THE GENERAL RADIO

EXPERIMENTER

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IN THIS ISSUE

New

Digital Time and Frequency Meter

Solid-State Data Printer

Ferrite Isolators

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CONTENTS

COVER

Type 1151-AP Counter measures period of output signal from a Type 1311-A Audio Oscillator. A Type 1137-A Data Printer provides a permanent record.

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

ZERO TO 300 kc WITH FIVE-DIGIT ACCURACY

The new TYPE 1151-A Digital Time and Frequency Meter is a more sophisticated brother of the TYPE 1150-A Digital Frequency Meter previously announced.[1] It does not replace the TYPE 1150-A, but it does extend the range of precision frequency measurement to low frequencies, where a simple counting frequency meter is inefficient. Low frequencies are determined rapidly and accurately by measurement of their periods or decimal multiples of the period. Measurement of higher frequencies is accomplished in the usual fashion, by the counting of zero-crossings per unit time, but an altogether new and highly efficient program is used. Provision is also made for frequency-ratio and multiple-interval measurements in addition to the usual totalizing or accumulative counting functions.

The input circuit includes the controls necessary for measurement of pulsed and low-frequency signals — trigger level, slope polarity, and ac or dc coupling.

The new counter is available in two versions, the standard model, TYPE 1151-A, and the TYPE 1151-AP* which can be used to drive auxiliary equipment — like the TYPE 1137-A Data Printer described elsewhere in this issue.†

The other elements of the TYPE 1151-A counter are similar to the TYPE 1150-A introduced a year ago. Counting decades, quartz-reference oscillator, power supplies, and package are substantially the same.

THE COUNTER PROGRAM

The program of the TYPE 1151-A is as efficient as a program can be made for a counter without storage. It is more complex than the elementary program of the TYPE 1150-A Digital Frequency Meter, less so than the highly efficient program of the TYPE 1130-A Digital Time and Frequency Meter with its storage system.[2]

Since the two useful intervals are those for counting and display, it is obviously desirable to minimize the zero interval that occurs between the

[1] R. W. Frank and J. K. Skilling, "A Five-Digit Solid-State Counter for Frequency Measurements to 220 kc," *General Radio Experimenter*, 36, 4, April, 1962.

*The TYPE 1150-AP Digital Frequency Meter is also now available.

†See page 9.

[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.

Figure 1. View of the Type 1151-A Digital Time and Frequency Meter.

end of the display interval and the start of the next counting interval. This has been done in the new counter, whose frequency-measurement program is shown in block form in Figure 2.

The time-base of the TYPE 1151-A counter is, like the ring counting decades previously described,[1] an innovation. This counter uses two identical binary scale-of-1000 dividers to control the counting gate duration and to produce variable display time. Since these dividers are aperiodic devices they can be used to produce multiple-period gating in decimal steps. These binary scaling devices cost less than many solid-state monostable dividers and are more reliable. They also make possible a more efficient program.

[1] *Loc. cit.*

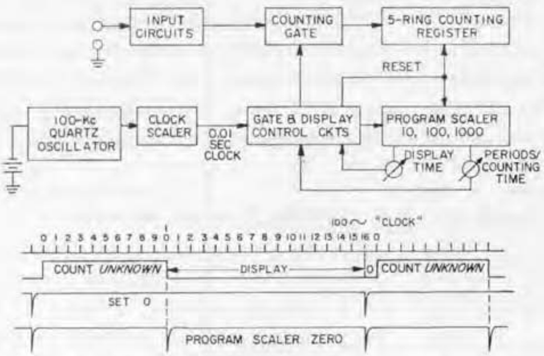


Figure 2. Elementary block diagram of the counter when used for frequency measurements. The program scaler determines the crystal-controlled counting time and the display time.

In a first scale-of-1000 divider, the 100-kc signal from the oscillator is reduced to 100 cps to supply clock pulses to operate the program. Assume that the counting register has just been cleared and the program scaler set to zero by a reset pulse. The next 100-cycle clock pulse will cause the main gate to open and the program scaler to advance 1 count. The program scaler is coded to count 10, 100, or 1000 clock pulses by the PERIODS/COUNTING TIME switch. When the appropriate number of clock pulses have been counted, the signal from the scaler closes the main gate. But the scaler's job is not finished. Upon main-gate closure, the scaler is reset and again begins to accumulate clock pulses. If, for example, a display interval of around 0.3 second is desired, the DISPLAY TIME switch set to its second position will terminate the display interval after $32(2^5)$ clock pulses have been accumulated. The program scaler operates in a pure binary fashion to count out 16, 32, 64, 128, 256, 512, and 1024 clock pulses corresponding to display time ranging from 0.16 to 10.24 seconds.*

At the conclusion of the display interval, the next clock pulse generates the reset pulse, and the very next clock pulse, 1/100 second later, will open the counting gate to begin a new measurement. The maximum "time out" for reset is 1/100 second, regardless of the gate time. Note that this program is what might be termed fully synchronous since all three intervals, counting, display, and reset, are continuously under control of the 100-cycle clock.

*This display interval has the same precision as the gate interval. This is incidental; unfortunately, no one has yet found a good use for it.

Figure 3 shows the rearrangement of the basic circuit blocks for period measurement.

Here, the input circuits produce their one pulse per cycle for the program, and the 100-kc oscillator pulses are passed through the counting gate to be accumulated in the register. Periods and their multiples are therefore measured in a minimum time increment of 10 μsec.

Let us assume, as with our previous example, that a reset pulse has just been produced. The next pulse from the input circuits will open the main gate and start the counting of the input pulses in the program scaler. If the scaler is not in the circuit, a single period will open and close the gate. If the PERIODS/COUNTING-TIME switch is set at 10, ten pulses must be counted before the gate closes, etc. Upon gate closure, the program scaler is reset to zero, and, as before, the pulses from the 100-cycle clock become its input signal. A binary sequence of 100-cycle clock pulses is now counted to establish the display interval. The signal from the scaler via the display-time switch initiates the reset pulse, and we are back where we started from. The next pulse from the input circuits will again open the counting gate.

The program for frequency-ratio measurement is exactly like that for multiple-period measurement, shown in Figure 3. The 100-kc oscillator which provided the precision clock for period measurements is simply replaced with a second, simple, set of input circuits. Suppose a signal of 10 cps is impressed on the main input terminals (with the MEASUREMENT switch set to PERIOD). The counting register will display its period as 10,000 (tens of μsec). If the MEASUREMENT switch is now placed in RATIO position and a 100-kc signal is admitted, the register will still read 10,000, now the ratio of frequency B to frequency A. If the periods multiplier is set at 10, the reading is 10 B/A, etc.

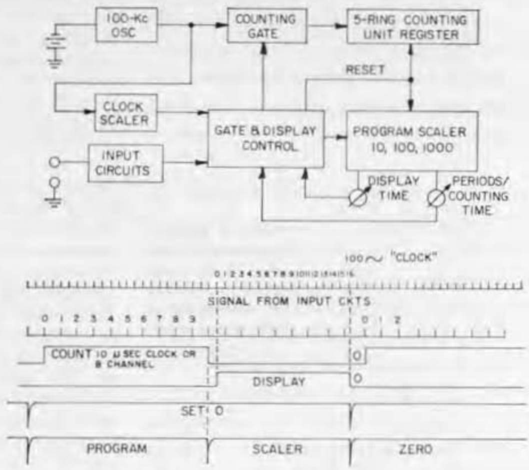


Figure 3. Elementary block and timing diagram of the counter when used for period measurement. The program scaler determines the number of periods measured and the display time.

INPUT CIRCUITS

The ideal digital frequency meter would be an automatic measuring instrument, to which one could connect a signal of any kind (no matter how weak, distorted, or noisy) and always get the correct answer. Furthermore, this perfect device should not burden the signal source with a load, either conductive, reactive, or radiational. While obviously never realized, this ideal is, nevertheless, the designer's objective. Input circuits should require an absolute minimum of adjustments and operator attention, should load the circuit under test as little as possible, and should radiate practically nothing. The input circuits of the TYPE 1151-A Digital Time and Frequency Meter are, we believe, the best available — almost without regard to cost.

To achieve the desired level of performance, the new counter has four input controls and switches (in contrast to the simple TYPE 1150, which had none). With these, one can choose:

(1) AC or dc coupling

(2) Zero-crossing slope for triggering

(3) Triggering level over a narrow range

(4) Higher sensitivity — 0.1 volt at 100-kilohm input resistance or, conversely, 1 volt into 1.0 megohm. (In other words, the input sensitivity is 1 microampere.)

While this flexibility is contrary to the ideal of automation, it does permit the counter to operate more successfully in noisy environments. Let us examine these input circuits to see what they can do.

Figure 4 is a simplified schematic of these circuits. It is not entirely new, but is a "transistorization" of an amplitude comparator designed for another instrument.[3] The circuit has the input characteristics of a Schmitt circuit, but has better common mode rejection for such things as variations in such power-supply voltage, temperature, etc.

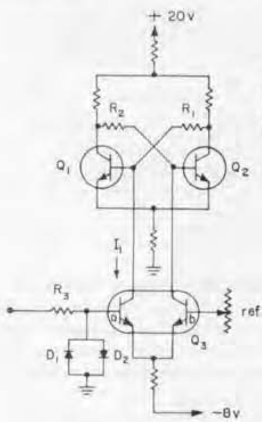


Figure 4. Elementary schematic diagram of the input-circuit amplitude comparator. Sensitivity is one microampere.

The pair of symmetrically connected transistors (Q_1, Q_2) forms a bistable switching circuit. A differential amplifier (Q_3), connected in the base circuits of the flip-flop transistors, modulates their base current with the input signal and causes switching at the signal rate. This differential-amplifier transistor is crucial to the circuit performance. It is a double silicon, planar, epitaxial unit with 20% gain (h_{fe}) balance, and less than 10 nanoamperes leakage.

[3] R. W. Frank, "How to Kill Time — Accurately," *General Radio Experimenter*, 32, 19, December, 1958.

The circuit operates in the following manner: Assume current balance in the differential amplifier and suppose that Q_1 is on. Q_1's low collector voltage, combined with the current passing the right side of the differential transistor, will keep Q_2 shut off and Q_2's collector voltage high. The higher current in R_3 to the base of Q_1 will, even in the presence of the equal current from the left side of the differential amplifier, keep Q_1 on. Now, suppose that the collector current of Q_{3a} (the left side of the differential pair) is decreased, owing to the presence of an input signal. The collector current of Q_1 will decrease and eventually would decrease sufficiently to permit Q_2 to go on. But, when Q_2 starts on, it begins to turn Q_1 off, and the circuit switches to the opposite state at a rate determined only by the gain-bandwidth product of Q_1 and Q_2. Remember, Q_3 helped Q_2 to go on in the first place and its other side was, at the same time, helping Q_1 to go off. But now the signal of Q_1 itself is keeping Q_2 on even when Q_3 is again at balance. Before the circuit can switch back to its original state, the current will have to be reversed in Q_3 to help Q_1 to go on. The amount by which the base current of Q_3 must be varied through the balance point to cause switching is the current sensitivity or "hysteresis" of the circuit. For the Type 1151-A Digital Time and Frequency Meter, this quantity is one microampere.

The input resistance at the base of Q_3 is low, but only one microampere is required to switch the circuit. One volt will cause switching when applied to the megohm resistor (R_3), and with 100 kilohms a tenth-volt is adequate. Input polarity is easily selected by simple interchange of the signal and reference. At one-megohm input impedance, this circuit typically has an input dc drift (the switching point) of less than 1 mv/°C with temperature, most of which is h_{fe} unbalance of Q_1 and Q_2 with temperature. The silicon diodes D_1 and D_2 are used to prevent saturation of high-beta transistors at elevated temperatures.

NOISE

The drifts in the operating point of the input switching circuit are a matter of concern, since they constitute a form of noise. This noise, which is due to thermal time constants, is very low in frequency and will only be significant when long periods are being measured, and then only during violent temperature changes.

Thermal drift is just one of the "noises" that detract from performance and which must be minimized in the in-

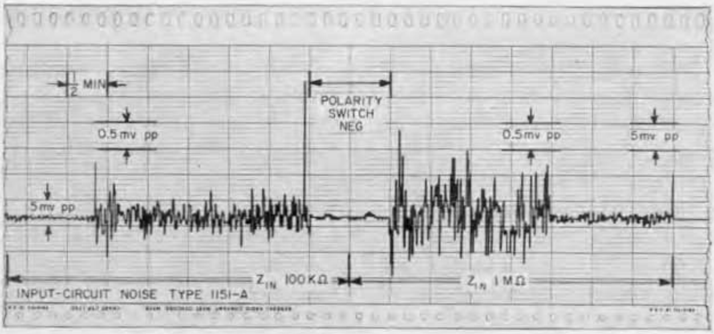


Figure 5. Analog recording of a continuous period measurement of a precise signal. The fluctuations of the curve indicate the counter's internal noise — less than 5 millivolts, peak-to-peak.

put circuits of a low-frequency counter. The specification for accuracy of a period measuring device always reads "±1 count ± time base accuracy ± error due to S/N of input signal." Often the counter manufacturer chooses to ignore the counter's own input-circuit noise. H. T. McAleer in a recent article in this publication[4] has discussed the effects of noises of all sorts on the accuracy of the measurements made by counters. Here we will repeat only the basic equation. When the input signal is a sine wave and triggering occurs on zero crossings, the error made in a period measurement due to input noise is:

$$(\text{error})\ \% = \pm \frac{1}{\pi} \frac{V_n}{V_s} \times 100$$

Where:

V_n = peak effective noise voltage
V_s = peak signal voltage

In this counter the equivalent input noise is less than 5 millivolts, peak-to-peak. In the best input circuit the irreducible input noise would be that in the input resistor and possibly the input transistor. In most counters, the noise is not random but is a relatively coherent signal, consisting of various signals produced within the counter. In the TYPE 1151-A counter, a lot of attention has been given to minimizing these noises.

Figure 5 is a recording showing fluctuations in the measured period of a low frequency (3 cps) signal. The period of this signal (a positive sawtooth) is precise, and its own noise is very low. The curve was obtained using a new storage-type digital-to-analog converter soon to be announced.

APPLICATIONS

A digital frequency meter is, as the name so clearly implies, an automatic instrument for the accurate measurement of frequency. It has two advantages over any other means of frequency measurement. First, it is accurate — as accurate, ultimately, as its reference oscillator (since provision is made for an external 100-kc precision source to control the gate time, accuracy is not necessarily limited to the accuracy of the built-in oscillator). Second, since the measurement is automatic and the result is displayed by big, bright, in-line indicators, the measurement can be made

[4] H. T. McAleer, "Digits Can Lie," *General Radio Experimenter*, 34, 12, December, 1962.

by unskilled people. The Type 1151-A Digital Time and Frequency Meter extends the range of accurate measurement to the frequencies where direct counting of the unknown is too time consuming.

The ratio channel is useful for direct-reading industrial measurements. A jack is provided at the rear for connection to the Type 1536-A Photoelectric Pickoff for measurements of rotational speed. By application of two input signals to the A and B channels, the counter can be made direct reading in any dimensional system, as ft/sec, rpm, gallons/-min, etc.

With appropriate transducers and terminal equipment the counter can indicate, and with the Type 1137 Data Printer can record, any measurement, as, for instance,

Units per anything
Force — weight — strain — pressure
Flow-rate
Velocity, linear or rotational
Voltage, current, resistance, via a voltage-to-frequency converter.

— R. W. Frank

SPECIFICATIONS

Frequency Measurement:
Range — DC to 300 kc.
Sensitivity — 0.1 volt, peak-to-peak, at 100 kilohms or 1 volt, peak-to-peak, at 1 megohm (1 microampere), switch-selected.
Counting Interval — 10 milliseconds to 10 seconds, extendible by multiplier switch.
Accuracy — ±1 count ± crystal-oscillator stability.

Period Measurement:
Range — DC to 20 kc.
Number of Periods — 1, 10, 100, or 1000.
Sensitivity — 0.1 volt at 100 kilohms or 1 volt, peak-to-peak, at 1 megohm (1 microampere), switch-selected.
Accuracy — ±1 count ± time base accuracy ± noise errors.
Input Noise — 5 millivolts equivalent open-circuit input noise at 1 megohm, less at 100 kilohms.
Counted Frequency — 100 kc.

Ratio Measurement:
Range — B/A, 10 B/A, 100 B/A, or 1000 B/A.
Frequency Range — A input, dc to 20 kc; B input, dc to 300 kc.
B Input — 1 volt peak-to-peak, 100 kilohms.

Display: 5-digit, in-line Numerik register, incandescent-lamp operated.

Display Time: 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, or 10.24 seconds, switch-selected.

Input Impedance: 1 megohm shunted by 50 pf or 100 kilohms shunted by 500 pf, switch-selected.

Input Trigger Level: ±1 volt at 0.1-volt sensitivity; ±10 volts at 1-volt sensitivity.

Input Trigger Slope: AC or dc coupled, positive- or negative-going.

Crystal-Oscillator Stability:
Short-Term — Better than ½ part per million.
Cycling — Less than counter resolution.
Temperature Effects — Less than 2½ parts per million for rise of 0 to 50 C ambient.
Warmup — Within 1 part per million after 15 minutes.
Aging — Less than 1 part per million per week after four weeks, decreasing thereafter.

Crystal Frequency Accuracy: The frequency is within 10 parts per million when shipped. Frequency adjustment is provided.

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

Accessories Supplied: Type CAP-22 Power Cord, eight replacement incandescent lamps, spare fuses.

Accessories Available: Type 1136-A Digital-to-Analog Converter and Type 1137-A Data Printer operate from output of Type 1151-AP model.

Cabinet: Rack-bench.

Dimensions: Bench model — width 19, height 3⅞, depth 12½ inches (485 by 99 by 320 mm), over-all; rack model — panel 19 by 3½ inches (485 by 90 mm), depth behind panel 12¾ inches (328 mm).

Net Weight: 19 pounds (9 kg).

Shipping Weight: 22 pounds (10 kg).

Type		*Code Number*	*Price*
1151-AM	**Digital Time and Frequency Meter**, Bench Model	1151-9801	$1195.00
1151-AR	**Digital Time and Frequency Meter**, Rack Model	1151-9811	1195.00
1151-APM	**Digital Time and Frequency Meter** (with output for printer or D/A converter), Bench Model	1151-9871	1250.00
1151-APR	**Digital Time and Frequency Meter** (with output for printer or D/A converter), Rack Model	1151-9981	1250.00

SOLID-STATE DATA PRINTER

Decimal-coded information can be reduced to a permanent, printed record through the use of a digital printer. For use with General Radio digital time and frequency meters, there is now available the TYPE 1137-A Data Printer, a precise, compact, and economical device, which is manufactured for the General Radio Company by Beckman Instruments, of Richmond, California. By fast parallel entry of 4-line BCD or 10-line code inputs, it can print at a rate of 3 lines per second with up to 12 digits per line.

The printer is equipped with plug-in solid-state code modules (see Figure 1) to control each digit column; a 4-line module which accepts 1-2-2-4, 1-2-4-8, or 1-2-4-2 coding; or a 10-line module which accepts either 10-line or 4-line data. Each printer contains the required quantity and type of code modules to operate with the intended digital instrument. Since the capacity of the printer is 12 columns, however, additional plug-in modules of either type are available for printing other data in the unused columns.

The digital information can be recorded in predetermined digit-columns and groups. The input cable provides a separate plug for each code module, so that input data can be programmed to specific digit-columns. In addition, the digital information can be separated into groups by application of a column-suppression signal to the code module

Figure 1. Multipurpose plug-in code modules with individual input connectors allow complete freedom for composing a desired printing format.

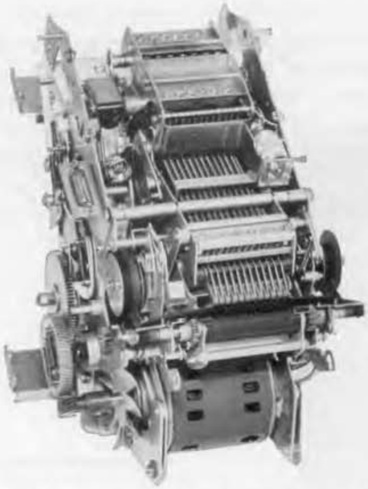


Figure 2. Compact, time-proven Burroughs printing mechanism is designed for continuous-duty operation with a minimum of maintenance.

of the digit-column in which a space is desired. Unplugging the appropriate code module will also accomplish this.

A two-color ribbon can be automatically or manually controlled to print black or red on standard 2¼-inch roll tape. This is a convenient means for indicating off-limit readings or readouts from different input sources.

The Type 1137-A Data Printer has a number of outstanding design features, which ensure optimum performance with a minimum of maintenance. Through the use of solid-state circuits and the absence of power-consuming keyboard actuators, over-all power requirements have been minimized. The extended front panel affords an unobstructed view of each line immediately after printing, and a useful flat surface for writing on the paper tape.

The solid-state code modules have convenient handles for quick removal from the top rear of the printer. To facilitate trouble-shooting or maintenance, the control circuit chassis is mounted vertically as an integral part of one of the side gussets.

The printing mechanism is a reliable Burroughs "10-key" tabulator, shown in Figure 2, which is designed for fast parallel-entry operation. Listing keys and intermediate keyboard have been replaced by small pawl-magnet devices, each of which controls an individual 0-to-9 type bar. This eliminates the need for complex mechanical linkages usually incorporated in digital printers. The stop-pawls and armatures (see Fig-

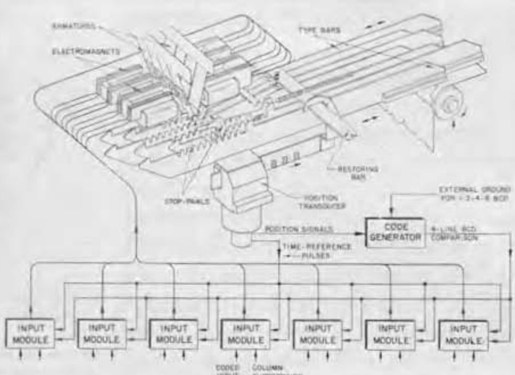


Figure 3. During the printing cycle the type bars move from "0" through "9", and the position transducer and code generator produce binary-coded voltages. When these voltages coincide with the input signals, the input modules transmit pulses to drop the stop pawls and hold the type bars until the cycle is completed.

ure 3) are reset mechanically; thus the associated electromagnets require only a minimum of power to hold their respective armatures in the actuated position. Each electromagnet is provided with an electrical suppressor. This — plus the use of an induction motor operated continuously — helps to minimize radiated electrical interference.

In place of the usual sliding-contact commutators or stepping switches, a single-position transducer and code generator are used to translate each position of the type bars into binary-coded voltages. These voltages are compared with the input signals in the plug-in code modules. Whenever the input code coincides with the internal type position code, a pulse is generated which releases the particular stop-pawl to lock the type bar in the proper digit position. This position-decoding process continues from "0" through "9" until all type bars are properly indexed. The platen is then mechanically engaged and shifted upward toward the in-line type, printing the correct digits on the paper tape.

Figure 4. View of the Type 1137-A Data Printer, Rack Mounted.

This compact printer is available in either a portable cabinet for bench use, as shown on page 9, or a relay-rack adaptor cabinet, as shown in Figure 4. The printer occupies only half the panel space of the relay-rack adaptor cabinet, leaving adjacent space for associated equipment.

A cable is supplied with the printer for direct connection to the companion instrument.

— H. T. McAleer

SPECIFICATIONS

Capacity: 12 columns.

Digits: 0 through 9 or blank (column suppression).

Printing Rate: 3 lines per second maximum.

Accuracy: Identical to input.

Input:

Logic Levels —

Source Resistance	*Binary 0*	*Binary 1*
100 kilohms	−8 to −50 v	0 to +50 v
2 megohms	−12 to −50 v	0 to +50 v

Code — 10-line code (one wire is binary 1, eight wires binary 0) or four-line BCD (1-2-2-4, 1-2-4-8, or 1-2-4-2) input.

Resistance — Approximately 10 megohms for minus input, 200 kilohms for plus input.

Internal Ground: Isolated from chassis. May be biased to ±100 volts.

Color-Control:

Manual — Two-position lever selects red or black print-out.

Remote — Red, binary 1 or open circuit; black, binary 0. Input resistance approximately 2 megohms.

Column Suppression: Single line grounded for each column suppressed (3 milliamperes maximum, +10 volts open circuit).

Print Command: Change from binary 1 to binary 0. Binary 0, 100 milliseconds minimum after print command; binary 1, 15 milliseconds minimum before next print command. Source resistance 1 megohm maximum.

Inhibit Reset Output: Occurs within 50 milliseconds after print command; 200 milliseconds maximum duration.

Printing Ribbon: 7/16-inch two-color adding-machine ribbon.

Paper: Standard 2¼-inch roll tape.

Power Requirements: Types 1137-9731, 1137-9732, 1137-9735, and 1137-9736 — 115 volts, 60 cps, 45 watts. Types 1137-9733, 1137-9734, 1137-9737, and 1137-9738 — 230 volts, 50 cps, 45 watts.

Accessories Supplied: Cable assembly for connection to counter, spare fuses.

Accessory Available: Types 1137-9604 and 1137-9605 Plug-In Code Modules.

Cabinet: Rack and portable models available.

SPECIFICATIONS (Cont.)

Dimensions: Rack model — width 19, height 8¾, depth 15¼ inches (485 by 225 by 390 mm), over-all; portable model — width 9, height 10, depth 16½ inches (230 by 255 by 420 mm), over-all.

Net Weight: Rack model, 45 pounds (20.5 kg); portable model, 35 pounds (16.0 kg).

Shipping Weight: Rack model, 55 pounds (25.0 kg); portable model, 45 pounds (20.5 kg).

	Type		*Code Number*	*Price†*
For use with Type 1130-A Counter*	**1137-9731**	**Data Printer,** Portable Model (115 v, 60 cps)	1137-9731	**$1675.00**
	1137-9732	**Data Printer,** Rack Model (115 v, 60 cps)	1137-9732	**1725.00**
	1137-9733	**Data Printer,** Portable Model (230 v, 50 cps)	1137-9733	**1700.00**
	1137-9734	**Data Printer,** Rack Model (230 v, 50 cps)	1137-9734	**1750.00**
For use with Types 1150-AP and 1151-AP Counters	**1137-9735**	**Data Printer,** Portable Model (115 v, 60 cps)	1137-9735	**1350.00**
	1137-9736	**Data Printer,** Rack Model (115 v, 60 cps)	1137-9736	**1400.00**
	1137-9737	**Data Printer,** Portable Model (230 v, 50 cps)	1137-9737	**1375.00**
	1137-9738	**Data Printer,** Rack Model (230 v, 50 cps)	1137-9738	**1425.00**
	1137-9604	**Plug-In Four-Line Code Module**	1137-9604	**55.00**
	1137-9605	**Plug-In 10-Line Code Module**	1137-9605	**75.00**

*Type 1130-A counters shipped before February 1963 require minor modification. A modification kit is included with these printers. †Prices applicable for sales in U.S.A. and Canada only.

NEW FERRITE ISOLATORS

Figure 1. View of the Type 874-H1000L Isolator (1.0 - 2.0 Gc).

Ferrite isolators are basically one-way transmission devices. An rf signal applied at one port of an isolator is attenuated very little in passing through the isolator to the second port. However, a signal applied at the second port of the isolator is substantially attenuated in passing through the isolator to the first port.

When an isolator is inserted between a signal source and a load, the energy from the source is transmitted to the load with very little loss, but, owing to the high attenuation in the reverse direction, the undesirable effects of changes in load conditions on the source amplitude and frequency are substantially reduced. The isolator thus offers the distinct advantage of low insertion loss over the ordinary attenuator pad. As a result higher system sensitivities (or levels) can be achieved for a given source power.

DESCRIPTION

Coaxial ferrite isolators are now available that offer high performance characteristics over relatively wide frequency

TABLE I

Type	*Frequency Range*	*Isolation*	*Insertion Loss*	*Can Be Used With These GR Oscillators*
874-H500L	0.5 to 1 Gc	10 to 15 db	0.5 to 1.5 db	1209-C, -CL, 1361-A, 1021-AU
874-H1000L	1 to 2 Gc	10 to 15 db	0.5 to 1 db	1218-A
874-H2000L	2 to 4 Gc	20 to 25 db	0.5 to 1 db	1220-A, 1360-A

bands, as shown in Figure 2 and Table I. They can actually be used over considerably wider frequency ranges than their rated 2-to-1 bands with some deterioration in performance. They are equipped with locking Type 874 Connectors and will handle up to 5 watts cw power.

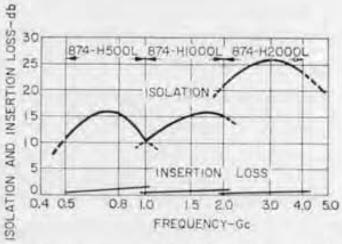


Figure 2. Average isolation and insertion-loss characteristics of several isolators.

THEORY OF OPERATION

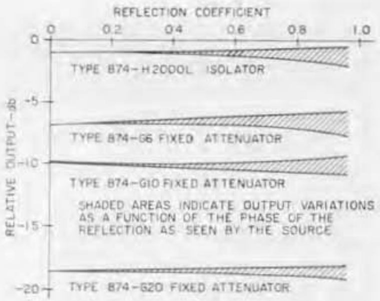
The isolators described here are based on the phenomenon of resonance-absorption. Their isolation characteristics depend on the absorption of energy that occurs at ferromagnetic resonance. To achieve this resonance, a ferrite material is placed in a region where the field is circularly polarized, and the ferrite is transversely magnetized by an external, static magnetic field. The resonance occurs when the strength of the external static field is such that the precession rate of the ferrite electron-spin axes caused by the static field is approximately equal to the frequency of the circularly polarized field. (The circularly polarized field is created in the coaxial isolator by placing dielectric material asymmetrically between the outer and inner conductors.)

When a signal is applied at one port of an isolator, the sense of rotation of the circularly polarized field generated by the dielectric is opposite to the direction of electron precession in the ferrite, and there is little interaction between the ferrite and the applied field. When the signal is applied to the other port of the isolator, the rotation of the field is in the same direction as the precession; the field is strongly coupled to the ferrite electrons, and a large amount of energy is dissipated in the ferrite.

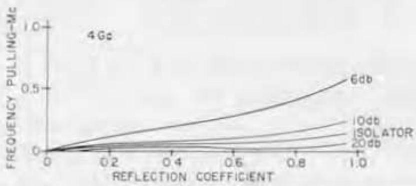
REFLECTIONS AND RF SOURCES

When an rf oscillator feeds a load directly, reflections from the load on arriving back at the source can influence the source output power and frequency. When the frequency of operation and the load conditions are fixed, the reflections, unless they are very large, do not usually affect the stability of the source output.

When changes are made in the load conditions, as for instance, when the load is an adjustable attenuator in an attenuation-measuring system, or when various loads or a sliding short circuit is connected to an impedance-measuring system, the change in load reflections can cause changes in the amplitude and frequency of the source. Similarly, when the source frequency is varied with fixed load conditions, the reflections (as observed from the source) change in amplitude and phase and affect the amplitude



Isolator *vs* fixed attenuators at 4 Gc, controlling output variations (Figure 3, *left*) and frequency pulling (Figure 4, *below*) of rf source (Type 1360-A Microwave Oscillator).



and frequency of the source. In either case, an isolator between the source and the load will improve the source stability.

The output impedance of an rf source is usually not 50 ohms. Many applications, however, require a matched source. Here the isolator can convert the effective source output impedance to 50 ohms over broad frequency ranges without tuning and with a minimum of power loss.

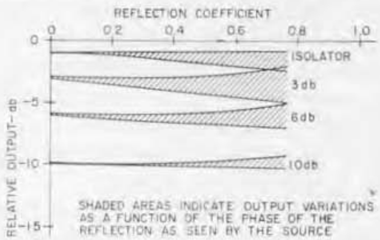
ISOLATORS VERSUS ATTENUATOR PADS

Figures 3 and 4 show the advantages of the isolator over the fixed attenuator pad. The data were taken with a General Radio Type 1360-A Microwave Oscillator operating at 4.0 Gc. Loads whose reflection coefficients vary from 0 up to approximately 1.0 were used, and their phases relative to the source were varied by means of a line stretcher between the source and the load. The isolator used was a Type 874-H2000L that, at 4.0 Gc, had an insertion loss of 0.9 db and an isolation of 24 db. Three Type 874-G Fixed Attenuators of 6, 10, and 20 db, respectively, were used for comparison. The shaded areas in Figure 3 show the variations in output at any given reflection coefficient as the phase of the reflected wave is varied through 180 degrees.

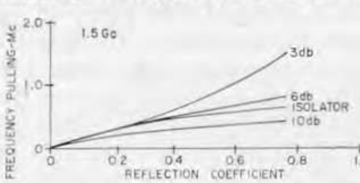
Figure 4 shows the frequency-pulling effects on the oscillator as a function of load reflection coefficient. Note that the isolator is better than the 10-db pad in controlling the frequency-pulling effects.

Additional data taken with a Type 1218-A Unit Oscillator operating at 1.5 Gc and a Type 874-H1000L Isolator (insertion loss of 0.9 db and isolation of 13 db) are presented in Figures 5 and 6.

Similar performance will be obtained with other types of oscillators. Triode, transistor, klystron, backward-wave, magnetron, and other oscillators having tightly coupled output circuits are subject to similar instabilities, and the use



Isolator *vs* fixed attenuators at 1.5 Gc, controlling output variations (Figure 5, *left*) and frequency pulling (Figure 6, *below*) of rf source (Type 1218-A Unit Oscillator).



of an isolator as opposed to an attenuator pad is equally advantageous with all types of sources.

APPLICATIONS

Attenuation Measurements

In the measurement of attenuators, filters, and other devices where attenuation may be high, it is usually important that the device under measurement be working between matched source and load. In addition, it is usually necessary to use all available power in order to attain sufficient sensitivity in the regions of high attenuation. Here the use of an isolator between the source and the device under test offers distinct advantages.

On the detector side, an isolator provides a match over more than a 2-to-1 frequency band while introducing a comparatively negligible loss in transmission. Neither tuners nor attenuator pads meet both these conditions.

Slotted-Line Measurements

In a slotted-line measurement system in which a tightly coupled, unmatched rf source is used, changes in frequency with changes in the impedance of the unknown connected can cause errors. For example, if the position of the desired reference plane is determined by the positions of voltage minima with the unknown and with a short- or open-circuit termination connected, a change in frequency will cause an error in the position of the reference plane. Similar errors can occur when a sliding short circuit is used. In systems in which sensitivity is a limitation, for instance, when very large VSWR's are measured, the use of an isolator in place of an attenuator can result in an improvement in measurement accuracy.

General

These isolators can also be used:

To match a detector to a 50-ohm line over a broad frequency band without tuning and without a significant reduction in sensitivity.

To improve the source amplitude stability in both fixed and sweep-frequency systems that require an amplitude-regulated rf output.

In a heterodyne detector to reduce the level of the local-oscillator signal appearing at the detector terminals by 10 to 20 db.

Wherever source output stability, impedance match, or minimum loss is an important consideration.

— T. E. MacKenzie

SPECIFICATIONS

Type	*Frequency Range — Gc*	*Insertion Loss db — Max*	*Isolation db — Min*	*VSWR Max*	*CW Power Watts — Max*	*Length*		*Net Weight*	
						Inches	*Millimeters*	*Pounds*	*Kilograms*
874-H500L	0.5 to 1	1.5	10	1.20	5	10¾	275	4	1.8
874-H1000L	1 to 2	1.0	10	1.15	5	7¾	200	1½	0.7
874-H2000L	2 to 4	1.0	20	1.18	5	8¼	210	2	0.9

Type		*Code Number*	*Price*
874-H500L	**Isolator**	0874-9581	**$550.00**
874-H1000L	**Isolator**	0874-9583	**325.00**
874-H2000L	**Isolator**	0874-9585	**275.00**

U.S. Patent No. 2,518,457.

General Radio Exhibit in Tokyo

General Radio was proud to be one of the firms taking part in the opening exhibit at the new U.S. Trade Center in Tokyo. The exhibit, featuring industrial instruments and laboratory apparatus from 58 U.S. firms, ran from April 2 to 26, and attracted some 10,000 visitors, including Undersecretary of Commerce Franklin D. Roosevelt, Jr., and U.S. Ambassador to Japan E. O. Reischauer.

The GR exhibit was presented by our representative in Japan, the Midoriya Electric Company, of Tokyo.

General Radio at new U.S. Trade Center in Tokyo, as seen by U.S. Undersecretary of Commerce Franklin D. Roosevelt, Jr., with representatives of Midoriya Electric. From left to right, the Messrs. Nagakura, Sales Engineer; Kuroha, President; FDR, Jr.; Sekido, Import Division Manager; and Ishizawa, Manager, Instrument Sales Section.

Personnel Changes at our Sales Engineering Offices

Ronald F. Mossman was recently transferred to the Toronto Office, after nearly a year at our plant in West Concord.

Harold Stevens joined the staff of our Los Angeles Office in March, 1963. His territory will include metropolitan Los Angeles plus the military installations in the Mojave Desert region of California.

Ronald Mossman

Harold Stevens

General Radio Company

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