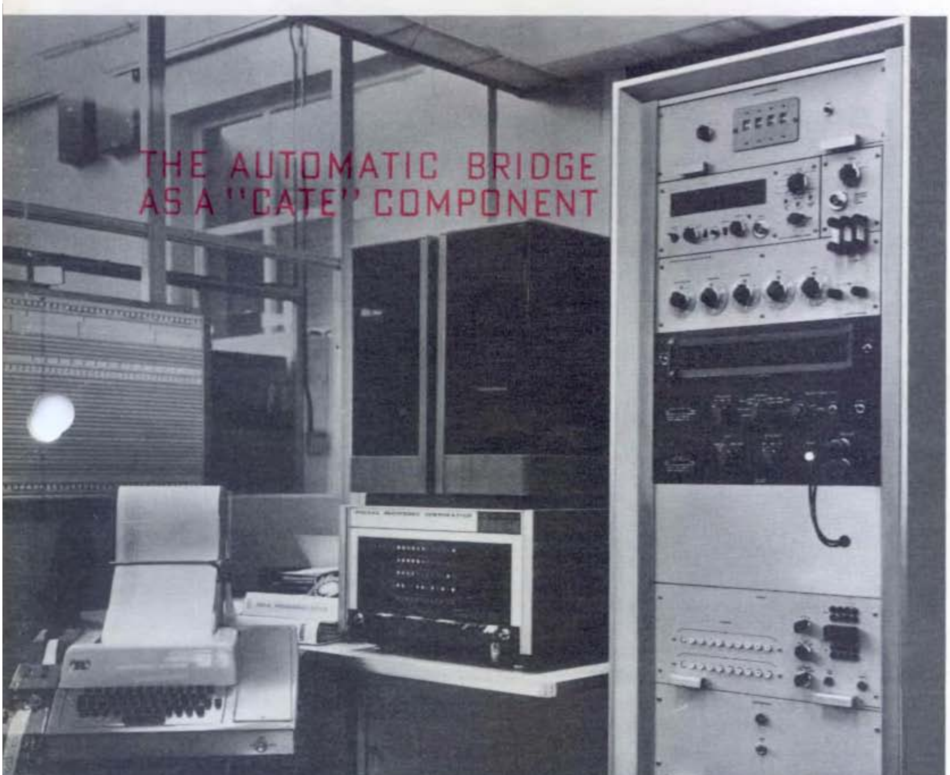
THE GENERAL RADIO

Experimenter

THE AUTOMATIC BRIDGE AS A "CATE" COMPONENT



ALSO IN THIS ISSUE

- A RECEIVER FOR PRECISE TIME CALIBRATIONS
- A PARALLEL-STORAGE UNIT FOR THE SYNCRONOMETER
- IMPROVED PERFORMANCE FROM THE 1115 FREQUENCY STANDARD

VOLUME 42 · NUMBER 3 / MARCH 1968

the GR Experimenter

Volume 42 • No. 3 March 1968

Published monthly by the General Radio Company

CONTENTS

ABOUT THIS ISSUE

General Radio owes its name to the glory that was "radio" back in 1915, when the Company was founded. Now, with "radio" a household synonym for "radio receiver," we sometimes find ourselves explaining to the public that despite our name we do not make radio receivers. Except for the one pictured on the opposite page, that is. Designed for use with the GR Syncronometer® digital time comparator, it covers WWV, CHU, and Loran-C frequencies and includes an oscilloscope for visual comparison of off-the-air time signals with the master tick of the Syncronometer. (It is, in other words, a special-purpose, and not a general, radio.)

Two other important companions to the Syncronometer—a parallel-storage unit and an improved frequency standard—are also introduced in this issue. The mission of the former is to store time information coming rapidly from the Syncronometer until slower data-handling equipment can accept it. The frequency standard is, of course, the key to the accuracy of a local time standard, and the improved crystal-oscillator performance announced in this issue is of obvious importance.

Cover: The Plessey Company's "CATE" (Computer-controlled and Automated Test Equipment) System for component testing includes a now-familiar combination: GR's automatic capacitance bridge and a digital computer. (See page 9.) (Photo courtesy The Plessey Company, Ltd.)

The *General Radio Experimenter* is mailed each month without charge to engineers, scientists, technicians, educators, and others interested in the instruments and techniques of electrical and electronics measurements. Address all correspondence to Editor, *General Radio Experimenter*, General Radio Co., West Concord, Mass. 01781.

The Type 1124 Receiver.

A RECEIVER FOR PRECISE TIME CALIBRATIONS

A common method of establishing accurate local time is to drive a local clock with a frequency standard, checking the absolute accuracy regularly against standard time signals broadcast by various agencies throughout the world. An elegant variation of this technique involves the use of primary time standards flown to the local site for periodic calibrations. The "flying-clock" method, though obviously expensive, offers the greater accuracy, since it eliminates the uncertainties of radio transmissions. However, once the clock flies away, there exists the problem of maintaining time until it flies in again. For this purpose, as well as for the many applications that require accurate timekeeping but that do not justify flying clocks, the use of broadcast time signals is the answer.

A time-comparison system using broadcast signals typically takes the form shown in Figure 1. General Radio has for years made two of the components used in such a system: standard-frequency oscillators and Syncronometer® digital time comparators (clocks). We now offer the rest of the system, a receiver designed specifically for time standardization with the GR Syncronometer, with a built-in oscilloscope for automatic visual comparison of the received signals against those from the local clock.

The General Radio time standard included in Figure 1 operates as follows: The 100-kHz output from the 1115-C Standard-Frequency Oscillator is fed to the Syncronometer, which translates the zero crossings into a pulse train and thence into a one-pulse-per-second master tick. These ticks are accumulated in six digital counting circuits, and the totals are presented as digital time-of-day infor-

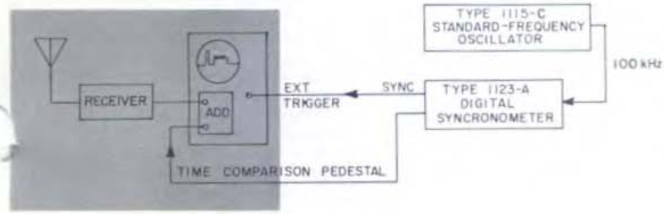


Figure 1. The components of a time-calibration system. Functions in shaded area are performed by the new 1124 receiver. (Antenna is included for Loran-C.)

mation (hours, minutes, and seconds) on the Syncronometer front panel.

To calibrate the system in terms of off-the-air time signals, one need only compare the one-second master tick with a one-second time signal broadcast by one of several agencies offering such services. Then, with both local and broadcast time signals on the oscilloscope, synchronizing the local master tick with the received signal is a simple matter of adjusting a few thumbwheels and pushing a button on the Syncronometer.

This procedure, which sounds simple in the telling, is complicated by the vagaries of radio propagation, by the high degree of precision usually required, and at times by the practical difficulties of integrating and interconnecting several instruments into an efficient system. A stable, sensitive receiver is obviously required. It is unreasonable to expect a general-coverage receiver to have optimum performance at a few selected frequencies, and a special-purpose receiver is usually preferred. If the receiver has its own built-in oscilloscope, the system is greatly simplified.

The new GR receiver (Type 1124) is specially designed for dependable, consistent reception and faithful display of time signals on six fixed frequencies. These are the 2.5-, 5.0-, and 10.0-MHz frequencies of WWV, two CHU fre-

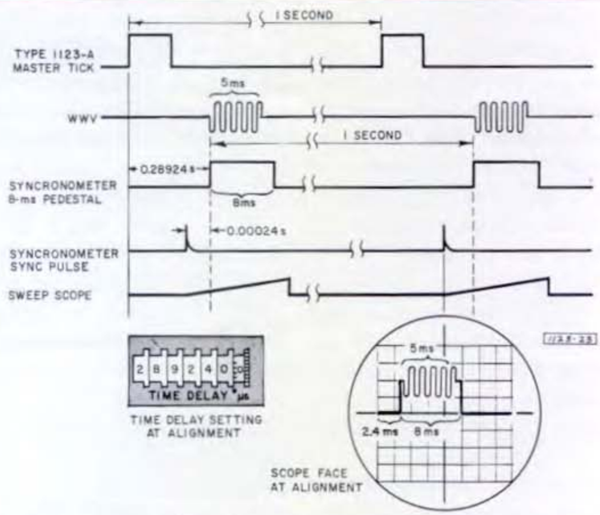


Figure 2. Syncronometrics: Above timing diagrams illustrate the principle of time standardization using the Syncronometer and off-the-air time transmissions. From top to bottom: The 1-second master tick from the Syncronometer; the 1-second time-signal transmissions from WWV; the 8-ms adjustable pedestal from the Syncronometer, the sync pulse from the Syncronometer, and the oscilloscope sweep. The thumbwheels on the Syncronometer are adjusted to bring the leading edge of the pedestal into coincidence with the beginning of the WWV tick. When this adjustment is made, the thumbwheel readout indicates the time interval between the master tick from the Syncronometer and the beginning of the WWV tick. With higher-precision Loran-C signals, a 1-μs pulse is used in place of the 8-ms pedestal.

quencies (3.33 and 7.335 MHz), and 100 kHz for Loran-C transmissions. An "external" mode permits use of signals from other sources (such as, for instance, flying clocks).

The five high-frequency circuits are all fixed-tuned with crystal-controlled local oscillators, and all are mounted on plug-in etched boards. The two used most frequently are left in the receiver and selected by a front-panel switch. Usable input sensitivity for the high frequencies is greater than 3 μV, and agc circuits hold the receiver output within 3 dB over an input-signal range of 10 μV to 100 mV. A 3-MHz crystal i-f filter and three tuned rf stages provide image and i-f rejection of more than 80 dB, with all other spurious responses at least 70 dB down. Low distortion of the modulating waveform, even with 90% modulation, ensures faithful pulse reproduction. There is an audio output monitor, isolated from the display to prevent loading.

The Loran-C receiver is a fixed-tuned amplifier with 100-kHz center frequency and a bandwidth of about 20 kHz (needed to preserve the Loran pulse waveshape). Its 50-ohm input impedance matches the impedance of the loop antenna supplied. Input sensitivity is 3 μV for a signal-to-noise ratio of 2 or greater. An important feature is a pair of notch filters for rejection of unwanted signals near 100 kHz. These filters tune from 80 to 95 kHz and from 105 to 125 kHz and have greater than 40-dB rejection. A gain control with a 60-dB range supplements the oscilloscope gain control for Loran-C presentations.

Dale O. Fisher joined General Radio in 1964, after receiving his BSEE degree from Northeastern University. A development engineer in GR's Frequency and Time Measurement Group, Mr. Fisher has specialized in the design of digital time comparators and related equipment. He is now completing work toward his MS degree from Massachusetts Institute of Technology.

Visual display is by means of a built-in Tektronix RM564 Storage Oscilloscope. The storage mode is especially useful in this application, since it will average out time variations due to unstable propagation characteristics and will increase the signal-to-noise ratio, since the random noise is stored less frequently than is the desired signal. The Tektronix Type 2B67 Time Base provides up to 1-μs/cm display for accurate Loran-C comparisons and allows single-pulse triggering for photographic records.

It is expected that the new receiver will be widely used for its Loran-C capability. Those interested in learning more about the use of Loran-C in precision frequency and time measurements are invited to ask for our recently published monograph on the subject. The 12-page booklet, No. 2 in GR's *Frequency/Time Notebook* series, is available free on request.

— D. O. Fisher

SPECIFICATIONS

HIGH-FREQUENCY RECEIVERS

Rf Frequencies: 2.5, 3.33, 5.0, 7.335, and 10 MHz. Any two are selected by a front-panel switch.

Sensitivity: Better than 3 μV.

Input Impedance: Approx 50 Ω.

Max Input Signal: >100 mV.

Bandwidth: I-f 3-dB bandwidth approx 3 kHz; 3.0 MHz center frequency of i-f amplifier and crystal filter.

Automatic Gain Control: Receiver output is within 3 dB for signal change of 10 µV to 100 mV.

Image and I-F Rejection: >80 dB; all other spurious responses at least 70 dB down.

LORAN-C RECEIVER

Center Frequency: 100 kHz; 3-dB bandwidth approx 20 kHz.

Sensitivity: 3 µV for S/N>2.

Input Impedance: Approx 50 Ω.

Max Input Signal: >100 mV.

Gain Control: 4 fixed steps, 60-dB total range.

Notch Filters: Two, front-panel screwdriver-control, 80 to 95 kHz and 105 to 125 kHz (other ranges with internal-capacitor change). Rejection >40 dB; 6-dB bandwidth <3 kHz.

EXTERNAL INPUT Intended for comparing other timing signals with the GR 1123 comparator.

Sensitivity: Approx 0.5 V for full-screen deflection.

GENERAL

Front-Panel Controls: Amplitude (20-dB range), vertical position, input-channel selector, gain; screwdriver controls: notch-filter tuning (2), 1123 pedestal amplitude, and 1123 marker amplitude.

Connections: Front panel: audio output, approx 1 V, for monitoring hf receiver. Rear panel (BNC connectors): Loran antenna, hf antenna, ext-signal input, and pedestal, sync, and marker pulses from 1123.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 240 W.

Accessories Supplied: Storage-oscilloscope accessories, shielded-cable set, 1124-P1 Antenna.

Mounting: 19-inch rack-mount.

Dimensions (width x height x depth): 19 x 7 x 18½ in. (485 x 180 x 470 mm).

Weight: Net, 42 lb (19.5 kg); shipping, c 70 lb (32 kg).

1124-P1 Antenna

Center Frequency: 100 kHz.

Bandwidth: Approx 20 kHz at 3-dB points, with 50-Ω load.

Dimensions (width x height x depth); 58 x 86 x 3¾ in. (1480 x 2200 x 96 mm).

Catalog Number	*Description*	*Price in USA*
1124-9701	**1124 Receiver**	**$3250.00**

GR1125

PARALLEL-STORAGE UNIT FOR THE SYNCRONOMETER

In the *Experimenter* article introducing the Type 1123 Syncronometer® digital time comparator,[1] we said, "No commercial equipment presently available can accept time readings as fast as the comparator can supply them. Required is a parallel-entry storage register with a capacity of 11 four-bit binary words. The register must accept and store the data from the clock in a time well under 5 microseconds." We can now drop the other shoe, by announcing the availability of the Type 1125 Parallel-Storage Unit.

The Syncronometer, it may be recalled, is essentially a precise accumulator of time in 10-microsecond increments. Feeding such fast-changing data to auxiliary data-handling equipment presents an obvious problem: Most such equipment (printers, tape punches, etc)

[1] D. O. Fisher, R. W. Frank, "A New Approach to Precision Time Measurements," *General Radio Experimenter*, February-March 1965.

Figure 1. Block diagram of local time standard with parallel-storage unit.

can't keep up with the Syncronometer, and the Syncronometer can't be interrupted for interrogation. Enter the parallel-storage unit, which accepts the time-of-day information — to 10-μs resolution — from the Syncronometer in 2 microseconds. On command from an external source, the unit displays the data on an in-line digital readout and simultaneously presents it in 1-2-4-8 BCD form (thus only the 1-2-4-8 version of the Syncronometer can be used here). Inhibit circuits, controlled either internally or by an external device, are incorporated to prevent storage while clock data are changing or while the storage-unit's output is being used.

The 1125 Parallel-Storage Unit is an all-solid-state instrument containing 11 four-bit storage registers, 11 indicator circuits, and command and inhibit program circuits. In normal operation, the unit receives data input and a 100-kHz inhibit signal from the Syncronometer, by way of cables supplied with the storage unit. These connections, as well as the command connection, the data output connection, and other connections provided for specialized systems applications, are made at the rear panel, leaving only the power switch, indicator brightness control, and indicators on the front of the instrument.

Systems Using the 1125

The simplest system using the storage unit includes an 1123 Syncronometer digital time comparator (driven by a frequency standard such as GR's 1115-C) and the 1125. This system, shown in Figure 1, stores time to a resolution of 10 μs each time a new "store" command is received at its input. Storage of data is automatically timed by means of the 100-kHz inhibit signal to avoid transitions of the counting registers in the Syncronometer. Stored data are displayed on the storage unit's 11 indicators, changing only when new data are stored.

Better use of the system can be made with the addition of a data printer such as GR's Type 1137 (Figure 2), which makes a permanent record of time information immediately after it is stored. The only connection required is made by a single cable between the 1125 and the 1137. In this application, the storage unit's internally generated print command and inhibit signals would be used to control the printer and to prevent storage of new data while the printer is operating. If the three-line-

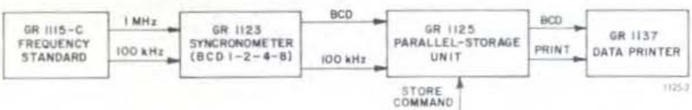


Figure 2. Addition of data printer greatly increases usefulness of system in many applications.

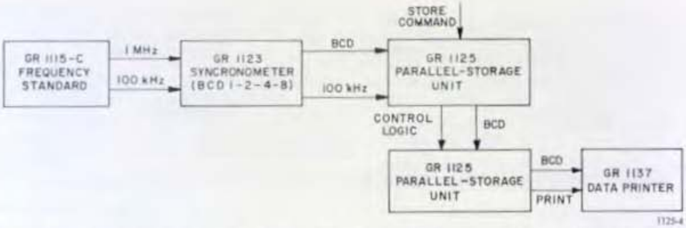


Figure 3. Two or more parallel-storage units can be cascaded to store time data arriving too fast for the printer.

per-second print rate of the standard 1137 printer is not fast enough, models with speeds up to 20 lines per second are available commercially.

If the events to be timed occur too closely together to be recorded by even a high-speed printer, another system is called for, in which two or more storage units are cascaded (Figure 3) to hold the time information until it can be transferred to the printer. The first time data are stored in unit 1, then immediately transferred to unit 2. The first unit will then be ready to accept new data in only 20 μs, rather than having to wait for a 5-ms or longer print cycle.

Numerous variations of serial or parallel combinations of storage units are possible, and inquiries for special systems are invited.

— D. O. Fisher

SPECIFICATIONS

TRANSFER CHARACTERISTICS

Capacity: 11 decimal digits (44 bits) parallel-entry jam-transfer; 10-μs resolution.

Transfer Time: 2 μs approx, for up to 8-ft data cables.

Mode: Data are stored until next store command.

INPUT

Data: 4-line BCD, 1-2-4-8; fully compatible with output of 1-2-4-8 versions of GR 1123 time comparator.

Store Command: Positive or negative transition (switch-selected) between 0 and at least +5 V. Input impedance >100 kΩ, dc coupled.

Inhibit Signal (from 1123): Inhibits transfer while input data are changing.

Inhibit Signal (internal or external): Inhibits transfer while stored data are read by output equipment. Internal inhibit is equal in duration to print command (see below). External inhibit signal can be presence of either 0 or at least +5 V (switch-selected); input impedance >100 kΩ, dc coupled.

OUTPUT

Data: 4-line BCD, 1-2-4-8 with GR 1123.

Logic Levels:
"1" — +10 V
"0" — 0 V

Output Impedance: Approx 6.8 kΩ at logic "1," approx 12 kΩ at logic "0."

Print Command: Pulse of +15 V behind 5 kΩ, duration adjustable 20 ms to 0.5 s; set initially for use with GR 1137 Data Printer.

Data-Ready Signal: Pulse of +15 V behind 5 kΩ, 50-μs duration, occurs 10 μs after transfer is completed.

Readout: 11 in-line digital indicators. Indicates 10's of hours through 10 μs.

GENERAL

Power Required: 90 to 130 or 180 to 260 V, 50 to 60 Hz, 25 W.

Accessories Supplied: Data and inhibit signal cables for connection to GR 1123, output data connector, power cord, spare fuses, mounting hardware with rack models.

Accessories Available: GR 1137 Data Printer and other digital-data acquisition instruments.

Mounting: Rack-bench cabinet.

Dimensions (width x height x depth): Bench, 19 x 3⅞ x 17 in. (485 x 99 x 435 mm); rack, 19 x 3½ x 16¾ in. (485 x 89 x 425 mm).

Weight: Net, 23½ lb (11 kg); shipping, 45 lb (20 kg).

Catalog Number	*Description*	*Price in USA*
	1125 Parallel-Storage Unit	
1125-9801	Bench Model	$2600.00
1125-9811	Rack Model	2600.00

HIGHER PERFORMANCE FOR THE 1115 FREQUENCY STANDARD

The time/frequency systems described in the preceding articles, like all other time and frequency measuring systems, are only as good as the local frequency standards driving them. The availability of a new, fast-stabilizing crystal has enabled General Radio again to upgrade the performance of its 1115 piezoelectric frequency standard.[1] Aging specifications are now less than 5×10^{-10} per day after three days (formerly 30 days) of operation, less than 1×10^{-10} per day, typically, after six months (formerly a year).

Like its predecessor, the new standard has outputs at 5 and 1 MHz and 100 kHz, excellent spectral purity, and a built-in nickel cadmium battery that automatically takes over for up to 35 hours in the event of power-line failure.

[1] H. P. Stratemeyer, "Type 1115-B Standard-Frequency Oscillator," *General Radio Experimenter*, June 1964.

Catalog Number	*Description*	*Price in USA*
1115-9803	**1115-C Standard-Frequency Oscillator** (Bench)	**$1800.00**
1115-9813	**1115-C Standard-Frequency Oscillator** (Rack)	**1800.00**

THE AUTOMATIC BRIDGE AS A CATE COMPONENT

GR's Type 1680 Automatic Capacitance Bridge and a digital computer are natural companions, frequently used in combination to perform measurement tasks that would have been unthinkable a few years ago. As an impressive example, take the CATE (Computer-controlled and Automated Test Equipment) system used by The Plessey Co.'s Product Assessment Laboratories at Titchfield, England.

The complete system, shown on the cover, is designed primarily to support reliability trials on thin-film components, resistive and capacitive. The 1680 is used to measure the capacitors. These are aluminum-silicon monoxide elements deposited on a glass substrate, two elements per substrate. Capacitance values range from 100 to 10,000 pF.

Under a long-term-reliability trial, 2000 of these elements are stored at an ambient temperature of 70°C, with maximum rated dc voltage applied. Periodically during the reliability trials the components are removed from the test environment for measurement under standard conditions at 20°C. Capacitors are connected to CATE in groups of 100 at a time, via multiway miniature coaxial connectors, which are in turn linked to a 100-channel scanner at the input to the 1680.

The computer, a Digital Equipment PDP-8, performs several functions: It controls the over-all sequence of operations, it commands the scanner to select the next channel, it recognizes the end of a measurement and transfers measured data to core storage, it calls up subroutines to process input data, and it feeds data to a typewriter and tape punch.

The BCD output from the 1680 is adapted to the PDP-8 by a special interface. The BCD digits are transferred to core in 12-bit words, each word containing three digits. The transfer of all display and range data requires 70 control instructions from the computer. Stored BCD digits can be decoded and converted to equivalent binary words, the capacitance and conductance values being assembled into double-precision binary numbers. The time required for transfer and conversion is less than 130 microseconds.

The simplest program transfers data directly from the 1680 to the teletypewriter, producing a printed output and an equivalent punched tape. CATE can easily handle more complex functions. It can, for instance, check values against preset limits and indicate out-of-tolerance results by, say, a typewritten asterisk. Or it can accumulate sequential measured values and calculate mean and standard deviations of parameter distributions. Or it can compare measured data with earlier data stored on paper tape, calculating percentage change. Since CATE also includes a temperature-measuring digital voltmeter, temperature coefficients can be calculated from changes in capacitance and temperature.

Acknowledgment: We are indebted to Mr. Brian A. Mair of The Plessey Company Ltd. for the information presented above.

MAKING THE 1602 AND 1607 BRIDGES DIRECT-READING BELOW 40 MHz

The susceptance standard supplied with the Type 1602-B Immittance Bridge and with the Type 1607-A Transfer-Function and Immittance Bridge is calibrated down to 40 MHz; below this frequency a correction is required if the bridge is to be direct-reading.

Either bridge can be made direct-reading below 40 MHz by the simple addition of a tee and a variable capacitor between the susceptance standard and the bridge. The 874-VCL Variable Capacitor (14-70 pF) and the 874-TL Tee are ideal for the purpose; an 874-ML Component Mount fitted with a low-loss variable capacitor or a fixed silver-mica capacitor, plus an 874-TL Tee, can also be used. The extra capacitance needed can also be supplied by an 874-L Air Line inserted between the susceptance standard and the bridge.

After these components are connected, capacitance is adjusted in accordance with the instruction book for the 1602-B (section 3.1) or the 1607-A (sections 3.1.3.2 or 3.1.8.3).

ADDENDUM

In "Precision Capacitance Measurements with a Slotted Line" (*Experimenter*, September 1967), the equation for C_x given on page 11 may not be entirely suitable at the higher frequencies. The following, more exact equation is now recommended:

$$C_x = \frac{41.072 \times 10^8}{f\sqrt{L(\omega)}\tan[1.61799 \cdot 10^{-8} f l \sqrt{L(\omega)}]}$$

where f is frequency in hertz
l is slotted-line position in meters
$L(\omega)$ is slotted-line inductance per unit length, in nH/cm
and the argument of the tangent is in radians.

GR Product Notes

KEEPING COAXIAL CONNECTORS CLEAN

In an increasingly polluted environment, it seems that cleanliness is next to impossible. It is also next to essential in precision microwave measurements, where a little dirt and grime on a connector contact surface can introduce significant error. With a connector as carefully designed and made as the GR900, anti-dirt warfare is especially important. The best weapon is a TYPE 900-TOC Connector Cleaning Kit, which includes a 16-ounce spray can of Freon TF solvent, two nylon brushes, a pipette, cloth patches, and an Allen wrench.

ROTATABLE GR900® CONNECTIONS

The gear teeth on a GR900® precision coaxial connector can occasionally present a problem in alignment. If, for example, GR900 connectors on two large pieces of equipment are to be mated, the teeth on the two connectors may be oriented so as to prevent connection.

Where this problem exists, one answer is the new 900-PKMR Panel Mounting Kit, which adapts standard GR900 connectors for panel mounting and which includes a rotatable gear ring. Another is a rotatable centering ring (Catalog No. 0900-9499) that replaces the ring on a standard GR900 connector.

CHOKE FOR VARIAC® AUTOTRANSFORMERS

The W50-P1 Choke is designed to eliminate circulating currents in parallel-connected Variac® autotransformers. The new choke can carry up to 60 amperes of load current and thus can handle a parallel pair of any size Variac. Additional chokes can be used for parallel connections of more than two autotransformers.

Catalog Number	*Description*	*Price in USA*
0900-9610	**900-TOC Cleaning Kit**	$ 7.50
0900-9500	**900-PKMR Panel Mounting Kit,** Rotatable	20.00
0900-9499	**Centering Ring,** Rotatable	15.00
3150-5016	**W50-P1 Choke**	16.00

Experimenter Index

An index to the *Experimenter* for the year 1967 is now available on request. Write to Editor, *General Radio Experimenter*, General Radio Company, West Concord, Mass. 01781.

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