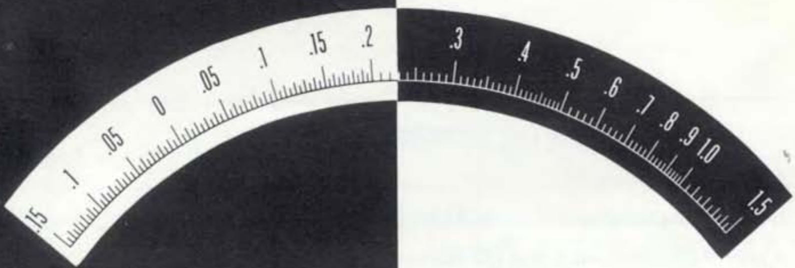
THE GENERAL RADIO

Experimenter

INTERNATIONAL EDITION

Microvolts & Nanoamps to 0.2%



- MEASUREMENT OF TRANSISTOR h-PARAMETERS WITH UNIVERSAL IMPEDANCE BRIDGE
- NEW MICROVOLTER

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A UNIQUE DC VOLTMETER

Among the instruments that can be classified as basic or essential to any electrical or electronics laboratory or production test facility is the dc voltmeter. Yet, with the state of the art in the electronic industry demanding increasingly specialized instruments, it is difficult to find one "basic" voltmeter to meet the needs of even several projects in a given research and development center.

General Radio's new TYPE 1807 DC Microvoltmeter/Nanoammeter was designed to fill this "versatility gap." It combines the features of microvoltmeter, nanoammeter, null detector, and differential voltmeter, all with 0.2% accuracy. As a microvoltmeter it offers nine decade ranges, from 15 μV (with resolution of 0.05 μV) to 1500 volts full-scale. An input filter is also provided for noise suppression.

As a nanoammeter it can read currents from 15 pA (0.05-pA resolution) to 10 mA full-scale.

As a null detector it has a common-mode rejection ratio of greater than 160 dB and a three-second recovery time for a 10^6 overload.

As a differential voltmeter it offers accuracy 10 times better than that of conventional voltmeters.

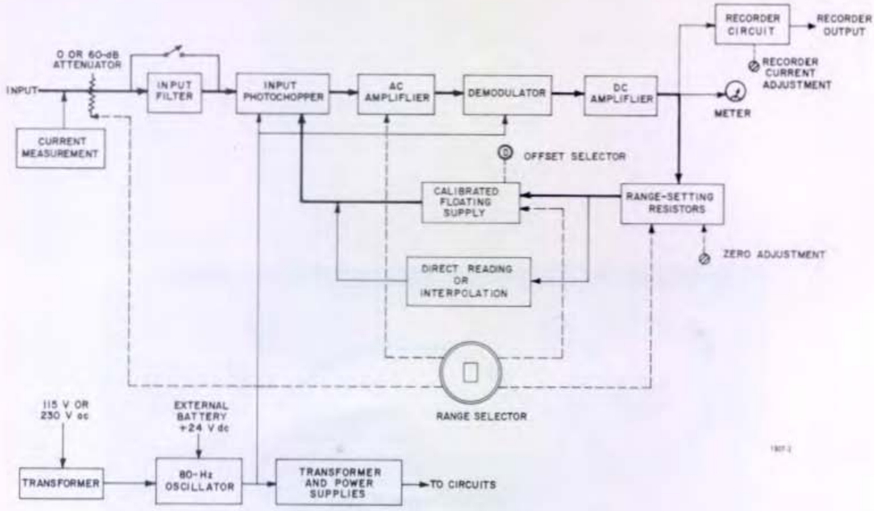


Figure 1. Block diagram of Type 1807 DC Microvoltmeter/Nanoammeter.

GENERAL DESCRIPTION

Figure 1 shows the block diagram of the 1807. What may not be obvious from this diagram is the method of achieving such a high common-mode rejection ratio. The key is Teflon* insulation to ground at all connections to the high and low terminals. For example, the meter is completely isolated by Teflon from the front panel. Even in the power transformer, Teflon is used as the insulation between windings.

The instrument can be operated from a 115-220-volt ac line or from a 24-volt dc supply.

Meter and Output Circuits

An unusual meter scale (see Figure 2) helps to improve the accuracy of reading and to provide higher resolution for null detection. Note that the meter is logarithmic above 10% of full scale and linear below 10% of full scale. The zero

* Registered trademark of E. I. du Pont de Nemours and Company.

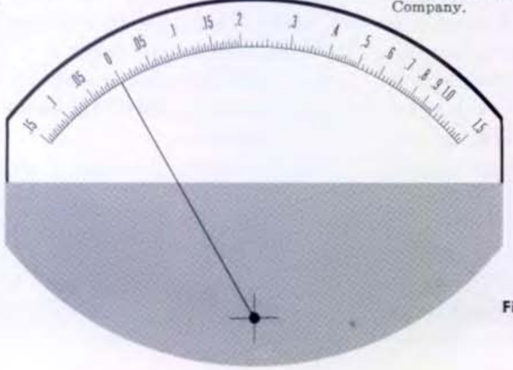


Figure 2. Meter scale of the 1807.

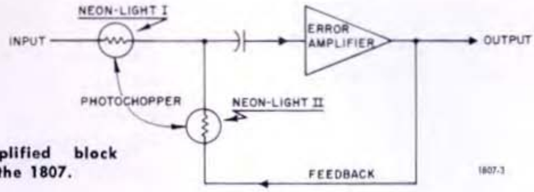


Figure 3. Simplified block diagram of the 1807.

is offset by about 20 degrees to allow the user to take readings about zero and still reserve most of the meter movement for higher resolution. A front-panel polarity switch enables the user to utilize the proper region of the meter.

The dc output amplifier can supply ±2.5 volts or ±1 mA, enough to drive most recorders. This voltage is adjustable at the front panel. Any load, even a short circuit at the recorder terminals, will have no effect on the operation of the instrument.

Interpolation-Offset Feature

The interpolation-offset feature allows the user to read the difference between two signals to within 0.1% of reading plus 0.1% of full-scale accuracy. The user, in setting the interpolation-offset switch, subtracts from the input a *calibrated* voltage equal to the most significant figure of the unknown; he then reads the difference in the conventional manner (see Figure 1). With this feature, the 1807 achieves accuracies usually associated with digital techniques, while preserving the versatility of an analog instrument.

Input Circuitry and Connectors

The high input impedance of the 1807, even down to the microvolt level, eliminates almost all loading errors. This impedance is achieved by means of the high loop gain in the error amplifier (see Figure 3) and the high impedance of the series-shunt cadmium-selenide (CdSe) photochoppers used at the input of the instrument.

The selection of a photochopper modulator was made in order to minimize noise, drift, and offset. Figure 4 shows a recording of the output noise of the 1807 in the picoampere range with no signal applied to the input. (There is a 1-megohm resistor across the input terminals on this range.)

One very annoying problem in the measurement of low-level dc is the presence of thermoelectric voltages generated when junctions of dissimilar metals are at different temperatures. Since it is difficult to keep all parts of the instrument at the same temperature, care was taken in the design of the 1807 to use copper-to-copper junctions at all points of the input circuitry. Thus, the input binding posts are gold-plated copper and the photocell leads

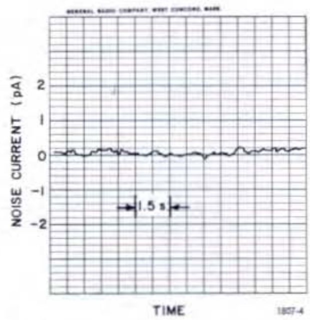


Figure 4. Recording of the output noise current referred to the input with 1 MΩ across the input terminals.

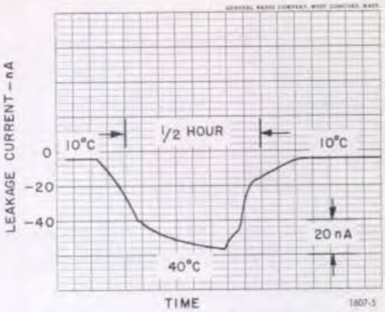


Figure 5. Recording of the leakage current for a Type 1N3604 diode cycled through a temperature change of 10°C to 40°C.

are Dumet, which has a thermoelectric voltage coefficient similar to that of copper.

The high input impedance of the instrument makes it feasible to use an RC low-pass filter with a cutoff frequency of 1.5 Hz at the input. This will filter out any ac noise that may be superposed on the dc signal. For faster response time, the filter can be switched out by means of a front-panel switch.

As an aid for routine voltage and current measurements, a Tektronix 1:1 probe (no attenuation) is available as an accessory. Note that this probe should not be used at extremely low voltage and current levels.

APPLICATIONS

Because of its versatility, the 1807 will undoubtedly find applications in physics, biology, and chemistry, as well as in electronics. Thus the applications discussed below should not be interpreted as being the prime uses of this instrument.

Diode or Transistor Matching

Quite often it is desirable to match a pair of diodes for leakage current or forward voltage drop (emitter-to-base voltage in case of transistors). The 1807 can be used to measure the forward voltage drop with a high degree of accuracy (using the interpolation feature) and the reverse leakage current with high sensitivity. Figure 5 shows a recording of leakage current for a type 1N3604 diode cycled through 10°C to 40°C.

Low-Level Differential Measurements

For comparison of various standard cells (e.g., saturated versus unsaturated), one is interested in making dc differential measurements of a few hundred microvolts with accuracies of about 1 or 2 μV. Figure 6 shows a recording of differential measurements

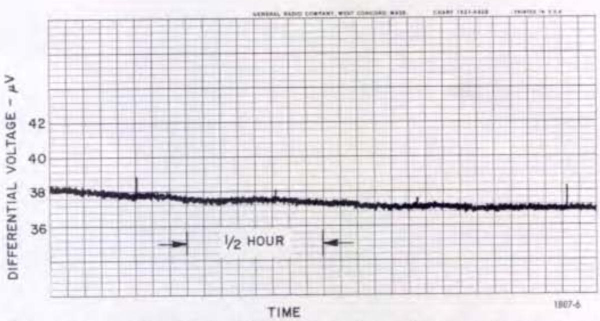


Figure 6. Recording of the drift of the voltage difference between two unsaturated standard cells at 25°C.

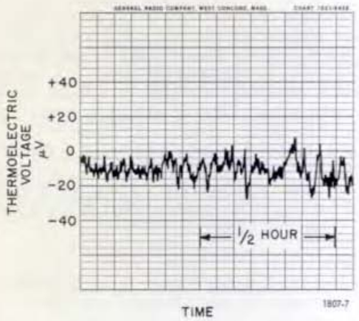


Figure 7. Recording of the thermoelectric voltage generated by a thermocouple.

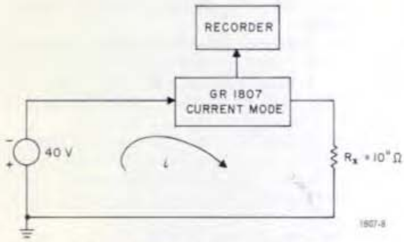


Figure 8. Test set-up for measuring unknown resistor R_x.

for two unsaturated standard cells. This recording, taken over a two-hour period, shows that the cells differed by 38.1 μV at the beginning of the test and by 36.8 μV at the end of two hours. The test temperature was 25°C.

Temperature Measurements

Figure 7 is a recording of the thermoelectric voltages generated by temperature difference between two points in a non-air-conditioned room. A copper-constantan thermocouple with a temperature coefficient of 39 μV/°C was used in this test. The recording, taken over a one-hour period, shows the thermoelectric voltage between the two junctions of the thermocouple to vary between +8 μV and −28 μV. Thus, the temperature variation is concluded to be about 0.9°C.

High-Value Resistance Measurements

The low-current sensitivity and the high accuracy of the 1807 make it suitable for very-high-resistance measurements. Figure 8 is a typical setup for such measurements. A nominal current i of 410 pA at 50°C was measured with the 1807, using the interpolation feature (Figure 9). Thus, the value of R_x at 50°C is calculated to be 9.75×10^{10} Ω. As the temperature was dropped to 0°C, the current measured by the 1807 decreased to 376 pA. The resistance of R_x at 0°C, therefore, is 1.06×10^{11} Ω.

— K. G. Balekdjian

A brief biography of Mr. Balekdjian appeared in the May 1968 issue of the *Experimenter*.

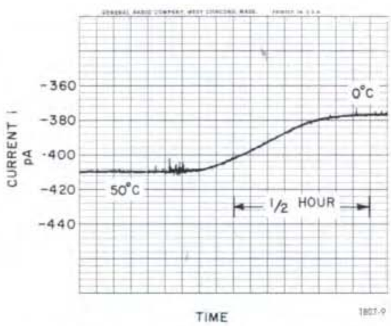


Figure 9. Recording showing the change in current i (Figure 8) as the ambient temperature changes from 50°C to 0°C.

SPECIFICATIONS

RANGE

Voltage (either polarity): 15 μV to 1500 V full scale in 9 decade ranges; 0.05-μV/div resolution near zero on most sensitive range.

Current (either polarity): 15 pA to 1.5 mA full scale in 9 decade ranges; 0.05-pA/div resolution near zero on most sensitive range.

ACCURACY

Record-Current Linearity: ±(0.1% of reading + 0.5 μV).

Interpolate: ±[0.1% of full scale (range) + 0.1% of reading + 0.5 μV].

Direct: ±(1.5% of reading + 0.5 μV) above 10% of full scale. ±(0.15% of full scale + 0.5 μV) below 10% of full scale.

Temperature Coefficients (typical)

Record-Current Zero Drift: ±(0.001% of full scale + 0.15 μV) per degree C.

Interpolate: ±(0.001% of reading + 0.001% of full scale + 0.15 μV) per degree C.

Direct: ±(0.02% of reading + 0.001% of full scale + 0.15 μV) per degree C.

INPUT IMPEDANCE

Voltage: 150-μV to 1.5-V ranges, > 500 MΩ on direct and typically 5,000 MΩ on interpolate; 15-μV range, > 50 MΩ; 15-V to 1500-V ranges, 10.5 MΩ.

Current: Internal Shunts, 1 MΩ in pA-μA ranges, 1 kΩ in nA-mA ranges.

Meter: Single scale from −1.5 to 15. Logarithmic (20 dB) above 10% of full scale.

Input Current: Less than 5 pA.

Noise: Typically 0.5 μV for 3σ with 1 kΩ across input.

Common-Mode Rejection: > 160 dB for dc with up to 600 V dc max above ground; > 120 dB for 60-Hz common-mode signal of <8 V pk with input filter.

Record-Current Response Time (typical): 0.1 s without input filter (1.5-Hz bandwidth), 0.3 s with filter (0.6-Hz bandwidth) on all ranges above 15 μV; 10 times slower on 15-μV range.

Maximum Overload: Voltage: 150 V on 1.5-V range and below, 1500 V on 15-V range and above. Current: 10 mA max all ranges.

Overload Recovery Time: Approx 3 s for 10^6 overload.

Recorder Output: Adjustable up to ± 2.5 V open circuit for full scale meter deflection; ± 1 mA into 1.5 kΩ max load.

GENERAL

Terminals: Gold-plated copper binding posts on front and rear panels. Ground connection on rear panel only. Battery connection on rear panel.

Power Required: 105 to 125, 205 to 250 V, 50 to 60 Hz, 5 W. Also operates from external 24-V dc supply; 1538-P3 Battery and Charger recommended.

Accessories Supplied: 274-QBJ adapts binding posts to BNC; fuse; power cord.

Accessories Available: Input probe, Tektronix type P6028; 1538-P3 Battery and Charger.

Mounting: Convertible-Bench Cabinet.

Dimensions (width x height x depth): Bench, 12 x 5⅞ x 10¼ in. (305 x 150 x 260 mm); rack, 19 x 5¼ x 8½ in. (485 x 135 x 220 mm).

Net Weight: Bench, 9½ lb (4.4 kg); rack, 10¾ lb (4.9 kg).

Shipping Weight: Bench, 16½ lb (7.5 kg); rack, 18 lb (8.5 kg).

Catalog Number	*Description*
	1807 DC Microvoltmeter/Nanoammeter
1807-9700	Bench Model
1807-9701	Rack Model
1807-9601	Input probe, Tektronix type P6028, Cat. No. 010-0074-00

TRANSISTOR MEASUREMENTS WITH THE 1650-B

As mentioned in the May *Experimenter*, the new TYPE 1650-B Impedance Bridge is useful not only for routine measurements on passive components but also for measurements of transistor *h*-parameters. The special test jig required for such measurements, as well as the procedure, is described below.

The *h*-parameters are defined in Figure 1, and the calculations that indicate how to obtain the four-terminal parameters h_{fe} and h_{re} from two-terminal measurements appear in Figure 2. Some thought about biasing the

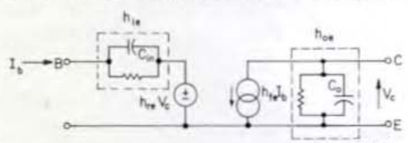
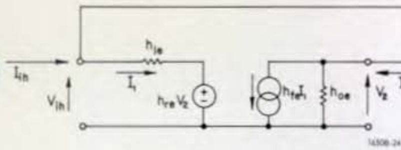
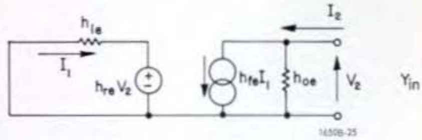


Figure 1. Equivalent circuit of a transistor, showing how the common-emitter h-parameters are defined.





$$I_{in} = I_1 + I_2 \qquad Z_{in} = \frac{V_{in}}{I_{in}}$$

$$V_2 = V_{in}$$

$$V_{in} = h_{ie} I_i + h_{re} V_{in}$$

$$I_2 = h_{fe} I_1 + h_{oe} V_{in}$$

$$\therefore I_1 = \frac{V_{in}\,(1 - h_{re})}{h_{ie}}$$

and $I_2 = h_{fe} \dfrac{V_{in}\,(1 - h_{re})}{h_{ie}} + h_{oe} V_{in}$

substitute and combine to get

$$Z_{in} = \frac{h_{ie}}{\underbrace{(1 - h_{re})}_{\approx 1}\,(1 + h_{fe}) + \underbrace{h_{oe}\, h_{ie}}_{\text{very small}}}$$

$$\boxed{\therefore\ h_{fe} \approx \frac{h_{ie}}{R_{in}}}$$

$$Y_{in} = \frac{I_2}{V_2}$$

$$V_1 = h_{ie} I_1 + h_{re} V_2 = 0$$

$$\therefore I_1 = \frac{-h_{re}}{h_{ie}}\ V_2$$

$$I_2 = h_{fe} I_1 + h_{oe} V_2$$

$$\therefore I_2 = \left(h_{oe} - h_{fe} \frac{h_{re}}{h_{ie}}\right) V_2$$

$$Y_{in} = \frac{h_{ie} h_{oe} - h_{fe} h_{re}}{h_{ie}}$$

$$h_{re} = \frac{h_{ie} h_{oe} - h_{ie}\ Y_{in}}{h_{fe}}$$

but $\dfrac{h_{ie}}{h_{fe}} \approx R_{in}$

$$\boxed{\therefore\ h_{re} \approx R_{in}\,(h_{oe} - Y_{in})}$$

Figure 2. Derivations of the formulas for h_{fe} and h_{re}.

transistor so as to isolate the particular impedance we want to measure yields the test circuits of Figure 3. These may be built into a convenient test jig using rotary switches or toggle switches with shielded leads going to the 1650-B's unknown terminals. The shields should be connected to the 1650-B case to guard out the stray capacitance between the center conductors. It is helpful to have the 1650-B plastic-coated condensed instruction sheet handy during measurements so that R_A, the ratio-arm resistance, can be determined.

The procedure is as follows:

a. Use the R_{ac} bridge and the h_{ie} test jig (Figure 3a). Turn the OSC LEVEL control way down to ensure a small-signal measurement of the forward-biased base-to-emitter junction. The diffusion capacitance of the junction is balanced using an external capacitance

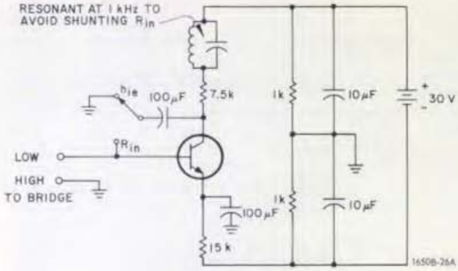


Figure 3a. The h_{ie} test jig.

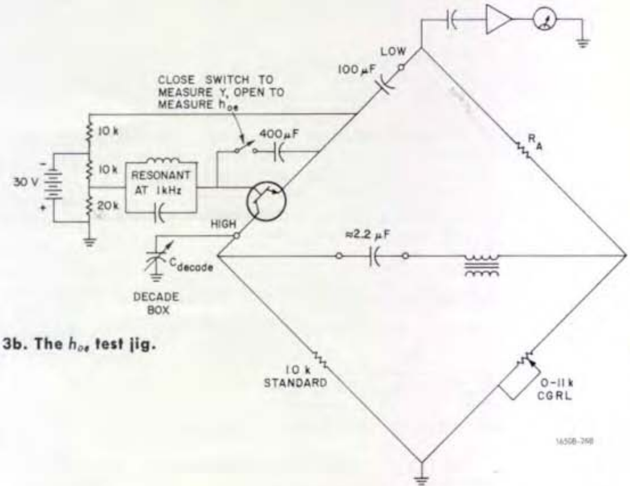


Figure 3b. The h_{oe} test jig.

decade box connected between the HIGH UNK terminal and the 1650-B ground. h_{ie} is usually a few thousand ohms and

$$C_{in} = \frac{10\ \text{k}\Omega}{R_A} C_{\text{decade}} ,$$

where R_A is the value of the ratio arm in kilohms (10 kΩ on the 1-kΩ multiplier range).

b. Throw a switch that connects the base to the collector with a large capacitor and measure R_{in}, which will be about 26 ohms for an emitter current of 1 mA. Calculate: $h_{fe} = \frac{h_{ie}}{R_{in}}$.

c. Use the G_{ac} bridge and the h_{oe} test jig (Figure 3b) and turn up the oscillator level for increased sensitivity. Measure h_{oe} directly in micromhos and balance the output capacitance, C_o, with the external capacitance decade box. Calculate: $C_o = \frac{R_N}{R_A} C_{\text{decade}}$,

where R_N is the reading on the CGRL dial (0-11 k) in kilohms and R_A is the value of the ratio arm in kilohms (100 kΩ on the ×10-micromhos range).

d. Throw a switch that connects the base to the emitter with a large capacitor and measure Y in micromhos. Calculate: $h_{re} = R_{in}\ (h_{oe} - Y)$.

— C. Havener

A brief biography of Mr. Havener appeared in the May 1968 issue of the *Experimenter*.

A NEW AUDIO-FREQUENCY AND DC MICROVOLTER*

Just as in 1933 when the first General Radio Microvolter was designed, there is still a need for an independent metered attenuator to obtain dc and audio-frequency voltages at the microvolt level. Many modern sources of ac signals, particularly of nonsinusoidal ones, are not metered and do not have an attenuator with the range or the shielding required for working at microvolt potentials. Yet the need for such a low-voltage source is clear, especially with today's wide use of very high-gain operational-amplifier techniques.

A Microvolter is simply a self-contained step attenuator preceded by a meter and a continuously adjustable potentiometer. The meter and potentiometer establish the input voltage of the attenuator over a one-decade range, and this is then reduced to the desired level in decade steps by the attenuator. The range of the instrument is determined by the full-scale sensitivity of the meter and by the amount of attenuation.

The new 1346 Audio-Frequency Microvolter, the third generation to follow the original 546, has many new features, of which the two most important are a dc meter scale and an internal battery, making it a self-contained "floatable" dc source. Output is adjustable from 1 μV to 10 V with either polarity. Gold-plated copper binding posts and careful construction keep thermal emfs negligible even at the lowest microvolt levels. An on-off switch, which in the off posi-

* Trademark registered in USA.

tion maintains the 600-ohm output impedance, permits easy dc zero setting. Since the impedance of the source remains the same, any offset voltage due to input current will be the same with or without the signal applied and will not affect incremental gain measurements.

The floatability makes it easy to apply a common-mode signal to measure common-mode rejection for various dc inputs. The battery can be removed and an external dc supply used if complete isolation is not needed or if periodic battery replacement is an inconvenience.

The ability to superpose a small ac signal on the dc greatly increases the usefulness of the Microvolter. If one wants to know when a dc amplifier is operating in its linear region and when it is in saturation, he can simply superpose a small ac signal on the dc through the input binding posts and check for the presence of this ac at the output with an oscilloscope.

Ac operation is improved also. A full 10 volts ac is available when the Microvolter is used with the common 20-volt, 600-ohm audio oscillators on the 10-volt ac full-scale range. A 1-volt ac full-scale range is provided for sources that have lower outputs. The minimum full-scale outputs are 1 and 10 μV respectively. The meter is calibrated for the rms value of a sinusoidal input, with the stated accuracy extending over a frequency range of 10 Hz to 100 kHz. The attenuator is accurate to even higher frequencies, but leakage from the source oscillator, radiation from connectors, and ground-loop effects often exceed microvolt levels at frequencies above 100 kHz.

Distortion introduced in the signal of the Microvolter is reduced to a level consistent with that of typical sources with which it may be used. The output

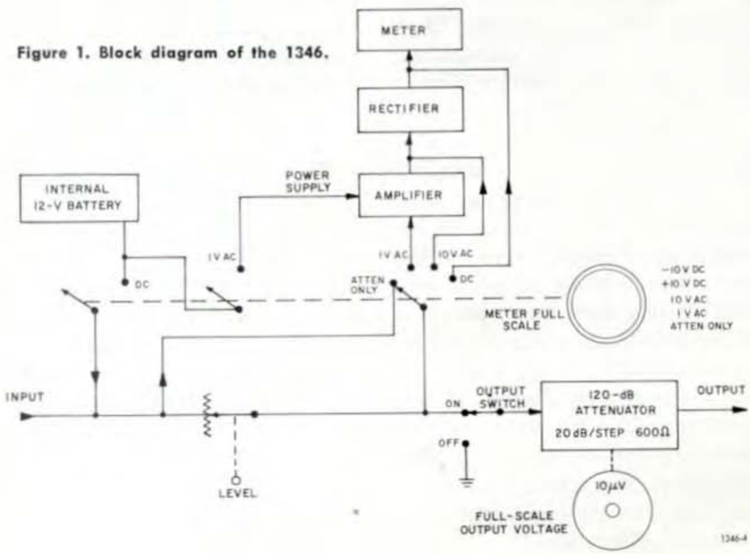


Figure 1. Block diagram of the 1346.

on-off switch that can reduce the output to zero while maintaining the same 600-ohm output impedance is fully as useful with ac signals as with dc. Noise sources due to ac pickup and ground loops are much easier to measure and to locate with the signal removed and with the impedance level, shielding, and circuit configuration remaining the same.

In addition to positions for the one dc and two ac sensitivities, the meter has an ATTEN ONLY position in which the meter is out of the circuit, leaving just the step attenuator between the input and output terminals. This is desirable when the signal is of unusual waveshape, as for example, a tone burst.

Figure 1 is a block diagram of the 1346, showing the circuits used in the different modes of operation. Note that the battery is used in the dc and 1-V ac positions only; the meter is self-powered on the 10-V ac range. This is the range most often used, because of the profusion of 20-volt audio oscillators available, and the battery thus should normally have a very long life. The battery is an inexpensive and readily available type.

— R. E. Owen

A brief biography of Mr. Owen appeared in the January 1968 issue of the *Experimenter*.

ACKNOWLEDGEMENT

The author acknowledges the assistance of Peter Young on the attenuator and Alan Ombrello on the meter designs.

SPECIFICATIONS

Function	*10 V ac*	*1 V ac*	*+10 V dc −10 V dc*	*Atten Only*
Open-Circuit Output Voltage	1.0 μV to 10 V ac	0.1 μV to 1.0 V ac	1.0 μV to 10 V dc	0 to −120 dB 20 dB/step
Accuracy at 23°C (above 10% of dc full scale)	±(4%+0.2μV) 10 Hz to 100 kHz	±(4%+0.02μV) 10 Hz to 100 kHz	±(3%+0.2 μV)	±(0.04 dB/step +154 dB below input level) dc to 100 kHz
Source	External ac required 10.0 V into 595 Ω	External ac required 1.0 V into 550 Ω	Internal battery or ext dc source 10 V max	Ext ac or dc source 10 V max input
Input Impedance (approx)*	595 Ω to 25 kΩ	550 Ω to 25 kΩ	610 Ω to 25 kΩ with int battery removed	550 Ω to 5 kΩ

* Input impedance varies as shown in table with setting of input level control. Can be adjusted to remain constant when varying the step attenuator for load impedance of ≥50 Ω.

Distortion (at 1 kHz): <0.01% in 1-V-ac mode, <0.05% in 10-V-ac mode, with level control at max setting.
Output Impedance: 600Ω ±0.5%.
Power Required: None required for 10-V-ac range. In other modes, 12-V dry battery: Eveready 228, RCA VS329, or Burgess PM8. Approx life, 33 hours at 2h/day in either dc mode, 316 hours at 2h/day in 1-V-ac mode.
Mounting: Convertible-Bench Cabinet.

Accessories Supplied: Battery; mounting hardware with rack model.
Accessories Available: GR 1309-A and 1310-A Oscillators, 1396-B Tone-Burst Generator, 1381 and 1382 Random-Noise Generators.
Dimensions (w x h x d): Bench, 8½ x 7½ x 7½ in. (220 x 190 x 190 mm); rack, 19 x 6 x 7⅝ in. (485 x 155 x 195 mm).
Weight: Net, 5¼ lb (2.4 kg); shipping, 9 lb (4.1 kg).

Catalog Number	*Description*
	1346 Audio-Frequency Microvolter
1346-9700	**Bench Model**
1346-9701	**Rack Model**

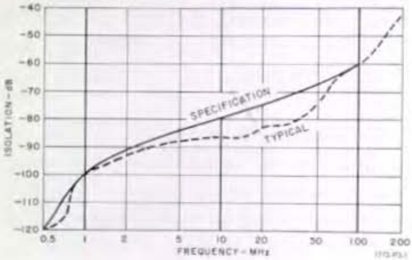
GR Product Notes

NEW SHIELDED SWITCH MODULE

The 1772-P3 module extends the capabilities of the 1770 Scanner System to the automatic scanning of signal lines by providing high isolation of signals up to 100 MHz. Isolation between lines is 120 dB at 500 kHz, 100 dB at 1 MHz and 60 dB at 100 MHz. Pulse reflections are typically less than 15%.

Other switch modules, the 1772-P1 and 1772-P2, accept input lines in a single shielded bundle; the new 1772-P3 accepts BNC-terminated cables. All three will switch 10 channels per module, thus providing up to 100 channels in a single 1770 Scanner System. The system has six scanning modes, with front-panel mode selection.

The 1772-P3 switch module contains ten dry-reed relay switches. Each relay requires 15 V at 30 mA to operate. The module is a special-order item, and the customer can specify the program boards, switching methods, and shielding that suit his application.



Isolation between channels of the 1772-P3 (determined by energizing one channel, applying a signal through it, and measuring the signal on any unenergized channel with a 50-Ω detector).

Typical of the many uses for the 1772-P3 is that of making automatic frequency-stability tests on many oscillators or signal generators. While the shielded modules connect the oscillator outputs in sequence to a single counter, the output data from the counter could also be switched, in order, to several recorders or to other logging devices through other modules.

PRECISION CAPACITOR

The 1422-CE is a stable and precise variable air capacitor intended for use as a continuously adjustable standard of capacitance. It is a dual-range, three-terminal capacitor with shielded coaxial terminals for use in three-terminal measurements. The calibrated direct capacitance is independent of terminal capacitance to ground and losses are very low.

This low-capacitance member of the 1422 family has ranges of 0.005 to 0.11 pF and 0.05 to 1.1 pF, resolution of 0.00002 and 0.0002 pF per division, respectively, and will satisfy the special requirements for use in the Harris ultralow-frequency capacitance bridge* built at the National Bureau of Standards.

Specifications are comparable to other models of the GR 1422 and are given in full in Catalog T.

* W. P. Harris, "A New Ultralow-Frequency Bridge fo[r] Dielectric Measurements," *1966 Annual Report, Conf[er]ence on Electrical Insulation and Dielectric Phenomena*, page 72.

NEW DIGITAL LIMIT COMPARATOR FOR 1681 AUTOMATIC IMPEDANCE-COMPARATOR SYSTEMS

The 1783 Digital Limit Comparator is similar to the 1781 (an accessory to the 1680 Capacitance Bridge[1]), but it has expanded capabilities for use with the 1681 Automatic Impedance Comparator.[2]

When used with the 1681 comparator, the 1783 automatically makes comparisons between the measured digits and the limit digits and presents the results as a panel-lamp display and as relay-contact closures at a rear-panel connector. The 1783 has independent upper and lower 5-digit limits for both impedance magnitude and phase angle. The limits are set manually on rows of thumb-wheel switches.

A 1681 impedance comparator and one or more 1783 limit comparators form a complete testing system that allows an operator to sort components manually into precise categories. These instruments can also be used with automatic handling equipment.

The 1783 is assembled on special order. It is available either alone or in a system custom designed by General Radio for your application.

[1] *General Radio Experimenter*, December 1966.
[2] *General Radio Experimenter*, June-July 1968.

DC-LEVEL CONTROL FOR THE 1398 PULSE GENERATOR

A new accessory can be used to control the dc level of the output pulse of a 1398-A Pulse Generator. The controlled parameter may be average, positive peak, or negative peak, and control is independent of duty ratio and prf. Time constant of the regulating circuit can be selected according to output-pulse duration.

The 1398-P1 DC Component Control attaches to the side of, and derives power from, the pulse generator.

Catalog Number	*Description*
	Precision Capacitor
1422-9833	1422-CE, with standard calibration
1422-9580	1422-CEP, with precision calibration
	1783 Digital Limit Comparator
1783-9801	Bench Model
1783-9811	Rack Model
1398-9601	**1398-P1 DC Component Control**
0480-9337	**480-P317 Rack-Adaptor Set** for combination of 1398-A and 1398-P1

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