Scanner is added, the test procedure can be automated.

The 1820 can also be used in automatic test setups for resistance sorting. One can measure resistances from 2.000 ohms to 20.00 megohms full-scale with the 1820-P2 automatically and without any external circuitry. With the -P1 plug-in, resistors up to 200 megohms can be measured, with no degradation in accuracy.

— K. G. Balekdjian

Catalog Number	*Description*	*Price in USA*
	1820-A Digital Voltmeter (no plug-in)	
1820-9700	Bench model	**$1985.00**
1820-9701	Rack model	**1985.00**
	Plug-ins and Accessories	
1820-9601	**1820-P1 DC Multimeter/UHF Voltmeter**	**525.00**
1820-9602	**1820-P2 AC/DC Millivoltmeter**	**550.00**
1820-9603	**1820-P3 Differential Adaptor** (for use with 1820-P1 or -P2 plug-in)	**90.00**
1806-9601	**1806-P1 Tee Connector**	**40.00**

Detailed specifications on the 1820 Digital Voltmeter appear in General Radio Catalog T

THE UNIVERSAL IMPEDANCE BRIDGE— NEW FACE, NEW FEATURES

Type 1650-B Impedance Bridge.

One of the truly basic laboratory instruments, along with the voltmeter and the oscilloscope, is the impedance bridge. Although there is a great variety of impedance bridges, by far the most popular is the general-purpose type that combines several bridges in one package to permit quick, convenient, reasonably accurate measurements of resistors, capacitors, and inductors.

The grandfather of this class of instrument was GR's Type 650 Impedance Bridge, succeeded about a decade ago by the 1650. The 1650, with its own generator, detector, and battery power supply, a basic 1% accuracy from 20 Hz to 20 kHz, an Orthonull® balancing mechanism that eliminated sliding balance, and a Flip-Tilt carrying case, soon won an excellent reputation on its own merits, even among a new generation that had never heard of the 650.

The next chapter in the story will be written by the 1650-B, which now replaces the 1650-A. A number of important improvements lie behind the change in letter suffix; despite this fact, it has been possible to reduce the price of the bridge.

The 1650-B offers all the features of the 1650-A plus the following:

1. A conductance bridge, which offers direct micromho readout and extends the range of resistance measurements to 1000 megohms.

2. A slow-motion mechanism on the CGRL dial, which automatically comes into play over a narrow sector each time the direction of rotation is reversed. The effect is a considerable improvement in operating convenience.

3. White sectors on the balance dials to indicate the ranges where the Orthonull balancing mechanism should be switched in for quickest, easiest balance.

4. A battery-check switch position and a corresponding sector on the meter scale.

5. Improved internal dc sensitivity for low-value resistors.

6. Provision for use of an external resistance decade box to extend the DQ range.

7. Access to the bridge arm opposite the unknown arm, so that an external capacitor can be added to obtain a reactance balance of inductive resistors.

8. Relocation of all jacks and terminals except the "unknown" terminals to a side panel, out of the way of the operator.

9. Automatic closure of the BIAS and EXT DQ phone jacks when they are not in use, so that one doesn't have to check the connection of shorting links between binding posts.

10. A redesigned bridge transformer, requiring less drive power at low frequencies.

"Who needs a conductance bridge, anyway?" Because the 1650 is used chiefly to measure components, not including conductors as such, this question will inevitably be asked. Answering it also gives us the chance to discuss the usefulness of ac resistance measurements, possible with the 1650 but not with some other "universal" impedance bridges. Here are just a few of the things you can do with ac resistance and conductance measurements.

Equivalent-Circuit Determinations

When developing an equivalent circuit of an unknown, one usually measures the reactive part on the 1% CRL dial and calculates the resistive part using a DQ measurement, which is only 5% accurate. With ac-resistance capability one can measure the resistive part to 1% and calculate the reactive part using the value of an external capacitor (Figure 1). Use of both methods leads to the most accurate determination of the equivalent circuit.

Impedance Measurements on Batteries

To measure the impedance of a battery, one has only to insert a blocking capacitor in the bridge's bias jack to

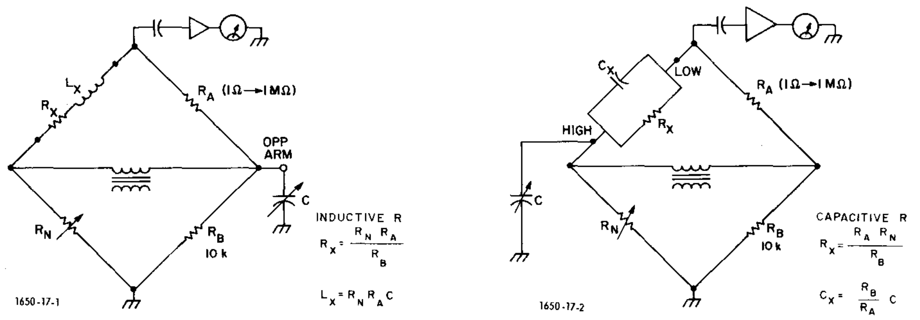


Figure 1. Diagrams showing use of the ac-resistance bridge to make reactive balances.

prevent the flow of large currents through the ratio arm (Figure 2). It is easy to tell sintered-plate (low resistance) and pocket-plate (higher resistance) nickel-cadmium batteries apart by the difference in resistance. The resistance is also a function of the batteries' state of charge. The short-

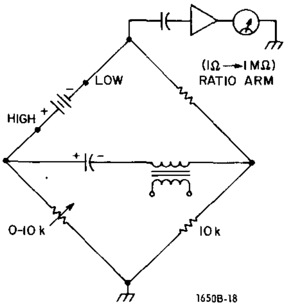
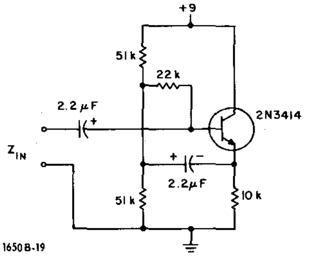


Figure 2. Capacitor inserted in bias jack stops flow of large dc currents through the low-resistance ratio arm.

circuit current of the cell is accurately predicted by the resistance measurement $I_{cell} = \frac{V_{cell}}{R_{ac}}$. This technique is valuable for measuring many low impedances (e.g., simple regulated power supplies and Zener diodes) with dc voltage present.

Input Impedance of Transistor Amplifiers and Other Active Circuits

The 1650-B can be used to determine the input impedance of transistor amplifiers and other active circuits. Consider the bootstrapped emitter-follower circuit of Figure 3a. The ac input resistance is measured and found to be about 760 kilohms, but the null is not sharp, indicating a large reactive component. A capacitor inserted between the OPP ARM jack and the case improves the balance, indicating that the input impedance is inductive. Finally, measurement on the series inductance bridge, with Orthonull, yields an inductance value of 4.92 henrys and a Q of 0.041, which corresponds to a series resistance of 755 kilohms, agreeing with the ac resistance measurement. Knowledge like this is invaluable in explaining the behavior that results when this ampli-



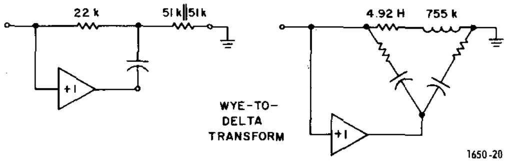
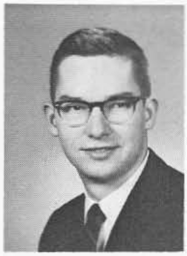


Figure 3a((left). Bridge can be used to determine input impedance of transistor amplifiers such as the bootstrapped emitter follower shown here. Figure 3b (right). A redrawing of the circuit of Figure 3a, showing why the input appears inductive.

fier is incorporated in a large circuit. Figure 3b shows why the input looks inductive.

In general, it is desirable to monitor the output voltage from an active circuit with an oscilloscope to ensure linearity. The oscillator level control can be decreased to prevent overdriving the active circuit.



Charles D. Havener joined GR in 1965, after receiving his B.E.E. and M.E.E. degrees from Cornell. As a development engineer in the Impedance Group, he has worked chiefly on bridge design. He is a member of IEEE and Eta Kappa Nu.

Measurement of Transistor h Parameters

All the complex hybrid parameters of a transistor for the equivalent circuit of Figure 4 can be measured with a 1650-B and an easily constructed test jig. The hybrid π model is in vogue these days, but its parameters are calculated in part from h_{ie}, h_{oe}, h_{fe}, and h_{re}; it is thus still necessary to measure these h parameters. The four-terminal parameters, h_{re} and h_{fe}, must be calculated from impedance values measured with the base ac-shorted to the collector or the emitter. This all may sound a little troublesome, but in practice the measurements go very smoothly. (Further details will appear in a future issue of the *Experimenter*.)

These measurements have proved quite accurate as verified by comparison with measurements made on other testers and by a computer simulation of an amplifier designed to emphasize the measured h parameters. The computed frequency response agreed with that measured within a few dB to 100 kHz when the capacitance in parallel with h_{ie} was included in the model.

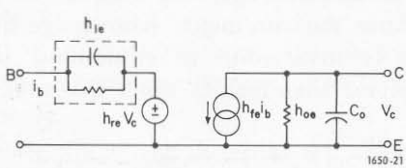


Figure 4. h-parameter equivalent circuit of a transistor.

Ac resistance measurements are also useful for determining the approximate magnitude of a completely unknown impedance, for measuring conductivity of solutions (where dc would polarize the electrodes), and for making incremental resistance measurements on nonlinear components (diodes, thermistors, etc).

Student Use of the Bridge

The universal impedance bridge has long been a mainstay of the student laboratory. In recognition of this fact, the latest in our series of Student-Experiment pamphlets is devoted entirely to the use of the 1650-B by students. Publication STX-107, "The Universal Impedance Bridge," discusses the principle and techniques of bridge measurement and includes some suggested student experiments. It is free on request.

— C. Havener

Catalog Number	*Description*	*Price in USA*
	1650-B Impedance Bridge	
1650-9702	Portable model	**$450.00**
1650-9703	Rack model	**450.00**

Detailed specifications on the 1650-B Impedance Bridge appear in General Radio Catalog T