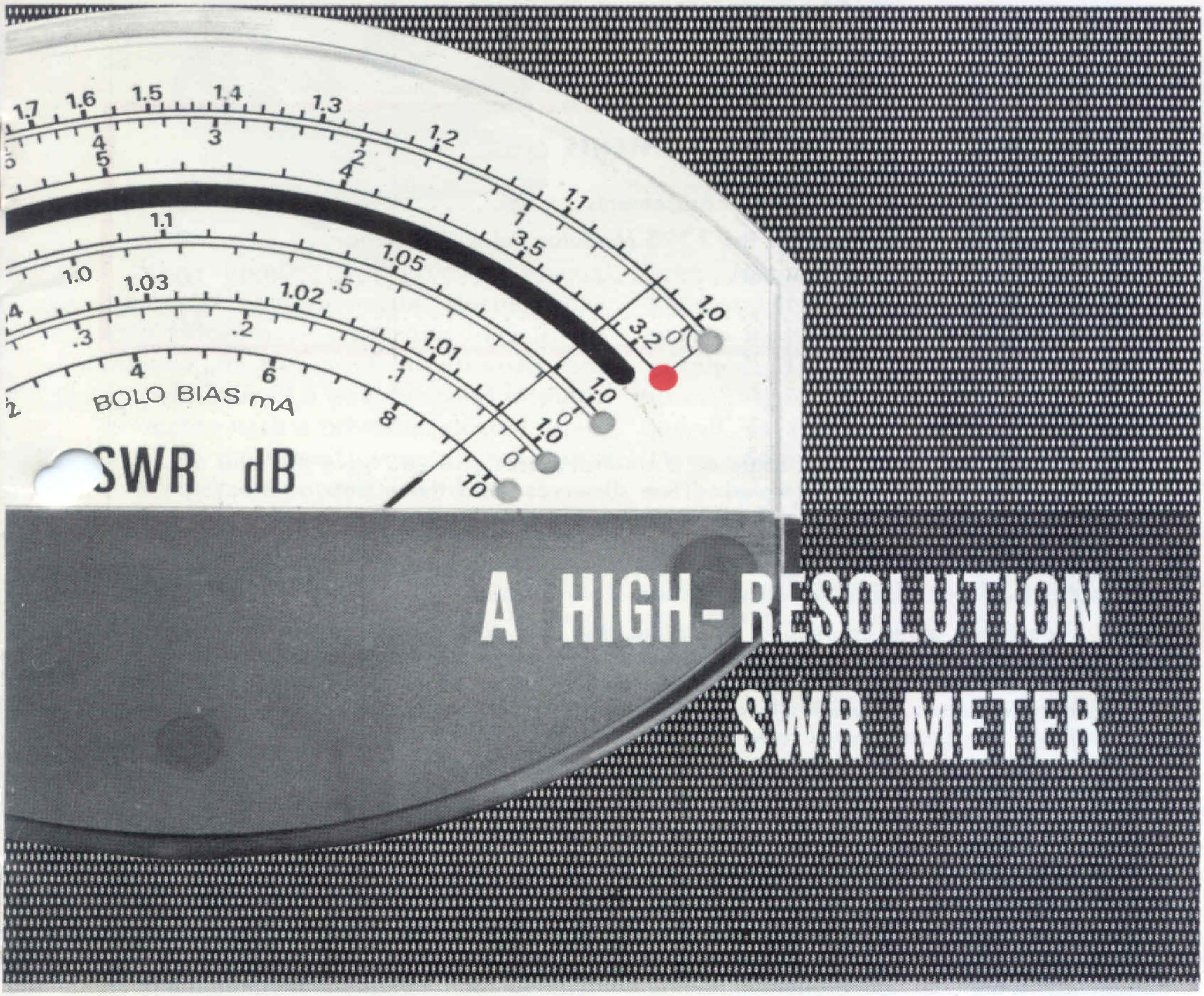
THE GENERAL RADIO

Experimenter



A HIGH-RESOLUTION SWR METER

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CONTENTS

Put a 1.0-to-1.05 SWR scale on a six-inch meter and you have the kind of resolution that an accurate slotted line deserves. Add three step attenuators and an attenuator "memory" dial and you have the means for fast, accurate attenuation measurements. Another feature of the Type 1234 Standing-Wave Meter is in the "why-doesn't-everyone-do-that?" category: a set of meter lights (see front cover) to tell you which scale to read.

We have gone on record as saying that the pulse-output possibilities of our Type 1395 Modular Pulse Generator are virtually limitless. To cement the case we introduce in this issue still another module: an NRZ (Non-Return-to-Zero) Converter/Sampler. In addition to its primary function of preventing voltage in a binary word from falling to zero until a zero is called for, the new unit can be coupled with a random-noise generator to yield random binary sequences.

Users of GR frequency synthesizers will want to note two important new accessories described in this issue: a standard-frequency oscillator and a programmable digit-insertion unit. The line is now fully programmable, right up to 70 MHz.

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.

AN SWR METER FOR PRECISION MEASUREMENTS

Figure 1. Type 1234 Standing-Wave Meter.

Since the advent of precision coaxial connectors and precision slotted lines, SWR values have been meaningfully expressed in terms of hundredths and thousandths. An obvious need in measurements with a precision slotted line is an SWR meter with enough resolution to translate the precision of the slotted line into precise measurement results. This need is now filled by GR's new Type 1234 Standing-Wave Meter, which numbers among its features a large scale that is expandable to a full-scale SWR value of only 1.05.

The new SWR meter is no less useful for larger SWR values, and its three step attenuators and an attenuator "memory" control permit fast, accurate attenuation measurements.

One of the chief objectives in the design of the 1234 was ease of operation and of reading, and the instrument features several interesting innovations in the so-called "human-engineering" area. For example, the usual annoyance and frequent confusion associated with a multiscale meter are neatly dispatched: The scale in use is always unmistakably identified by a light adjacent to it (see front cover photo). Once one is on the right scale, reading it is no problem; the meter is of the familiar and highly popular GR design, with a large 6-inch face, a mirror scale, and a tracking accuracy or linearity of ½ percent.

Description

The 1234 is basically a low-noise tuned ac amplifier, calibrated for use with square-law detectors. The circuit (Figure 2) comprises five stages of audio amplification and four stages of controlled attenuation, staggered to provide optimum signal-to-noise ratio. The total attenuation range is 70 dB, of which 20 dB is controlled by the meter range switch. This feature, which simplifies high (> 4) SWR measure-

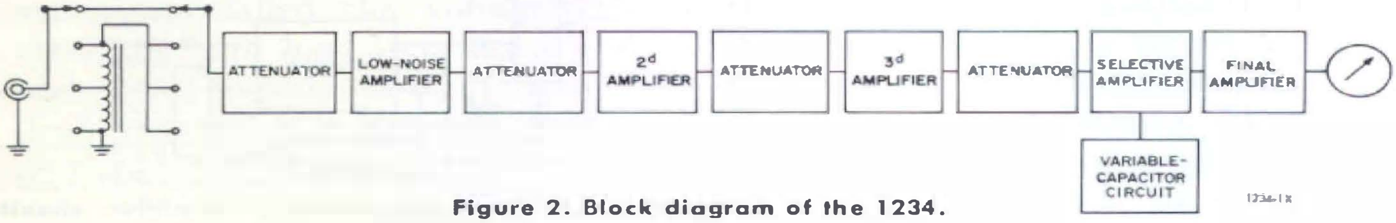

Figure 2. Block diagram of the 1234.

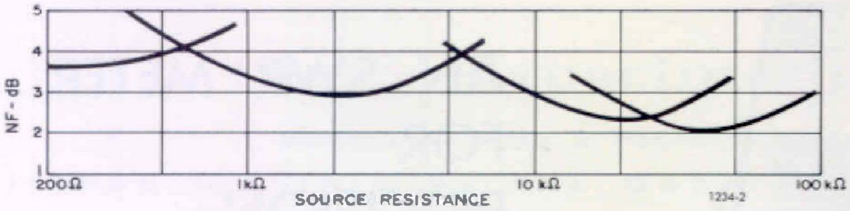

Figure 3. Typical noise figure as a function of source resistance.

ments by eliminating the need for adjustment of the attenuator control, also limits use of the expanded scales to measurements with at least 20 dB in the circuit — in other words, to measurements where the signal-to-noise ratio permits accurate measurements.

At the input, an rf low-pass filter prevents rf signals that leak past the detector bypass capacitor from causing measurement errors. The input stage is a high-input-impedance, low-noise amplifier, whose optimum source resistance is adjustable between 200 ohms and 35 kilohms in four steps. Figure 4 is a plot of noise figure vs source resistance.

The amplifier circuit is designed so that gain is essentially independent of frequency and bandwidth adjustments. The frequency-selective circuit (Figure 3) is a feedback amplifier in which positive and negative feedback are equal at resonance, and the feedback circuit does not affect circuit gain. At other frequencies, however, the positive feedback is less than the negative feedback, reducing gain.

The main attenuator covers a range of 45 dB in nine steps. A "memory" dial permits attenuation measurements by substitution techniques to be made without subtraction of readings and possible resulting errors. A third attenuator covers 5 dB in 1-dB steps. This attenuator, in conjunction with the 1.6-dB expanded scale, yields a resolution of 0.025 dB. With the second expanded scale the resolution is 0.005 dB (i.e., 0.02 dB per small, 1/8-inch-wide division).

Two outputs are available for use with recorders or other auxiliary equipment: a dc output of 1.5 volts behind 1.5 kilohms at meter full scale and a 1-kHz output of 0.1 to 1 volt rms maximum (depending on range switch position) behind 500 ohms.

A 60-ohm impedance between circuit ground and line ground reduces potentially troublesome ground loops. Errors are eliminated when recorders with balanced inputs are used and are usually small even with unbalanced-input recorders.

A highly regulated power supply makes amplifier gain virtually independent of line-voltage changes. Figure 5 shows a barely noticeable gain change on the highest expansion range as the line voltage is changed ±10%. The 1234 can be operated from battery as well as ac voltage. Any battery capable of supplying 90 mA at from 22 to 35 volts can be used. Gain will not be affected noticeably as long as the battery voltage stays above 22 volts. The Type 1538-P3 Battery and Charger unit is available as an accessory. The 1234 will operate for 40 hours on one charge of this nickel-cadmium battery.

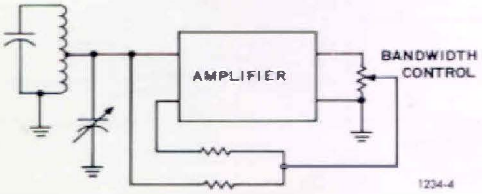

Figure 4. Frequency-selective amplifier circuit.

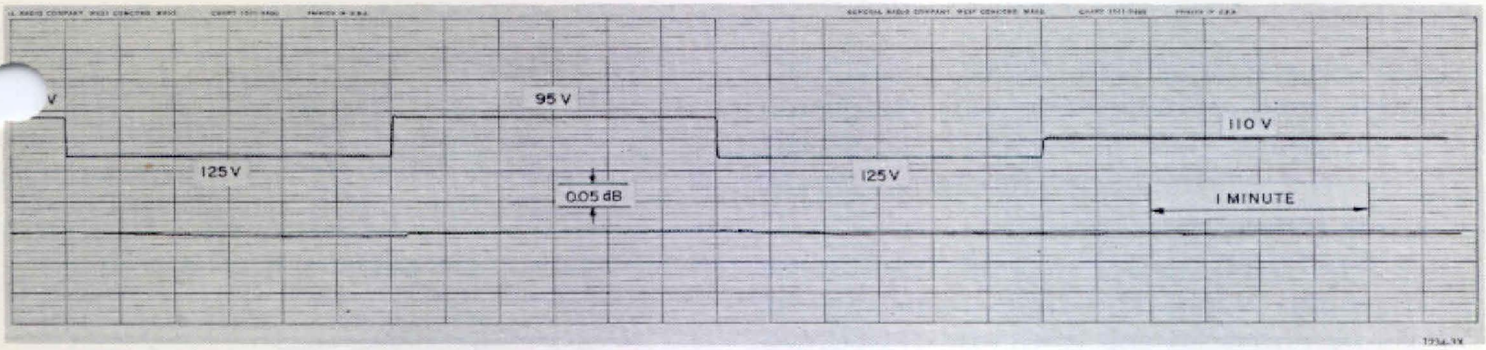

Figure 5. Recording showing gain stability with line-voltage changes, as measured on a production instrument.

Use with Bolometers

The bolometer is often preferred over the crystal detector for accurate measurements. The signal level must be at least five times the residual noise level for an error of 0.1 dB or less. The power level required to produce such a meter deflection has been measured on a typical instrument to be −52 dBm peak, with a 100%-modulated signal. The high limit for a 0.1-dB error is generally about 0 dBm. For errors of less than 0.05 dB the peak power must be limited to the range of −45 to −15 dBm.

Accurate measurements at high signal levels require a high input impedance. In the 1234, the input circuit is designed to provide an optimum signal-to-noise ratio over a wide range of source resistances, while presenting a high input impedance to the source. In the two bolometer-input positions of the SOURCE switch, this optimum source resistance is 200 ohms, while the input impedance is 3.5 kilohms in parallel with 5 kilohms inductive reactance. At high input-signal levels, a low impedance will increase the bolometer's deviation from square law. This error is sometimes called the voltage-transfer error.[1] A high load impedance (i.e., a high input impedance of the amplifier) will reduce this effect to the point where it may become negligible.

Another factor affecting bolometer accuracy is the bias-current supply. If this current is not supplied from a high-impedance source, the source impedance may be considered to appear in parallel with the input impedance of the amplifier, thus aggravating the voltage-transfer error. The 1234 supplies a bolometer dc bias current from a true current source (source resistance about 10^5 ohms). The current is adjustable ±10% of the nominal value by means of a potentiometer accessible through a hole in the rear cover of the instrument. The current source is voltage-limited to protect the bolometer element.

Use with Crystal Detectors

The crystal diode, although its dynamic range is less than that of a bolometer, is widely used as a detector because of its higher sensitivity. The power level required to produce a meter deflection five times the noise level is about −60 dBm. The upper limit, where the deviation from square law becomes significant, is about −30 dBm. This level can be raised by the selection of a proper load impedance for the crystal. At impedances very low compared with the dynamic resistance of the diode, the deviation from square law is positive — that is, the output voltage or current increases more than

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[1] G. J. Sorger and B. O. Weinschel, "Comparison of Deviations from Square Law for R. F. Crystal Diodes and Barreters," *IRE Transactions on Instrumentation*, Vol. I-8, No. 3, December 1959, pp 103–111.

the input rf power does. With very high load impedances the deviation from square law is negative, since the detector approaches the linear operating region.

We found that the best results are obtained when the load resistance is about equal to the dynamic resistance of the diode. Measuring the dynamic resistance is a simple matter of connecting a resistor across the top of the detector and calculating R_D from the resulting voltage drop. Dynamic resistances of point-contact diodes vary from 5 to well over 100 kilohms. A shunt resistor to reduce the error at high levels will of course decrease the detector sensitivity, but the ability to change the optimum source resistance helps to reduce this loss in sensitivity, so that this method can be used to increase dynamic range significantly.

An example appears in Figure 6. The diode dynamic resistance is 7 kilohms. The 6.8-kilohm shunt resistor reduces sensitivity by 2 dB. For a maximum error of 0.1 dB on the high-level and 0.1 dB at the low-level end, the dynamic range is increased from 35 to 45 dB.

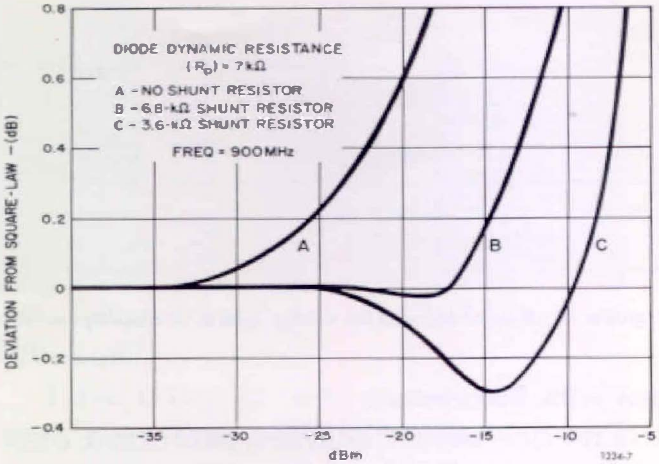

Figure 6. Extension of the square-law range of a diode detector by a shunt resistor across the detector output.

When the meter deflection is at least five times the residual noise deflection, the error due to the noise contribution is less than 0.1 dB.[2] However, the ability to read the meter correctly is limited by the fluctuations of the meter needle. The "slow," or damped, meter response reduces these fluctuations to the point where accurate readings are possible.

— M. KHAZAM

A brief biography of Mr. Khazam appeared in the July-August 1967 issue of the *Experimenter*.

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[2] W. R. Bennett: "Response of a Linear Rectifier to Signal and Noise," *Bell Systems Technical Journal*, Vol. 23, January 1944, pp 97–113.

SPECIFICATIONS

Input:	Crystal				Bolometer
Optimum Source R	35 kΩ	20 kΩ	2 kΩ	200 Ω	200 Ω
Input Impedance	1 MΩ	350 kΩ// 80 H	35 kΩ// 8 H	3.5 kΩ// 0.8 H	3.5 kΩ// 0.8 H
Sensitivity (fs)	1.2 μV	1 μV	0.32 μV	0.1 μV	0.1 μV
Noise*	0.2 μV	0.2 μV	0.06 μV	0.02 μV	0.02 μV

* Equivalent input noise level with source resistance equal to optimum and with minimum bandwidth.

Meter Scales: SWR, 1 to 4, 3.2 to 10, 1 to 1.2, and 1 to 1.05; dB, 0 to 10, 0 to 1.6, and 0 to 0.45; bolometer current, 0 to 10 mA.

Meter Accuracy: 0 to 10-dB scale, ±(0.01 dB + 1.5% of reading); 0 to 1.6-dB scale, ±0.02 dB; 0 to 0.45-dB scale, ±0.007 dB.

Attenuator: Three separate attenuators: 20 dB in 10-dB steps, accuracy ±0.1 dB/10 dB; 45 dB in 5-dB steps, accuracy ±0.05 dB/5 dB; 5 dB in 1-dB steps, accuracy ±0.01 dB/1 dB.

Bandwidth: 10 to 100 Hz, adjustable with constant gain.

Frequency: 1 kHz, adjustable ±30 Hz.

Gain Control: Coarse and fine, 6-dB range.

Bolometer Bias Current: 4.3 and 8.7 mA, adjustable ±10%. Voltage limited for bolometer protection.

Meter Speed: Slow and fast, switch selected.

Outputs: Dc, 1.5 V max behind 1500 Ω. Ac, 0.1 V rms (1 to 4 SWR range), 0.3 V rms (1 to 1.2 range), and 1 V rms (1 to 1.05 range); 500-Ω source impedance. Load resistance > 6000 Ω.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 60 Hz. Or 22 to 35 V dc, 90 mA from ext battery, 1538-P3 Battery and Charger suitable.

Accessories Supplied: Spare fuse, battery connector.

Accessories Available: 1538-P3 Battery and Charger.

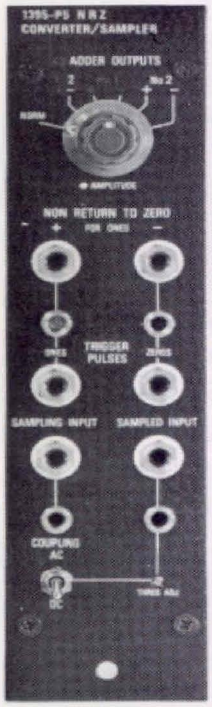
Mounting: Flip-Tilt case.

Dimensions (with x height x depth): 8⅜ x 8¾ x 11¼ in. (215 x 225 x 290 mm).

Weight: Net, 9 lb (4.1 kg); **shipping,** 12½ lb (6.0 kg).

Catalog Number	*Description*	*Price in USA*
1234-9701	1234 Standing-Wave Meter	$495.00

NRZ AND RANDOM PULSES FROM THE 1395 MODULAR PULSE GENERATOR



NRZ Converter/Sampler.

It often happens in the course of work on digital equipment that binary words of non-return-to-zero (NRZ) pulses are required. The 1395-A Modular Pulse Generator[1] is now available with a new plug-in module, the 1395-P5 NRZ Converter/Sampler, designed to provide NRZ pulses when used in conjunction with the Type 1395-P6 Binary-Word Generator.

The NRZ Converter/Sampler is easy to use. A timing signal, normally derived from the same master clock (a Type 1395-P1 PRF Unit) that drives the Type 1395-P6 Word Generator, commands the NRZ Converter/Sampler to examine the signal at its SAMPLED input. The signal at this input is the output of the Word Generator, stretched with the use of a 1395-P2 Pulse/Delay Unit. The NRZ Converter determines whether the SAMPLED input is in the one or zero state at the moment the SAMPLING pulse arrives. The appropriate output terminal then assumes a high or low voltage and holds that state until the sampling process finds the opposite state at the input.

There are two output terminals for the NRZ signal: One gives high-level voltage for ones; the other gives low-level voltage for ones. Both outputs are available simultaneously. The exact voltage levels are set at the user's pleasure by a gain control on the NRZ Converter/Sampler and by the DC Component control on the 1395-A

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[1] G. R. Partridge, "Pulses to Order," *General Radio Experimenter*, May 1965.

Gordon R. Partridge received his BE, ME, and PhD degrees in Electrical Engineering at Yale University. His academic background also includes an associate professorship in EE at Purdue University. He joined GR in 1962 as a Development Engineer, and he has since specialized in the design of pulse generators and amplifiers. He is the author of *Principles of Electronic Instruments*, published by Prentice-Hall in 1958.

Modular Pulse Generator (main frame), which sets the baseline voltage.

Since trigger pulses as well as NRZ pulses may be desired, the NRZ Converter/Sampler also provides triggers corresponding to its one or zero decisions. The user may select trigger pulses for ones or trigger pulses for zeros; both are available simultaneously at front-panel output jacks.

Communication links, whether in the sense of person-to-person, as in pulse-code modulated telephony, or between business machines involving binary data, normally are subject to interference from random trains of pulses at the same bit rate as the message. Such trains may be generated for test purposes by the NRZ Converter/Sampler operating with a random-noise generator such as the GR 1381 or 1382.[2] Unlike systems of pseudo-random noise generation, this method does not restrict the maximum number of ones or zeros it is possible to obtain in a continuous sequence. The result is a truly random set of ones and zeros.

The noise-sampling technique is also useful for producing low-frequency white noise. The power spectrum of a random sequence of non-return-to-zero ones and zeros is given by Rice.[3]

Specifically, this spectrum follows a (sin x/x)^2 law, where x is the product $\pi f h$. The quantity h is the time between SAMPLING pulses, and f is the frequency at which the power density in watts/cycle is being evaluated. As f approaches zero, the value of sin x/x approaches unity, showing that at low frequencies, the power density is essentially independent of frequency and therefore "white." The table below

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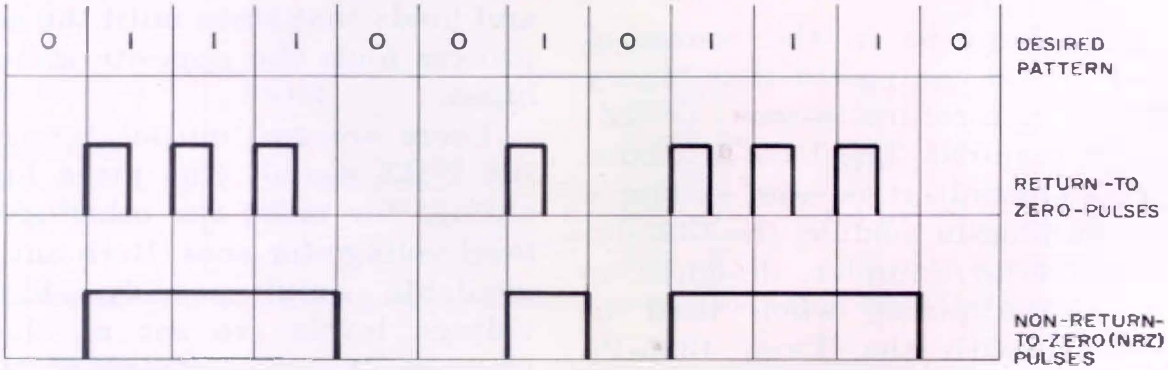
[2] J. J. Faran, "Random-Noise Generators," *General Radio Experimenter*, January 1968.

[3] S. O. Rice, "Mathematical Analysis of Random Noise," *Bell Systems Technical Journal*, Vol. 23, pp 282–332, July 1944. In particular, note Rice's equation 2.7-9.



What is an NRZ pulse? In the above diagram, a binary word (top line) is shown as converted to return-to-zero (center) and non-return-to-zero (bottom) pulse sequences. In return-to-zero sequence, voltage drops to zero at end of each "1" pulse, whether or not a "0" follows. With NRZ pulses, voltage returns to zero only at binary "0".

shows the relationship between whiteness and the SAMPLING frequency, which is the reciprocal of Rice's time interval h.

FREQUENCIES AT AND BELOW WHICH NOISE IS "WHITE" WITHIN TOLERANCES LISTED

Sampling Frequency (Hz)	*Frequency in hertz equal to or less than* (0.1 dB)	(1.0 dB)	(3.0 dB)
1	0.083	0.261	0.440
3	0.249	0.783	1.32
10	.83	2.61	4.40
30	2.49	7.83	13.2
100	8.3	26.1	44.0
300	24.9	78.3	132.
1000	83.	261.	440.
3000	249.	783.	1320.
10000	830.	2610.	4400.
30000	2490.	7830.	13200.
100000	8300.	26100.	44000.

The random binary pulse train is available at the NRZ output terminals of the NRZ Converter/Sampler. No other plug-ins are required except a 1395-P1 PRF Unit to generate a SAMPLING frequency. The total cost of such a system for generating random binary pulses, including the required random-noise generator, is then better than a thousand dollars under that of the most nearly similar commercially available generator of random binary sequences.

Since the NRZ Converter/Sampler gives a trigger pulse output each time a SAMPLING pulse is received, it follows that the basic assembly just described may be enlarged by the addition of other 1395-family plug-ins. Thus, the virtually limitless variety of pulses that can be produced with a 1395 Modular Pulse Generator are now available in random sequence.

— G. R. PARTRIDGE

SPECIFICATIONS

SAMPLING INPUT

Pulses: 10 to 15 V, positive-going, 75- to 150-ns duration, dc to 2.5 MHz.

Sine Wave: At least 17 V rms, 1 to 2.5 MHz. Sine-wave sampling below 1 MHz not recommended.

Input Impedance: Approx 4500 Ω across 40 pF.

SAMPLED INPUT

Sensitivity: 0.2 V pk-pk up to 2.5 MHz, optimized by adjustment of threshold control. Input required increases at other settings.

Coupling: Ac or dc, switch-selected.

Threshold Control: Compensates for dc components between approx ±0.6 V.

Input Impedance: Approx 100 kΩ across 40 pF.

NRZ OUTPUTS Both positive- and negative-going transitions are available simultaneously with the dc component controlled by the 1395.

Amplitude: >20 V, open circuit: >1 V across 50 Ω.

Transition Times: <15 ns with 50-Ω load at max input. Typically 80 ns + 2 ns/pF of load capacitance for high-impedance loads.

Output Impedance: 1 kΩ max.

TRIGGER OUTPUTS Two outputs available simultaneously: pulse generated when SAMPLED terminal is in ONE state, another when terminal is in ZERO state.

Amplitude: $> +10$ V. **Duration:** Approx 70 ns.

Output Impedance: Approx 160 Ω.

Delays: Trigger and NRZ outputs are delayed approx 190 ns from the SAMPLING input.

Accessories Supplied: Eight patch cords — two each TYPES 274-LMB, 274-LMR, 274-LSB, 274-LSR; two double plugs, four insulated plugs.

Catalog Number	*Description*	*Price in USA*
1395-9605	1395-P5 NRZ Converter/Sampler	$295.00

A GR900® COMPONENT MOUNT

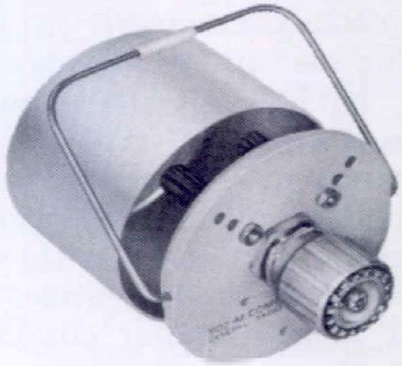


Figure 1.
Type 900-M Component Mount.

The gateway to many precision measurements is the GR900® precision coaxial connector, but if what you are measuring has a simple pair of wire leads, the problem becomes that of finding a gateway to the gateway. Just adapting from wire lead to coaxial is not enough; the transition must be made in such a way that the component is measured with the same lead length and dressing as it will have in the circuit in which it is used, and the leads must be positioned to produce minimum inductance or capacitance.

The solution to the problem is the new Type 900-M Component Mount, which permits reproducible measurements of wire-lead components (e.g., resistors, capacitors, inductors, diodes, transistors) at a well-defined reference plane and which also serves as a coaxial packaging device for the permanent mounting of components to be used as standards or terminations.

It is a particularly useful accessory for GR900-equipped instruments, such as the 1606-B RF Bridge, the 900-LB Precision Slotted Line, and the 1609 Immittance Bridge. It is also a very convenient housing for capacitance standards, which can be accurately calibrated on a GR900-equipped 1615-A Capacitance Bridge.

The mount, shown in Figure 1, consists of a GR900 precision coaxial connector, a length of coaxial line, a mounting disk, and a removable cover. The inner conductor of the coaxial line is kept from rotating by a dielectric rod that has been compensated so that it is essentially reflectionless. The line length (i.e., the electrical length of the mount) is exactly 4 cm to correspond to the electrical lengths of the 900-WN4 and -WO4 short and open circuits.

A sample measurement of a 1000-pF disk ceramic capacitor was performed to demonstrate the use of the mount. The lead lengths were 3/32 inch. The resulting reactance-vs-frequency characteristic is shown in Figure 2.

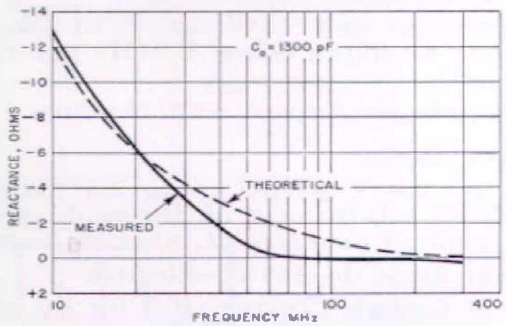


Figure 2. Measured reactances of 1000-pF disk ceramic capacitor with 3/32″ long leads.

SPECIFICATIONS

Electrical Length: 4.0 cm ±0.04 cm to ideal short circuit at terminals.

Residual Capacitance (at low frequencies): 2.93 pF, typical, with screw.

Accessories Required: 900-WN4 Precision Short Circuit, 900-WO4 Precision Open Circuit for establishing reference plane.

Weight: Net, 8 oz (230 g); shipping, 11 oz (315 g).

Catalog Number	*Description*	*Price in USA*
0900-9540	900-M Component Mount	$70.00

GR Product Notes

COMPLETE PROGRAMMABILITY FOR GR SYNTHESIZERS

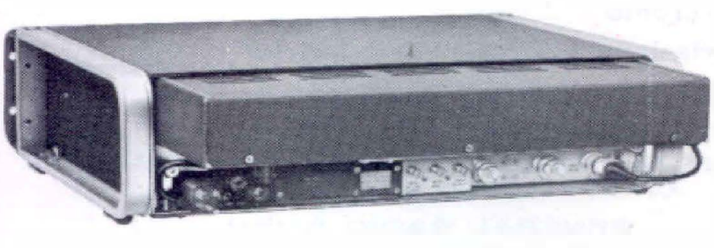
With the introduction of the Type 1164-RDI-3 10-MHz/step Programmable Digit-Insertion Unit, GR's frequency-synthesizer line is completely programmable, from lowest frequency to highest (70 MHz). The 1164-RDI-3 is a plug-in replacement for the highest-frequency (X-10 MHz) module in a Type 1164 synthesizer. Conversion from nonprogrammable to programmable is just a few minutes' work. Of course, any synthesizer can be ordered equipped with programmable decades.

STANDARD-FREQUENCY OSCILLATOR FOR USE WITH SYNTHESIZERS

For many applications, the crystal oscillator built into a GR frequency synthesizer provides adequate stability. The way to higher stability, for those who need it, is a phase lock with an external frequency standard such as GR's Type 1115. Now, for those applications requiring less than the ultimate in stability but more than the synthesizer alone can provide, an inexpensive solution is available — an accessory standard-frequency oscillator that mounts inconspicuously on the rear of the synthesizer without adding to over-all height.

The oscillator (Type 1160-P3) uses a 5-MHz crystal in a temperature-controlled oven, a buffer amplifier, and its own power supply (so that it can be operated from the power line independently of the synthesizer).

The oscillator holds frequency within 1 part in 10^8 of its room-temperature frequency for any ambient temperature between 0 and 50°C. Aging is less than 3 parts in 10^9 per day. This performance puts the 1160-P3 significantly ahead of a "barefoot" synthesizer but still behind the synthesizer phase-locked to a frequency standard such as the GR Type 1115.



Accessory standard-frequency oscillator mounts neatly on rear of synthesizer, requires no additional relay-rack height. Separate power connector allows oscillator to run independently of synthesizer.

Catalog Number	*Description*	*Price in USA*
1164-9489	**1164-RDI-3 Programmable Digit-Insertion Unit, 10 MHz/step**	**$575.00**
1160-9650	**Hookup cable, 50-ft, 12-conductor, shielded, for above unit.**	**15.00**
1160-9603	**1160-P3 Standard-Frequency Oscillator**	**525.00**

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