basic accuracy of the bridge is ±0.1% of reading for capacitance and conductance. In cases where this high accuracy is not required — in production-testing of 10% capacitors, for example — the balance speed can be increased by reduction of bridge sensitivity. A rear-panel sensitivity control is available for such purposes.

No error is introduced by stray capacitance if shielded cables are used. A three-terminal connection is thus made to the capacitors under test — both of the leads to the unknown being shielded by a grounded guard terminal. The stray capacitances to guard shunt the low-impedance ratio transformer and detector and therefore do not affect the accuracy. Series resistance of leads, however, can cause errors on the highest capacitance range. The curves given in the specifications include the effects of lead resistance up to 50 milliohms.

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Figure 7. Type 1680-P1 Test Fixture.

ASSOCIATED EQUIPMENT

Type 1680-P1 Test Fixture

As mentioned earlier, the automatic bridge is an amazing time-saver even without auxiliary instruments. One operator using one automatic bridge to measure capacitors can replace several operators using manually balanced bridges. The only auxiliary equipment really needed is some means of connecting the capacitors to the bridge terminals. The Type 1680-P1 Test Fixture (Figure 7) is ideal for this purpose. It includes adjustable, insulated, fast-action spring clips to receive the component leads and a built-in switch to start the balance procedure. Its top plate is removable so that it can be easily adapted to specialized contact arrangements. Shielded cables connect this jig to the bridge. Although it is designed primarily for axial lead components, the jig is easily adapted to accept parallel-lead units.

Automatic Input Devices

The process of connecting capacitors to the bridge can be completely automated. Automatic input equipment may be justified where the fastest possible measurement rate is required or where capacitors are to be measured in a test environment, out of human reach.

The scanner is the most likely instrument for sequentially connecting capacitors to the bridge. This is basically an electronic or mechanical switch, with a number of shielded leads to the components to be tested and a single pair of shielded leads to the bridge. Important requirements of such a scanner are low series contact resistance and low stray capacitance across the terminals.

Automatic Output Devices

Manual recording of measurement data can be every bit as time-consuming — and just as subject to error — as manual bridge balancing. Fortunately, the technology of data processing has advanced to the point where there is a fairly wide range of reasonably priced, relatively simple instruments to record data automatically. These include printers, tape- and card-

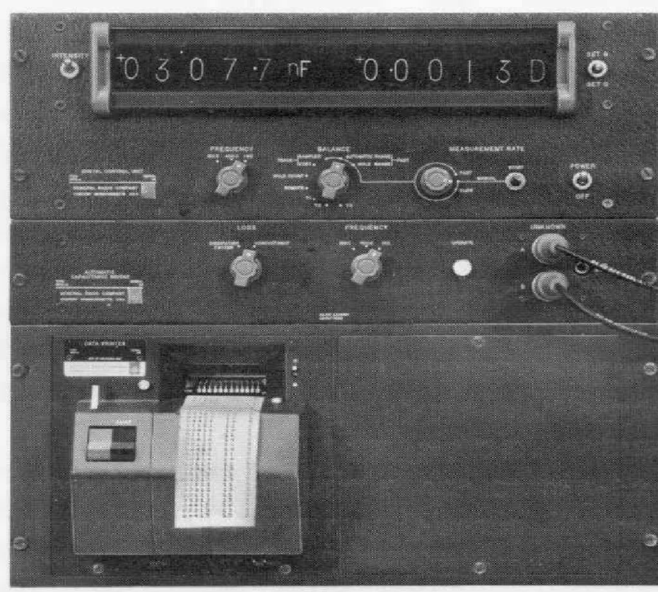

Figure 8. Type 1137-A Data Printer rack-mounted with the automatic bridge.

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punches, analog recorders, typewriters, and magnetic-tape recorders.

Printers

The General Radio TYPE 1137-A Data Printer (Figure 8) is designed for use with GR digital equipment. This is a 12-column printer, which therefore handles the full capacitance and dissipation-factor readouts (five digits each), with two columns left over. Since the printer does not print out the decimal point and units as they appear on the bridge's visual readout, one of the remaining two columns is usually used to indicate the range on which the bridge was balanced.

The printer is probably the simplest and least expensive way to record measurements made by the automatic bridge. Its disadvantage is that the printed tape it produces is not machine-readable, and it cannot, therefore, be fed into a computer for processing.

Tape Punch

A tape punch is the least expensive way to record data in machine-readable form. The measured values from the bridge are punched on the tape in binary-coded form, the presence or absence of a hole on the tape indicating a binary 1 or 0.

Binary-coded output data corresponding to all digits of the bridge readout are presented simultaneously (i.e., in parallel) at the bridge output connector. The tape punch, on the other hand, can accept and punch the data only one digit at a time (i.e., in series). Therefore, a parallel-to-serial converter (sometimes called an interface or intercoupler) is required between the bridge and the tape punch.

Fig. 9. IBM Model Printing Summary Punch operating from output of automatic bridge. Capacitance values are automatically punched; operator adds serial numbers. Also in relay rack are data printer and (top) intercoupler required for parallel-to-serial conversion.

Card Punch

The punched card has many advantages as a data-storage device. It is machine-readable. Cards can be automatically sorted or rearranged. A single card, bearing complete measurement data on a component, can travel with the component.

Figure 9 shows the bridge driving an IBM Model 526 Card Punch, with the aid of a parallel-to-serial converter.

Analog Recorders

In certain applications (in the plotting of temperature coefficients of capacitors, for example), an analog recording is the most useful presentation. This can be an X-Y chart or a strip chart, such as that produced by the GR TYPE 1521-B Graphic Level Recorder. Either way, a digital-to-analog converter is needed to translate

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the digital output of the bridge into a voltage analog. The Type 1136-A Digital-to-Analog Converter is compatible with recorders made by General Radio and by other manufacturers.

Digital Limit Comparators

In almost all high-volume capacitor test programs, a decision immediately follows each measurement. The capacitor is good or not good, higher or lower than nominal, inside or outside tolerance. A human operator can make these decisions, or they, too, can be handled automatically. A two-limit digital comparator can be programmed to indicate whether each capacitor is within a given set of limits, too high, or too low. The indication can be a simple set of panel lights or it can be in the form of relay contact closures used to sort capacitors into various bins. If the comparator is combined with a data printer, the latter can be made to print out-of-tolerance results in a second color.

The limit comparator is especially valuable in quality-control, production testing, and acceptance applications, where it can reduce hours of work to minutes. One can select a group of components, for example, measure them, and then glance at a printed tape to check for rejects. The tape can be filed with the acceptance report or returned to the supplier.

Other Output Devices

Typewriters and magnetic tape recorders are among the other output devices that can be used to record data from the automatic bridge. Both require a parallel-to-serial converter.

Realizing that the automatic bridge will more often than not be part of a larger measurement system, General Radio has arranged to supply complete systems incorporating auxiliary instrumentation described above.

APPLICATIONS

The automatic bridge was designed primarily for the rapid, automatic measurement of capacitance. The following are some of the specific applications calling for such a capability:

Incoming inspection

The automatic bridge is of obvious value in incoming-inspection applications, and especially in those involving many short runs of widely differing values. No set-up time, no sets of standards are required; the bridge can measure capacitors as fast as an operator can drop them into a test jig.

Environmental testing

A batch of capacitors can be measured over and over to determine the effect of aging, humidity, etc, on capacitance. For such measurements, a scanner is useful at the input, and a tape or card punch at the output.

Temperature-coefficient tests

The capacitance of a component can be measured as a function of temperature. An obvious arrangement consists of an X-Y plotter accepting capacitance data from the bridge, temperature data from a thermocouple and preamplifier.

Production testing

Large quantities of capacitors can be presented sequentially to the bridge by means of a belt, reel, or other type of component handler. A tape or card punch is recommended to store data.

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Production sorting

A digital limit comparator, as noted earlier, can be used with the bridge to inspect components rapidly on a go-no-go basis or according to programmed tolerances.

Other applications

Several ingenious customers have already discovered ways to use the bridge for applications other than the straightforward measurement of capacitors. The bridge, for instance, becomes a capacitance comparator if an external reference capacitor is connected to the proper terminals on the bridge. The bridge will then indicate the difference, positive or negative, between the unknown capacitor and the external standard. This permits extra accuracy and resolution over some of the range, and it is also useful where large numbers of capacitors must be padded to a given value. As each capacitor is connected to the bridge, the bridge indicates directly the value of the required padding capacitor.

The bridge will balance not only for capacitors, but also for resistors, inductors, and complex impedances. When measuring resistors, the bridge will automatically select the range and indicate the effective conductance ($G = 1/R$) of the resistor along with its stray capacitance. For inductors, the indicated value will be in terms of a negative capacitance ($C = -\frac{1}{(2\pi f)^2 L}$). The bridge will balance for impedances between about 1 ohm and 100 megohms at 1 kc/s. This range covers most of the complex networks and integrated-circuit values. While the units indicated on the bridge are not particularly convenient for such measurements, tolerance-checking and sorting can easily be accomplished if the test limits are first converted into equivalent capacitance or conductance values.

Remote-Control applications

Most of the front-panel controls can be operated remotely. This feature, along with the digital outputs, makes the bridge suitable for inclusion in specialized systems for automatic sorting of components or controlling of production processes.

SERVICE FEATURES

Just as surely as automatic equipment saves its users money when it is working, it is very costly when it is forced out of action for service. Therefore, we have designed into the bridge several features to help keep "down time" to a minimum. All components except some in the power supply are mounted on plug-in, easily replaceable fiberglass etched boards (see Figure 10). "Test" positions of the front-panel BALANCE control allow the user to "walk" the bridge through the complicated balance logic one step at

Figure 10. Plug-in etched boards are easily removed for service or replacement.

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a time to check operation. With this troubleshooting aid, a faulty circuit card can quickly be isolated.

CONCLUSION

With this, the first in a projected series of automatic instruments, General Radio has combined a classic bridge circuit with modern digital control techniques to produce the first true bridge that is truly automatic. The practical consequence of this development is the speedup, by a factor of 10 or more, in the measurement of capacitors. The resulting economic advantage to any large-scale producer or user of capacitors needs no elaboration.

— R. G. Fulks

ACKNOWLEDGMENTS

Many people assisted in the development of the automatic bridge. The author wishes particularly to acknowledge the assistance of M. J. Fitzmorris in the development of the instrument.

SPECIFICATIONS

		At 120 c/s	*At 400 c/s*	*At 1000 c/s*
RANGES	**Capacitance (parallel)*:**	100 pF-1000 μF	0.01 pF-100 μF	0.01 pF-100 μF
	Conductance (parallel):	0.1 μmho-1.0 mho	100 pmho-1.0 mho	100 pmho-1.0 mho
	Dissipation Factor (direct reading)	0.0001-1.00 (100%)	0.0001-1.00 (100%)	0.0001-1.00 (100%)
	(Measured as conductance):	0 to ∞	0 to ∞	0 to ∞
BASIC ACCURACY (see curves)	**Capacitance:**	0.1% of reading	0.1% of reading	0.1% of reading
	Conductance:	0.1% of reading	0.1% of reading	0.1% of reading
	Dissipation Factor:	1% of reading	1% of reading	1% of reading
SPEED OF BALANCE (approx) (Speed may be somewhat slower than that listed when dissipation factor is measured near the low end of each range.)	**Fast Modes:**			
	No range changes	2.5 seconds	0.35 second	0.25 second
	With range changes	5.0 seconds	0.6 second	0.5 second
	Tracking Modes:			
	10-count change	1.0 second	0.1 second	0.1 second
	100-count change	2.0 seconds	0.35 second	0.2 second
	1000-count change	11.0 seconds	2.6 seconds	1.1 seconds

* For series capacitance measurements a correction (chart supplied) can be used: If $D_x = 0.1$ (10%), correction = 1%.
If $D_x = 0.03$ (3%), correction = 0.1%.

EFFECTS OF LEADS: There is no error introduced by stray capacitance if shielded cables are used. Series resistance of leads can cause errors on the highest range. Accuracy curves include the effects of up to 50 mΩ of external cable.

VOLTAGE ACROSS UNKNOWN: 1 V on lower capacitance ranges, decreasing to 1 mV on highest range. Can be set (internally) as low as 1/10 of these values with a proportionate loss in resolution.

DISPLAY: Two 5-digit banks of bright-light, numerical indicators, with decimal points and units of measurement. Lamp burnout does not affect instrument operation or coded output. Lamps can be replaced from front panel.

DC BIAS: Can be introduced from external source.

REMOTE CONTROL: Start and balance controls can be activated remotely by contact closures.

OUTPUT SIGNALS

Numerical Data: 10 digits BCD 1-2-4-2 code.

Range Code (1 to 7): 1 digit BCD 1-2-4-2 code.

Print Command at Completion of Balance: Change from "1" level to "0" level — returns to "1" level at end of display interval.

Signal Levels: "1" level, 0 V; "0" level, — 12 V; both with respect to reference line, which is at +6 V above chassis ground. Impedance of lines = 12 kΩ.

MEASUREMENT RATE: Panel control allows adjustment of measurement rate so that display time between measurements is between approxi-

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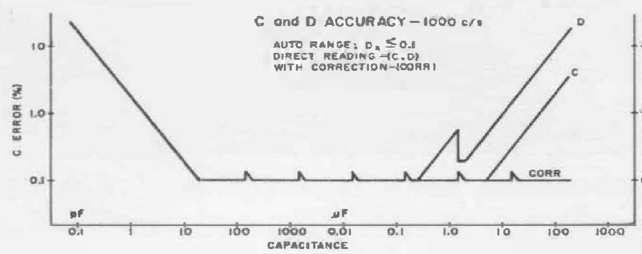

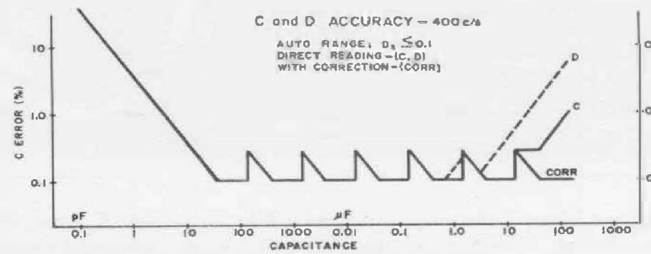

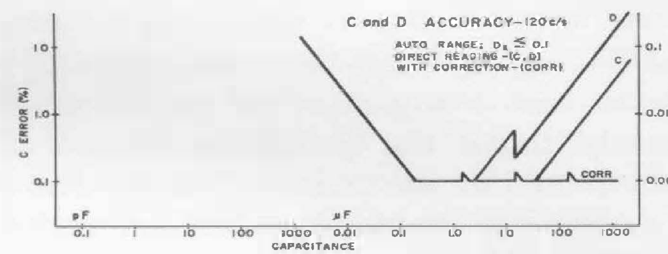

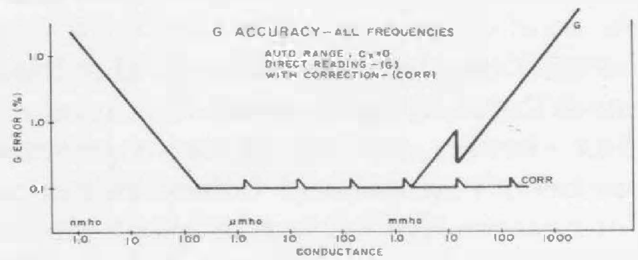

mately 0.1 and 5 s. The rate can be set manually (or remotely) at any rate compatible with balance time.

OPERATION AT OTHER MEASUREMENT FREQUENCIES: With internal factory modification, the measurement frequencies can be changed to any frequency between 100 c/s and 2 kc/s.

DIFFERENCE MEASUREMENTS: By the addition of a suitable standard to terminals provided, the bridge can be made to indicate the deviation, either positive or negative, from a nominal value, over part of the range.

GENERAL

Power Required: 105 to 125 V, 195 to 235, or 210 to 250 V, 50 or 60 c/s, 100 W. Internal 120-cycle oscillator is locked to power line for 60-cycle operation.

Auxiliary Controls: A rear-panel sensitivity control can be used to minimize balance time by a decrease in resolution.

Mounting: The Automatic Capacitance Bridge Assembly consists of two components, Type 1672-A Digital Control Unit and Type 1673-A Automatic Capacitance Bridge. End frames for bench mount and hardware for rack mount are both supplied.

Dimensions: Panel 19 by 10½ in (485 by 270 mm), depth behind panel 18 in (460 mm).

Net Weight: 71 lb (33 kg).

Shipping Weight: 145 lb (67 kg).

Catalog Number	*Description*	*Price*
1680-9701	**Type 1680-A Automatic Capacitance Bridge Assembly**	**$4850.00**
1680-9601	**Type 1680-P1 Test Fixture**	**75.00**

U. S. Patent No. 2,548,457. Patents applied for.

The agony and the ecstasy. A GR Type 1551-C Sound-Level Meter registers 115 dB at a Beatles' concert in Sydney, Australia. (Photo courtesy Australian Consolidated Press Ltd.)

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PRECISION COAXIAL CONNECTOR PAIRS WITH CALIBRATION CERTIFICATE

Since the introduction of the TYPE 900-BT Precision Coaxial Connector in 1963, every one of these connectors has been VSWR-tested before shipment. Connectors are tested in *pairs* at 1.5, 3, 4.5, 6, 7.5, and 9 Gc/s and are then separated and sold singly, with the actual test specification for the pair used as the guaranteed specification for the single connector. The VSWR of two connectors bought singly could be as high as twice that specified for a single connector, even though it is almost certainly much lower than that. On the other hand, if one could be sure of buying the same two connectors that were tested together, he would effectively halve the guaranteed VSWR of the pair. For the benefit of those whose applications demand exact calibration data or connector-pair performance guaranteed within the specifications of the IEEE Recommended Practice,[1] we are now offering pairs of Type 900-BT Connectors, together with calibration certificates.

The 0900–9407 Connector Pair comprises a pair of serial-numbered con-

[1] "Coaxial Microwave News," *The General Radio Experimenter*, February–March 1965.

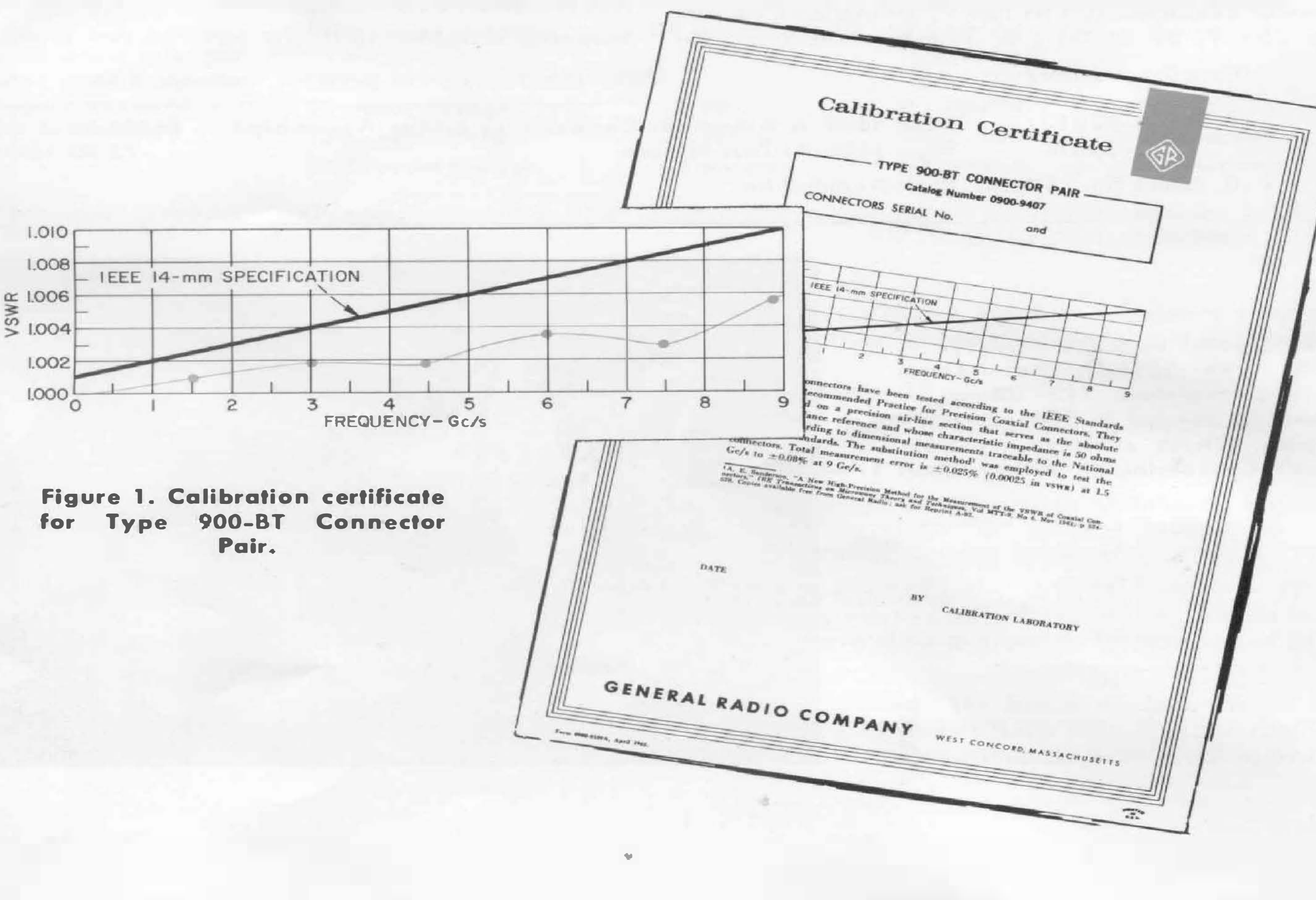

Figure 1. Calibration certificate for Type 900-BT Connector Pair.

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nectors and a certificate of compliance with VSWR specifications. Specified VSWR data apply whether the two connectors are mated together or mounted on opposite ends of low-loss, low-VSWR lines, 10, 20, 30, or 40 cm long (including connectors). When the connectors are installed on lines of other lengths, the insertion VSWR may differ from the calibration values. This is also true when only one connector of the pair is used. In practice, this discrepancy is small because of the excellent basic design of the connector.

The discontinuities in the connectors are small, and the connectors are relatively short electrically; it is therefore valid to connect the six calibration points with a continuous curve on the calibration chart (see Figure 1).

Test Procedure

The connectors are mounted on precision 50-ohm air-line sections and are tested by the substitution method.[2,3] The air lines, including the connectors, are 10 cm long and are therefore half-wave multiples at the test frequencies. Characteristic impedance of the air-line section is held to better than $\pm 0.015\%$. Except for the influence of skin effect, the impedance of a rigid air line is strictly a function of its diameters. These diameters are measured with precision gauges, whose accuracy is traceable to the National Bureau of Standards. The total measurement error including repeatability is 0.025% at 1.5 Gc/s, increasing linearly to 0.08% at 9 Gc/s.

[2] A. E. Sanderson, "A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IRE Transactions on Microwave Theory and Techniques* Vol MTT-9 No 6, p 524–548.

[3] A. E. Sanderson, "An Accurate Substitution Method for Measuring the VSWR of Coaxial Connectors," *The Microwave Journal*, Vol 5, No 1, Jan 1962, p 69–73.

[4] I. A. Harris and R. E. Spinney, "The Realization of High Frequency Impedance Standards Using Air-Spaced Coaxial Lines," Conference on Precision Electromagnetic Measurements, National Bureau of Standards, Boulder, Colo, June 1964. (Publication scheduled in *IEEE Transactions on Instrumentation and Measurement*, Dec 1964.)

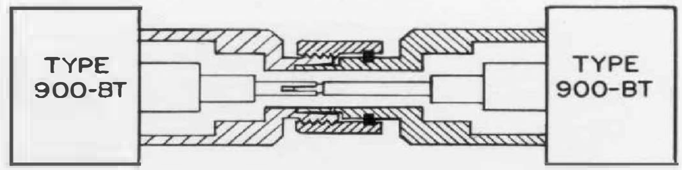

Figure 2. Use of calibrated connector pair to test UG adaptor pair. Electrical length of complete test device should be multiple of 10 cm.

At lower frequencies, the test-line impedance deviates from 50 ohms because of skin effect. In precision applications, the connectors are installed on air-line sections similar to those on which the connectors were tested. Therefore, the skin-effect impedance deviation does not introduce reflections in the transmission-line system. Skin-effect corrections are, however, required for some applications at frequencies below about 500 Mc/s. Such corrections have been discussed in the literature.[4]

Applications

The 0900–9407 Connector Pair is recommended for use where a mated pair of connectors having an accurately known VSWR is required, where guaranteed compliance with the pertinent sections of the IEEE Recommended Practice is sought, and in the testing of transitions, connectors, adaptors, and other low-loss transmission devices (see Figure 2).

— J. Zorzy

Catalog No.		*Price*
0900–9407	**Type 900-BT Precision Coaxial Connector Pair with Calibration Certificate**	**$72.00**

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OPEN HOUSE

It is our pleasure to extend to all *Experimenter* readers an invitation to attend an Open House at General Radio Company, Monday, June 14. One reason for this festivity is our fiftieth anniversary — which happens to fall on that very day. Another is the desire to introduce our new Bolton plant, now in full operation. If you can conveniently visit us at West Concord or at nearby Bolton, we'd be very pleased to see you. Hours at both plants are 10:30 AM to 3:30 PM.

1964 INDEX

The index to Volume 38 of the *Experimenter* is now available. A letter or postcard to General Radio at West Concord or to one of our sales engineering offices (see page 2) will bring you a copy promptly.

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