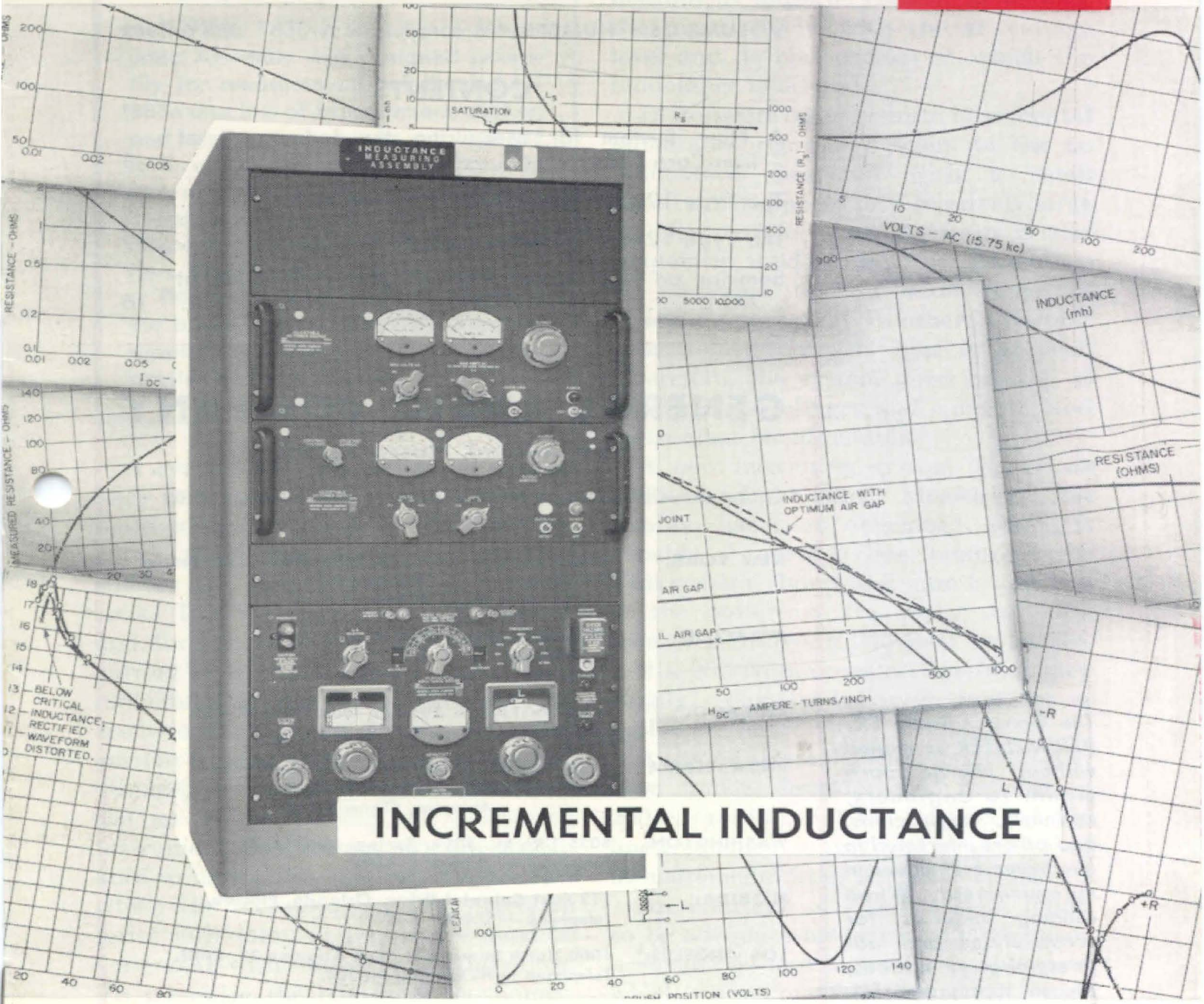
THE GENERAL RADIO EXPERIMENTER



INCREMENTAL INDUCTANCE

VOLUME 36 No. 5 MAY, 1962

IN THIS ISSUE

New Incremental-Inductance Bridge with Power Supplies

THE GENERAL RADIO EXPERIMENTER

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A NEW SYSTEM FOR MEASURING THE INDUCTANCE OF IRON-CORE COILS

The TYPE 1630-A Inductance Measuring Assembly was designed primarily for measurements of the inductance and loss of transformers, chokes, and similar components at high dc and ac excitation levels. Easy to operate and flexible in application, it can also measure other nonlinear elements such as Zener diodes, rectifiers, thermistors, and lamps.

This article describes the design of the bridge and its associated power supplies and shows a number of examples of measurements.

A system for measuring the inductance and loss of coils with ferromagnetic cores is necessarily more complicated than the simple bridge that suffices for measurements on air-core coils. The iron-core coil is nonlinear, and, for a sinusoidal applied voltage, the current will contain harmonics. Since inductance is usually defined with respect to the fundamental component of current flowing with a sinusoidal applied voltage, for meaningful measurements the ac source driving the measuring instrument must have a very low impedance to harmonics, and any impedances which the measuring system places in series with unknown impedance must be very small with respect to the unknown. To minimize the effects of harmonics, the detector must be sharply tuned to the fundamental frequency. In addition, because the inductance is a function of the applied ac voltage, dc bias current, and previous history of the core, the instrument must be capable of making the measurement with the ac voltage level and dc bias current at which the inductance is desired.

In iron-core coils the term incremental inductance rigorously refers to the ac inductance measured with a small signal superimposed on a relatively large dc bias current,[1] but the term is also frequently used to describe inductance as measured over a wide range of ac and dc excitation. In other important measurements no dc bias is applied. Therefore, the system must be able to handle high voltages and currents, and these must be adjustable.

A new measuring system, the TYPE 1630-AL Inductance Measuring Assembly, has been developed, which is capable of meeting these requirements. This system, shown in Figure 1, operates at the power-line frequency and consists of a bridge, a 200-watt dc source, and a 200-voltampere ac line-frequency supply. The bridge unit includes a null detector.

A second assembly, the TYPE 1630-AV, now under development, includes a 200-va audio oscillator in place of the line-frequency supply and is capable of measurements from 20 cps to 20 kc.

An accuracy of 1% has been found to be adequate for practically all measurements on ferromagnetic components, which makes possible the use of a convenient single-dial readout for inductance and another for series resistance or Q.

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[1] F. E. Terman, *Radio Engineering*, 3rd Edition, McGraw-Hill, 330 West 42nd St., New York 36, N. Y.

Many other nonlinear elements present the same measurement problems as iron-core coils, and the Type 1630 assemblies are well suited to measurements on such components as Zener diodes, rectifiers, neon lamps, incandescent lamps, and thermistors.

THE BRIDGE CIRCUIT

The Type 1633-A Incremental-Inductance Bridge, the main element in the measuring system, uses a new circuit, which includes active elements,[2] in order to achieve important operational features. The active elements are three multistage, transistor, feedback amplifiers, designed to have parameters at least an order of magnitude more stable than is required for the desired bridge accuracy. Two amplifiers are used for isolation and a third for a phase inversion. Figure 2 is the elementary bridge schematic.

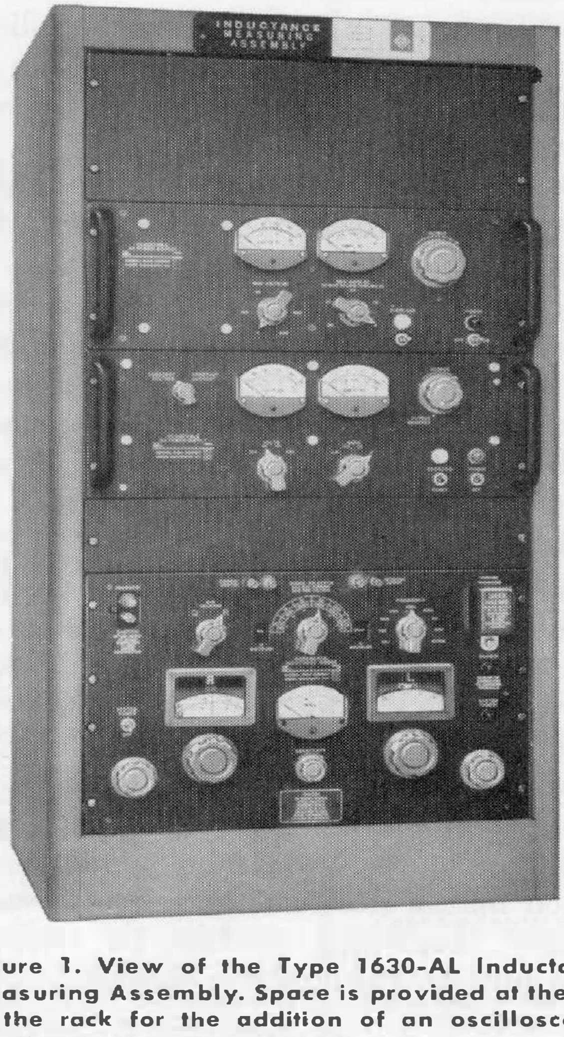

Figure 1. View of the Type 1630-AL Inductance Measuring Assembly. Space is provided at the top of the rack for the addition of an oscilloscope, which permits the current waveform or the hysteresis loop to be viewed during the measurements.

Each isolation amplifier is used with a potentiometer to form a variable-voltage source with a low output impedance. This permits the use of fixed capacitance and conductance standards, C_S and Q_S, because the current through these impedances is adjusted by variation of the voltage applied to them, rather than by variation of their magnitudes. Thus, both adjustments are simple, easily balanced potentiometers rather than multiple decade assemblies. The negative-gain amplifier on the right-hand side of the bridge converts the voltage from the resistive divider into a current of opposite phase, which is required for a bridge balance.

Null Conditions

The equation for null can be easily obtained by setting the sum of the currents into the detector equal to zero (Figure 2). If we let R'_B equal the total resistance to ground from point B, including R_F, then

$$\frac{I_1 + I_2 + I_3 + I_4}{E_{\mathrm{IN}}} = \frac{R'_B}{R'_B + R_X + j\omega L_X}\left(\frac{1}{R} + \alpha j\omega C_S + \alpha\beta G_S\right) - \frac{R_D}{R_E(R_C + R_D)} = 0$$

where α and β are the ratios of potentiometer output voltage to input voltage,

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[2] H. P. Hall, R. G. Fulks, "The Use of Active Devices in Precision Bridges," *Electrical Engineering*, May 1962.

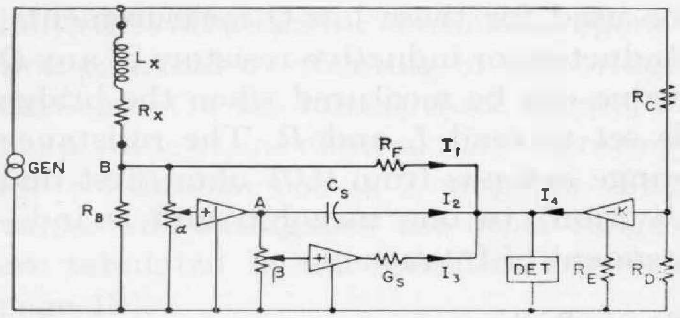

Figure 2.
Simplified schematic of the bridge.

or $\frac{1}{R_F} + \alpha j\omega C_S + \alpha\beta G_S =$

$$\frac{R'_B + R_X + j\omega L_X}{R'_B} \times \frac{R_D}{R_E(R_C + R_D)}$$

If

$$\frac{1}{R_F} = \frac{R_D}{R_E(R_C + R_D)},$$

then

$$L_X = \frac{\alpha C_S R'_B R_E(R_C + R_D)}{R_D}$$

$$R_X = \frac{\alpha\beta G_S R'_B R_E(R_C + R_D)}{R_D}$$

$$Q_X = \frac{\omega L_X}{R_X} = \frac{\omega C_S}{\beta G_S}$$

The unknown inductance is proportional to the value of α, and the dial of the α potentiometer is calibrated to read L. For the connection shown in the schematic, Q_X is inversely proportional to β, so that the dial on the second potentiometer reads Q_X. However, if this potentiometer is connected to point B instead of point A, α disappears from the equation for R_X, making resistance proportional to β, and the dial therefore reads R_X.

Advantages of the New Circuit

This circuit has several advantages over conventional Maxwell or Owen bridges as ordinarily used for this measurement.

1. Both balance controls are single-dial potentiometers permitting rapid balances.
2. The bridge reads either R_X or Q_X directly. A measurement in terms of R_X is desirable for low-Q values where the Q arrangement has a bad "sliding null" (slow balance convergence).
3. The bridge can read Q directly, with no multiplying factor, at several frequencies if the value of G_S is switched as the operating frequency is changed.
4. The voltage and current applied to the bridge and the unknown inductor are constant as the balance adjustments are made. This is a valuable feature in the measurement of nonlinear devices.
5. The generator and detector are both grounded, avoiding the need for bridge transformers that may be susceptible to magnetic pickup.

The use of active elements, which make possible these features, may bring to the minds of some readers a host of difficulties long associated with vacuum-tube amplifiers, particularly those employing little feedback. However, such problems as gain stability, life, hum, noise, excess heat, and warmup time can be completely eliminated or greatly reduced by the use of multistage, transistor, feedback amplifiers. When one thinks of the high precision and reliability of the operational amplifiers used in modern analog computers, one wonders why they have not been used more extensively in bridge circuits.

Ranges and Accuracy

The arrangement of the panel controls is shown in Figure 3. The six ranges of inductance are more than adequate for practical measurements at any given frequency. Moreover, the standard capacitor, C_S, is switched by the frequency-selector switch so that the inductance range is changed to give reasonable values at the various operating frequencies. For example, the inductance range extends up to 1,000 henrys on the four lower frequency positions, but an inductance of this size would surely be above resonance at 1 kc, so that the maximum range is 100 henrys at 1 kc and is reduced to 10 henrys at 10 kc. This shift in range permits measurements down to 0.1 μh at the higher frequencies.

The bridge reads *R* or *Q* as selected by the panel control. The *Q* scale is direct reading at nine frequencies, which include common power frequencies and their second harmonics, as well as other standard test frequencies. The *Q* range is ∞ to 1, below which a bothersome sliding null occurs; the *R* scale should be used for these low-*Q* measurements. Inductors or inductive resistors of any *Q* value can be measured when the bridge is set to read *L* and *R*. The resistance range extends from 0.01 ohm (first dial division) to one megohm and is independent of frequency.

Power Ratings

The maximum current and voltage that may be applied depend upon the value and power rating of, respectively, the bridge resistor (R_B) in series with the unknown and the other resistor (R_C) adjacent to the unknown. The resistance R_B should be as low as possible for low dissipation, and low compared to the reactance of the unknown inductor for minimum waveform distortion, but is also limited to reasonable values by sensitivity and lead-resistance considerations. In this bridge, R_B has a rating of 100 watts, but the power dissipation is

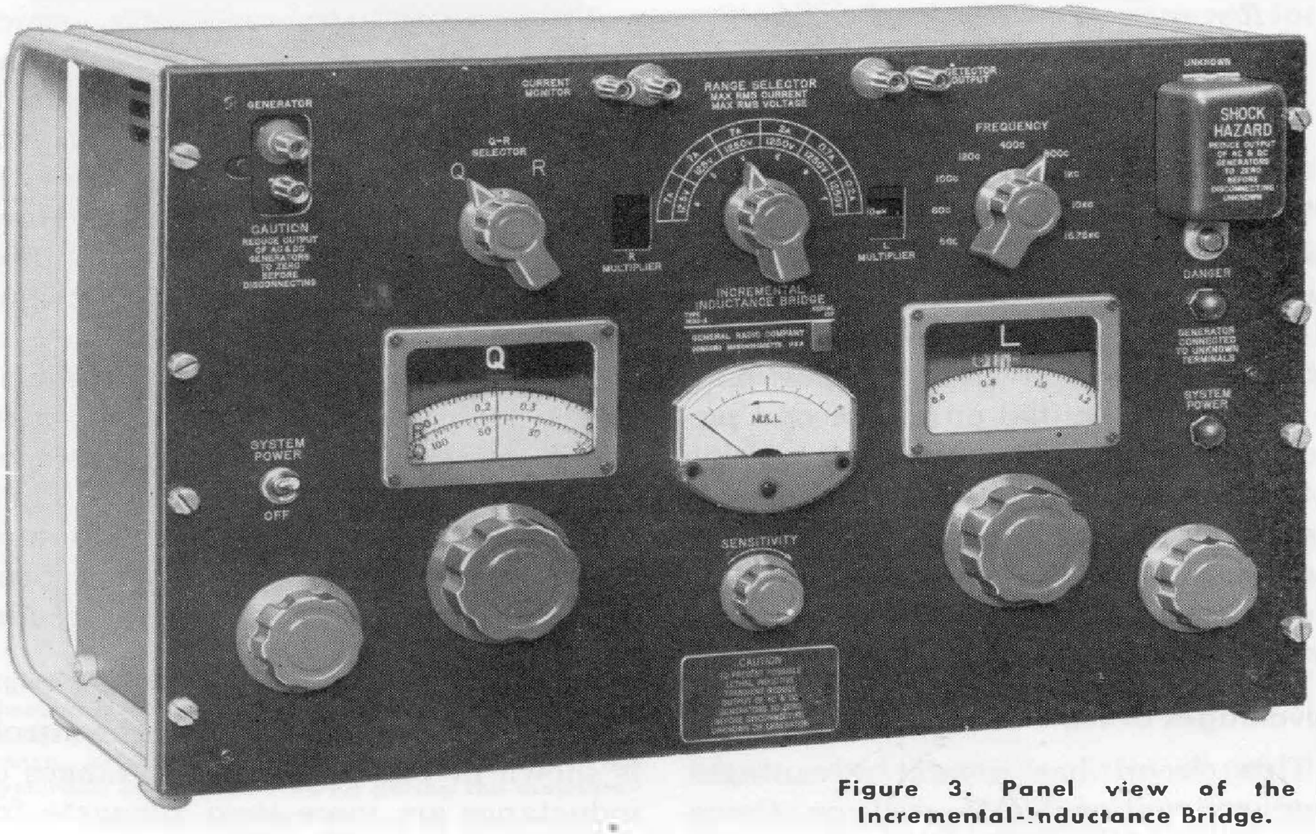

Figure 3. Panel view of the Incremental-Inductance Bridge.

limited to 50 watts for continuous operation to avoid overheating of the bridge elements. On the lowest three ranges, it has a value of one ohm, so that the rating for continuous use is 7 amperes. The values and ratings for the other ranges are tabulated in the specifications (see page 13).

The highest voltage that can be applied is determined by R_C. On the four highest inductance ranges it has a value of one megohm and permits 1250 volts to be applied to the bridge. On the lower ranges, where the impedance of the unknown inductor is lower, current rating is the more important, and the voltage decreases, becoming 12.5 volts on the lowest range.

For those applications requiring more than 7 amperes, the TYPE 1633-P1 Range-Extension Unit,* which contains a 0.1-ohm resistor, can be externally connected to shunt R_B on the three lowest bridge ranges; the inductance and resistance values are then reduced by a factor of 10. With this resistor, measurements up to 50 amperes, ac or dc, are possible.

The Internal Detector

Measurements on nonlinear impedances require the use of a highly selective detector because the large harmonic signals developed are not nulled at the fundamental balance. When magnetic circuits are highly saturated, it is possible to have harmonics as large as the fundamental itself and therefore approximately 40-db rejection would be necessary for a balance of 1%. Even more rejection is desirable.

The detector in this bridge was designed to meet these requirements. It is selective at the nine fixed frequencies at which the bridge Q scale is direct reading. Two cascaded, active, RC, selective amplifiers are used to obtain a second-harmonic rejection of 60 db. When measurements at other test frequencies are required, an external null detector should be used. The TYPE 1232-A Tuned Amplifier and Null Detector is recommended. This detector has a 35-db second-harmonic rejection, which is adequate for most measurements. However, if a given test frequency is to be used often, it is not difficult to change the detector and the bridge circuit to obtain selectivity and a direct Q reading at the desired frequency.

Due to high detector sensitivity and low noise, measurements can be made at excitation levels below one volt on the high inductance ranges and below 10 millivolts on the lowest range. Hence, on any range, the ac excitation can be varied over a span of more than 1200 to 1.

An additional detector feature is the high degree of amplitude compression, which makes repeated gain-control adjustments unnecessary.

THE COMPLETE SYSTEM

In the complete measuring system the ac supply, a dc supply, and the bridge are connected in series as shown in Figure 4. Descriptions of the two supplies now available are given elsewhere in this issue.

In Figure 4 the output circuit of each power supply is shown in greatly simplified form, to indicate the path of the high dc and ac excitation currents. Each supply is capable of passing the maximum current available from the other. The rms sum of the maximum dc and ac currents (5 amperes each) is equal to the

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*Available on special order.

rated bridge current of 7 amperes. It should be noted that the maximum power rating of the bridge is 1250 volts at 7 amperes or 8750 voltamperes, far greater than the output of these 200-watt power supplies. Users who require power of this magnitude will presumably construct their own power supplies.

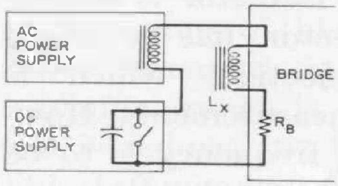

Figure 4. Simplified diagram of the system high-current circuit.

The ac voltage applied to the inductor should be as sinusoidal as possible. If the unknown inductor is nonlinear, the current will be distorted, and the series impedance in the loop must be low to avoid subtracting a large distorted voltage from the generator signal. Therefore, the output impedance of the Type 1266-A Adjustable AC Power Source and the ac impedance of the Type 1265-A Adjustable DC Power Supply have been made very low. Resistor R_B is also in this loop, but in most cases it is much smaller than the unknown impedance and is usually smaller than the winding resistance of the coil being measured. On the other hand, the dc applied should be from a constant current source. Current, rather than voltage, is the variable that should be controlled, because it determines the dc ampere turns (magnetic field intensity, H) applied. When the inductor dissipates a large amount of dc power, it will heat up, and its winding resistance will increase. The dc supply is therefore current regulated to keep the applied current constant.

Protective Devices

Because the bridge is designed to measure inductors in which the stored energy can be very large, a number of features have been incorporated to protect the equipment and to alert the operator to possible danger. The most prominent among these is a hinged cover over the UNKNOWN terminals. A lock on this cover is mechanically connected to a switch that shorts the generator terminals to ground (through a 1-ohm, 50-watt resistor). Thus, any current in the unknown inductor is discharged harmlessly before the operator disconnects the unknown. A panel light under the UNKNOWN terminals indicates when the generator is *not* shorted.

The SYSTEM POWER switch controls the power to two receptacles on the rear panel of the instrument, so that the bridge and its ac and dc generators can be conveniently controlled by the same switch. In this way the generators are also prevented from supplying power when the bridge power and warning light are turned off.

If the generator is disconnected with current flowing in the circuit, the induced voltage transient is applied directly across the bridge. Thyrite varistors have been included to limit this voltage and to help prevent damage to the bridge.

APPLICATIONS

The wide impedance, signal, and frequency ranges over which the Type 1633-A Incremental-Inductance Bridge is useful suggest many applications. The major use is undoubtedly the measurement of iron-core* components, but there are many other important applications in the measurement of nonlinear resistances.

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*The term "iron-core" as used here includes all types of ferromagnetic cores.

Iron-Core Components

The ability of this bridge to operate with almost any generator waveform and at high power levels makes possible the measurement of an inductor, transformer, motor, or other electromagnetic device with the generator voltage either supplied by the circuit of the inductor or simulated by the bridge generators.

A dc power-supply filter choke provides a good illustration of this type of measurement. Since the resistors in the bridge circuit are arranged to cause very little extra loading of the generator, the bridge can simply be inserted in the leads of the choke in the power-supply circuit and be measured under the actual source and load conditions. Connections for a typical measurement are shown in Figure 5. Here the generator signal is a full-wave rectified sine wave. Since the sharply tuned detector discriminates against harmonics, the bridge can easily be balanced at the fundamental frequency of this waveform, which is twice the line frequency, or 120 cps. A plot of the measured inductance of a choke as a function of load current is shown in Figure 6. The actual measured points are indicated by crosses.

In order to provide a comparison, the generators of the Type 1630-AL Inductance Measuring Assembly were set up to measure the same choke with the same dc current and the same ac flux density (set on the ac supply) as in the above measurements. The rms fundamental component (120 cps) of the full-wave rectified sine wave is $\frac{2\sqrt{2}}{3\pi} E_{\text{peak}}$. To get the same flux density at 60 cps requires half this voltage. The points measured with the simulated generator are shown as circles in Figure 6. The difference between the two curves is very small except at low currents where the inductance is less than "critical,"[1] and the waveform in the full-wave case becomes distorted due to the discontinuous current in the choke. This measurement shows that the operating conditions can be duplicated without duplicating exactly the actual waveforms.

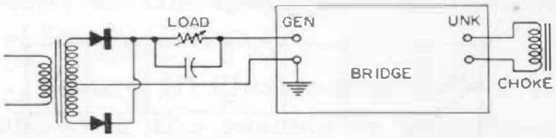

Figure 5. Circuit for measuring filter choke under load conditions.

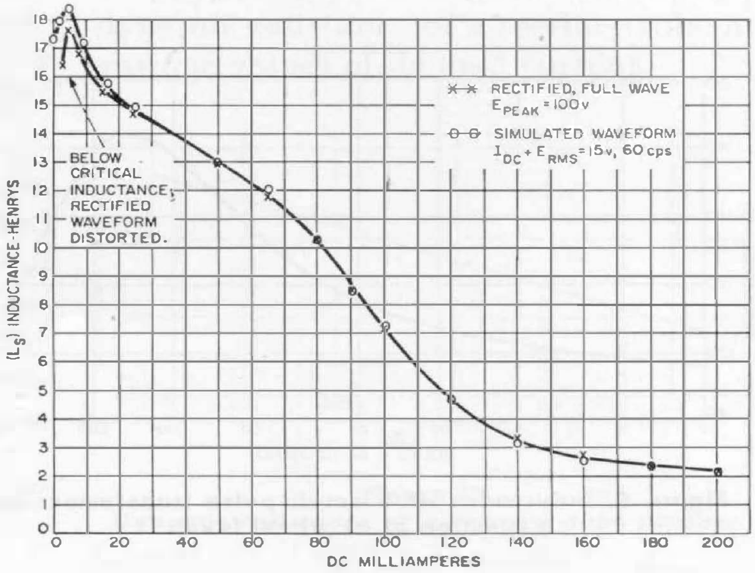

Figure 6. Plot of measured inductance of choke as a function of load current.

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[1] Op. cit.

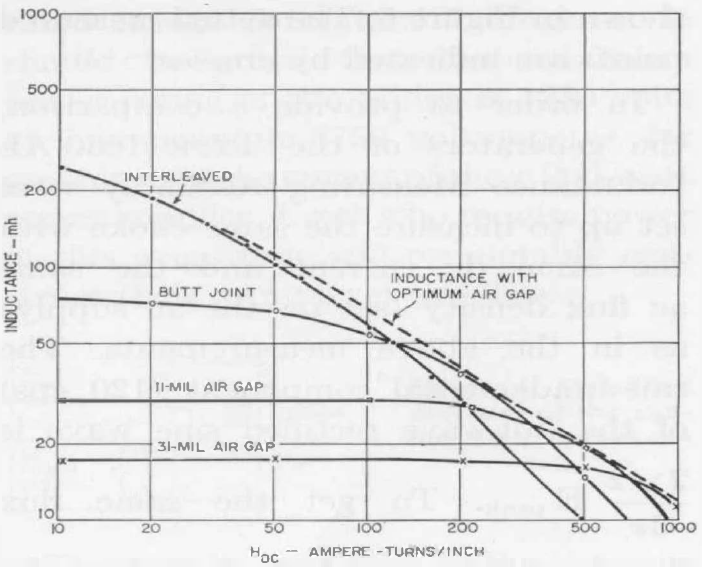

Figure 7. Inductance of choke as a function of dc amperes-turns with various air gaps.

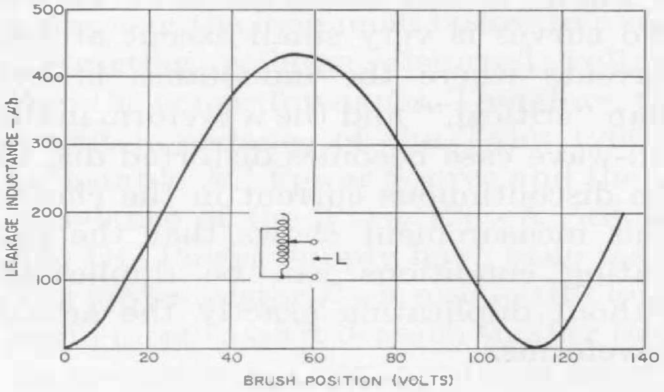

Figure 8. Leakage inductance of a Type W50 Variac Autotransformer at 50 amperes.

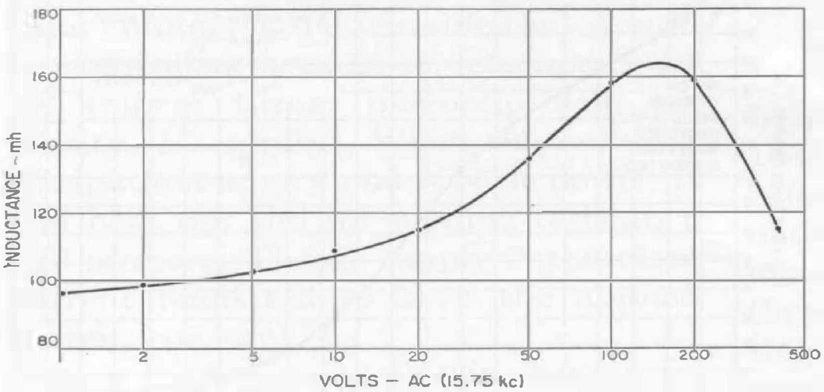

Figure 9. Inductance of a small pulse transformer as a function of ac signal level.

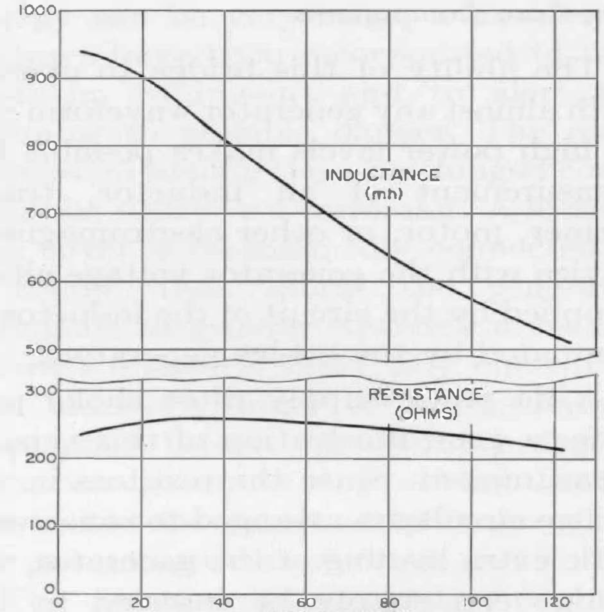

Figure 10. Measured inductance and resistance of the control winding of an ac servomotor.

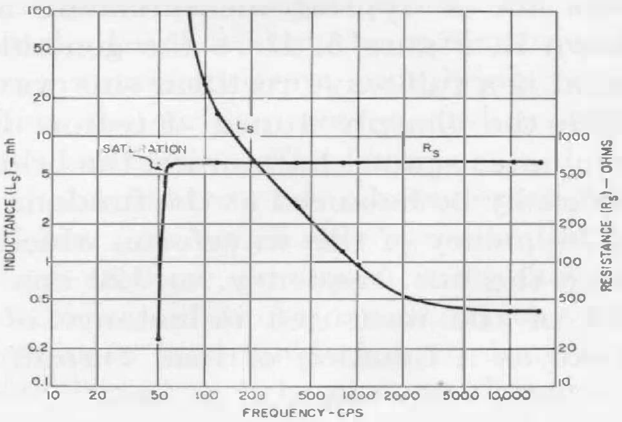

Figure 11. Input impedance of a loaded audio-frequency transformer.

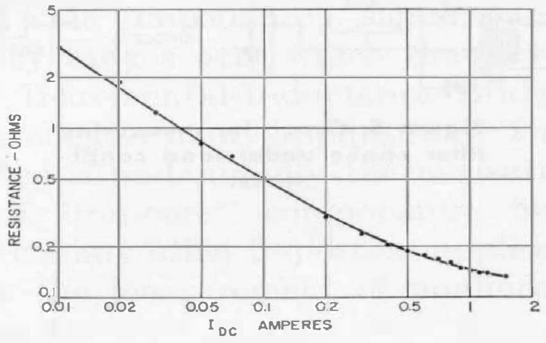

Figure 12. Zener diode: dynamic impedance.

A power-supply choke usually has an air gap in the magnetic circuit to prevent the core from saturating. With a given core, coil, and dc current, there is an optimum air gap for maximum inductance. A systematic procedure for the design of such inductors has been described by C. R. Hanna[3] and is widely used. The measurements required for such a design can easily be made with the Type 1630-AL assembly. An example showing the inductance of a coil *vs* direct current with several air-gap sizes is shown in Figure 7. The locus of the optimum-gap inductance values is shown by the dotted line. Figure 8 shows a measurement at high current. Data for this curve of the leakage inductance of a Type W50 variac® Autotransformer were taken at 50 amperes, with the Type 1633-P1 Range-Extension Unit shunting the internal bridge resistor (R_B).

There are many measurements at low signal levels where the ability to set the signal to a known value independent of the balancing procedure is necessary. Figure 9 shows the inductance of a small pulse transformer measured at 15.75 kc as a function of ac signal level. This frequency position was included in the bridge frequency calibration for measurements on the magnetic components used in the horizontal circuits of television receivers.

Figure 10 illustrates another example showing the measured inductance and resistance of the control winding of a small ac servomotor. From such measurements it is a relatively simple matter to determine the value of series capacitors necessary to give any desired phase relationships at a particular operating point. It also indicates the load on the servoamplifier.

Another useful application of the bridge is in the measurement of loaded transformers of high power rating. Figure 11 shows the input-impedance components of an audio-frequency transformer terminated in its normal load.

AC Resistance Measurements

An important group of applications comprises ac resistance measurements on level-sensitive components. A typical example is the measurement of the dynamic impedance of Zener diodes, in which a small ac signal is superimposed on a dc bias current. For this measurement the bias current is supplied by the Type 1265-A DC Power Supply and the ac signal by the Type 1266-A AC Power Source. A dc voltmeter across the Zener diode measures the breakdown voltage at the test current. An example of this measurement is shown in Figure 12.

A similar measurement is that of the dynamic forward impedance of rectifiers. This information is useful in the voltage and regulation calculations in the design of power supplies. Figure 13 shows a dynamic resistance of a rectifier tube at various values of dc load current.

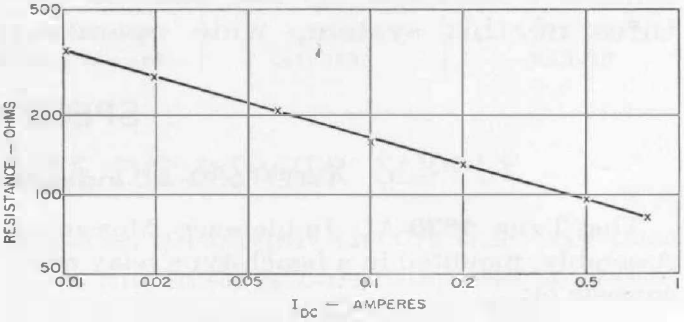

Figure 13.
Dynamic resistance of a vacuum-tube rectifier.

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[3] C. R. Hanna, "Design of Reactances and Transformers Which Carry Direct Current," *Journal of AIEE*, February 1927, pp 5-8.

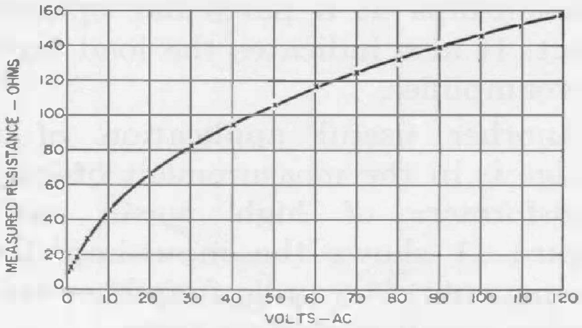

Figure 14. Dynamic resistance of a 100-watt lamp.

Lamp bulbs and thermistors are often used in controlled applications where their resistance is a function of the power applied. The peak current surge when incandescent lamps are turned on can be calculated from the knowledge of the cold resistance of the lamp. A plot of the resistance of a 100-watt, 110-volt lamp bulb is shown in Figure 14.

Figure 15 shows the dynamic inductance and resistance of a neon lamp. The negative resistance was measured by adding sufficient series resistance to make the sum positive. The effective inductance is due to the ionization time of the gas.

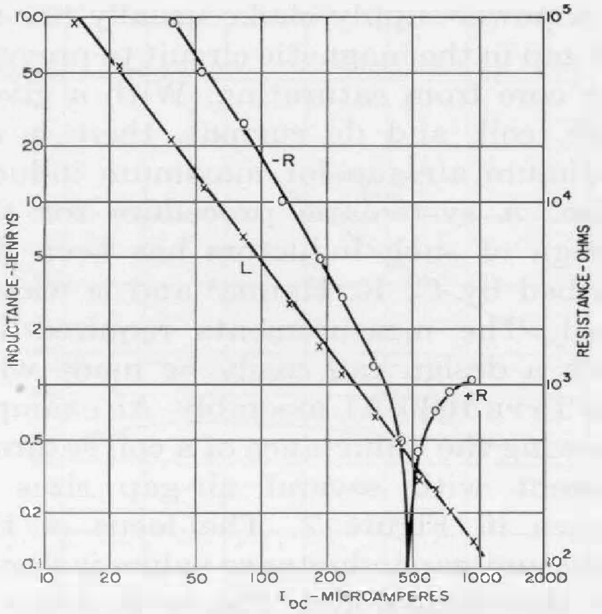

Figure 15. Dynamic inductance and resistance of a neon lamp.

From these examples it is evident that the TYPE 1630-AL Inductance Measuring Assembly will satisfy most of the requirements for measurements on nonlinear components having resistive or inductive impedances. The unusual features of this system, wide operating ranges, easily set signal levels, and simplicity of operation, are intended to take the measurement of nonlinear components out of this special-measurements class and put them in the category of general-purpose measurements.

— R. G. FULKS

— H. P. HALL

CREDITS

The TYPE 1633-A Incremental-Inductance Bridge was developed by R. G. Fulks and H. P. Hall. R. A. Soderman, Administrative Engineer; H. C. Littlejohn, Design Engineer; J. E. Norton, Layout Draftsman; W. H. Higginbotham, Production Engineer; D. B. Bradshaw, Test Engineer, and S. P. Roberts, Engineer, have all contributed to the final design.

— Editor

SPECIFICATIONS

TYPE 1630-AL Inductance Measuring Assembly

The TYPE 1630-AL Inductance Measuring Assembly, mounted in a bench-type relay rack, consists of:

TYPE 1633-A Incremental-Inductance Bridge
TYPE 1265-A Adjustable DC Power Supply
TYPE 1266-A Adjustable AC Power Source

A connecting cable is supplied.

Type		*Code Word*	*Price*
1630-AL	**Inductance Measuring Assembly. . . . .**	CANON	**$2300.00**

SPECIFICATIONS (Continued)

TYPE 1633-A Incremental-Inductance Bridge

	Frequency	Full-Scale Ranges						Smallest Division
		a	b	c	d	e	f	
L	50c, 60c, 100c, 120c	10 mh	100 mh	1 h	10 h	100 h	1000 h	20 μh
	400c, 800c, 1 kc	1 mh	10 mh	100 mh	1 h	10 h	100 h	2 μh
	10 kc, 15.75 kc	100 μh	1 mh	10 mh	100 mh	1 h	10 h	0.2 μh
R	all	10 Ω	100 Ω	1 kΩ	10 kΩ	100 kΩ	1 MΩ	10 mΩ
Q	all	∞ — 1 Direct Reading at Above Frequencies						$Q = 1000$
	Max rms volts	12.5	125	1250	1250	1250	1250	
	Max rms amp*	7	7	7	2	0.7	0.2	

*Maximum rms current $= \sqrt{I_{dc}^2 + I_{ac}^2}$

ACCURACY

Inductance: ±1% of reading or 0.1% of full scale, $\pm \left(\frac{2\pi}{100} \times \frac{f_{kc}}{Q_x}\right)\%$.

Resistance: ±2% of reading or 0.1% of full scale, $\pm \frac{Q_x f_{kc}}{2\pi}\%$.

$\frac{1}{Q}$: ±2% or 0.001.

INTERNAL DETECTOR

Frequency: Selective at any one of nine specific frequencies, accurate to ±1%, 50, 60, 100, 120, 400, and 800 cps, and 1, 10, and 15.75 kc.

Response to Second Harmonic: Approximately 60 db below fundamental.

GENERAL

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cps; power consumption, approximately 6 watts.

Accessories Supplied: One TYPE CAP-22 3-wire Power Cord and spare fuses.

Accessories Required: Generator to cover desired ranges of frequency and power, and a source of dc bias current (if desired).

Accessories Available: TYPE 1265-A Adjustable DC Power Supply (200 watts); TYPE 1266-A Adjustable AC Power Source (200 voltamperes).

Mounting: Relay-rack panel in aluminum cabinet. End frames are supplied with bench models.

Dimensions: Bench model, width 19, height 12¾, depth 10¼ inches (485 by 325 by 260 mm), over-all; rack model, panel 19 by 12¼ inches (485 by 315 mm); depth behind panel, 8¾ inches (225 mm).

Net Weight: 31 pounds (14.5 kg).

Type		*Code Word*	*Price*
1633-AR	**Incremental-Inductance Bridge, Rack Mount.**	ABYSS	**$925.00**
1633-AM	**Incremental-Inductance Bridge, Bench Mount**	AUGER	**925.00**

THE TYPE 1265-A ADJUSTABLE DC POWER SUPPLY

The characteristics required for dc power supply for use with the incremental-inductance bridge are somewhat specialized and are not met by available units of conventional design. Among them are wide ranges of current and voltage, an output circuit that will pass high alternating currents, and a choice of voltage or current regulation.

The TYPE 1265-A Adjustable DC Power Supply, a completely solid-state design, includes these features. The in-

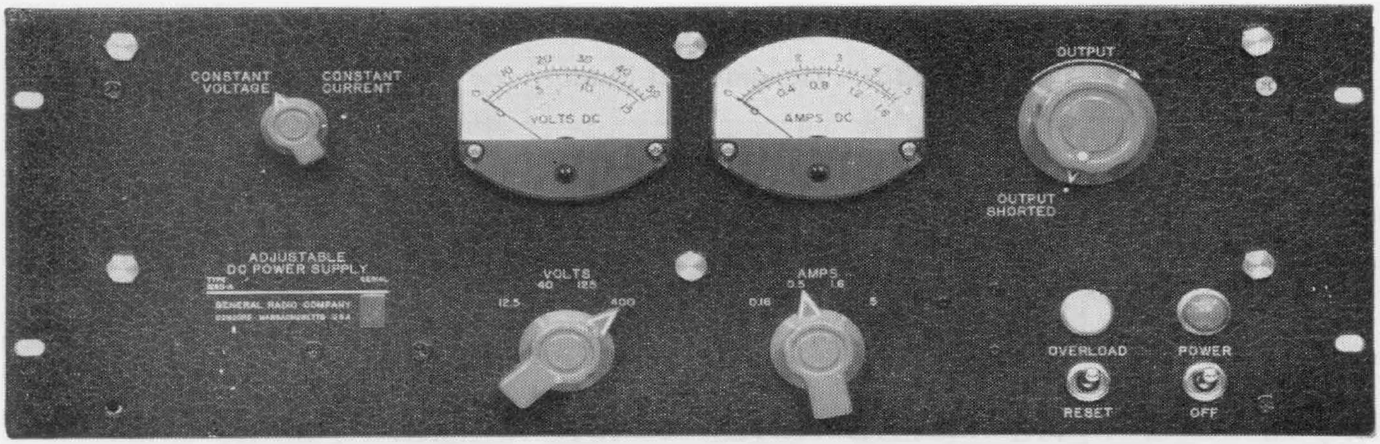

Figure 1. Panel view of the Adjustable DC Power Supply.

strument has four voltage ranges and four current ranges (see specifications below), and it will deliver its maximum rated power of 200 watts to not just one optimum resistance but to 8 ohms, 80 ohms, or 800 ohms.

A conventional regulated supply has a low ac output impedance obtained by large feedback. As a result, this impedance is low over only a limited dynamic range and only a relatively small ac current can be passed through the output. In applications where ac and dc must be combined to form a composite signal, a passive, low ac impedance is much more attractive.

The elementary diagram of the TYPE 1265-A is shown below. It shows the control loop used for regulation. Either the output voltage or current is sampled, amplified, and then used to control the conduction angle of two power-transistor trigger circuits used as controlled rectifiers. These rectifiers control the current into the output transformer whose several taps provide a choice of output voltages. The selected voltage is rectified and then filtered by components that are switched with both the voltage and current range adjustments in order to keep the output-circuit time constants independent of range. It should be noted that the output is sampled before the filter. Except for losses in the filter, which are compensated for, the dc voltage and current are the same on either side of the filter. Putting the sampling elements before the filter avoids the impossible stability problem that would arise from having the filter and the load (which could have any impedance) in the control loop.

Other important features are voltage and current metering, a mechanical connection between switches that prevents switching to range combination over 200 watts, and a trigger circuit that prevents damage to the instrument from overloads.

— H. P. HALL

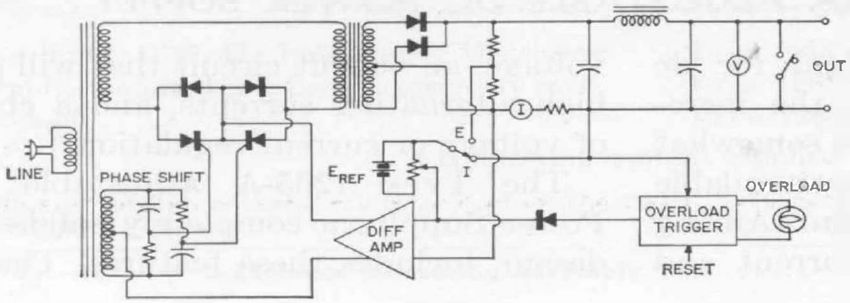

Figure 2. Simplified schematic of the dc power supply.

SPECIFICATIONS

Full-Scale Output Ranges: 12.5, 40, 125, 400 volts, dc; 0.16, 0.5, 1.6, 5 amperes, dc; in any combination up to 200 watts.

Meters: Voltage and current; ranges are switched with output ranges.

Overload Protection: Overload circuit trips at approximately 1½ times full-scale current.

Regulation: (Voltage or current) 0.2% for 20% of line-voltage change; 1% for 100% load change.

Speed of Response: Approximately 0.1 second.

Hum Level (rms): Approximately 70 db below full scale dc output (60 db on 12.5-volt, 5-ampere range).

Accessories Supplied: TYPE CAP-22 3-Wire Power Cord and spare fuses.

Dimensions: Bench model, width 19, height 7½, depth 17¼ inches (485 by 190 by 440 mm), over-all; rack model, panel 19 by 7 inches (485 by 180 mm), depth behind panel, 15 inches (385 mm).

Net Weight: 70 pounds (32 kg).

Type		*Code Word*	*Price*
1265-AR	**Adjustable DC Power Supply, Rack Mount . .**	ABASE	**$875.00**
1265-AM	**Adjustable DC Power Supply, Bench Mount .**	BAIZE	**875.00**

THE TYPE 1266-A ADJUSTABLE AC POWER SOURCE

The TYPE 1633-A Incremental-Inductance Bridge requires relatively large amounts of alternating and direct-current power and the bridge and power sources must tolerate alternating and direct currents, simultaneously.

The TYPE 1266-A Adjustable AC Power Source has been designed to meet these specific requirements. Six voltage ranges and five current ranges are selected by rotary panel switches, mechanically interlocked to interdict any combination that might exceed the 200-voltampere capacity of the supply. Voltage, in each range, is continuously adjustable from zero to the maximum value selected, by means of a VARIAC® adjustable autotransformer. Meters are

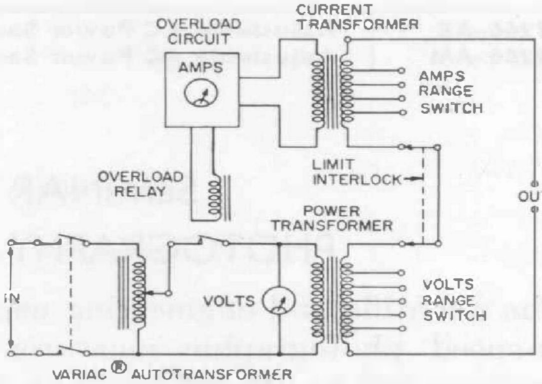

Figure 2. Simplified schematic of the ac power source.

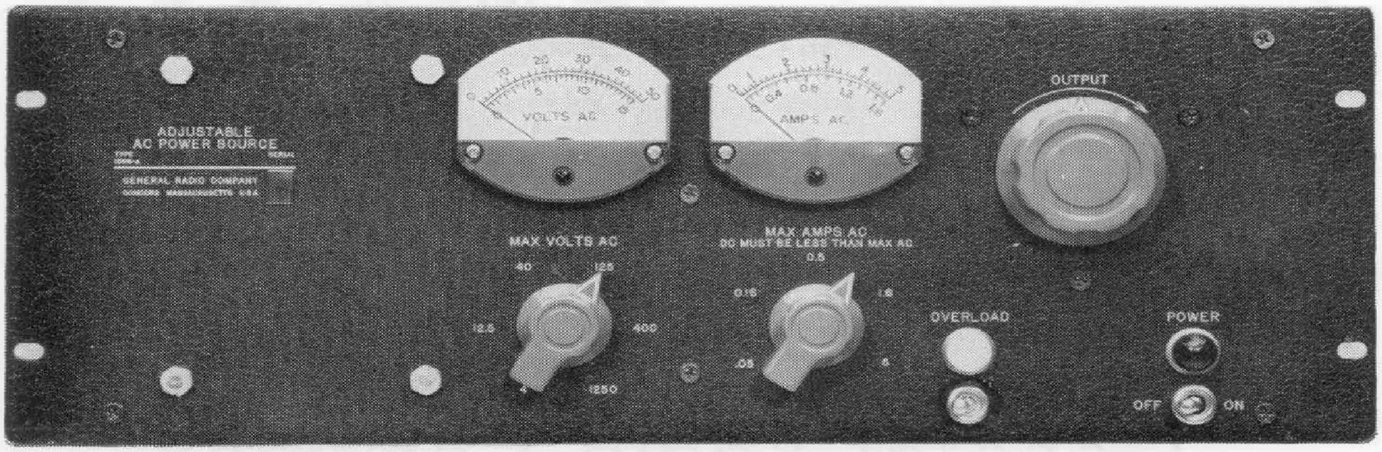

Figure 1. Panel view of the Adjustable AC Power Source.

provided for both voltage and current. An automatic trip circuit, with manual reset, protects the source against unintentional overload. The transformers are designed to tolerate a direct current at least as great as the maximum alternating current for the range selected.

These characteristics will be found useful wherever an adjustable 200-voltampere, 60-cycle power source is required.

— GILBERT SMILEY

SPECIFICATIONS

Frequency: Power-line frequency (50 to 60 cps).

Full-Scale Output Ranges: 4, 12.5, 40, 125, 400, 1250 volts, rms; 0.05, 0.16, 0.5, 1.6, 5 amperes; in any combination up to 200 voltamperes.

Dc currents up to the rated ac current may be superimposed on output from external source.

Meters: Voltage and current; ranges are switched with output ranges.

Overload Protection: Overload circuit trips at approximately 1½ times full scale of current meters; can be reset by panel switch.

Accessories Supplied: TYPE CAP-22 3-Wire Power Cord and spare fuses.

Dimensions: Bench model, width 19, height 7½, depth 17¼ inches (485 by 190 by 440 mm), over-all; rack model, panel, 19 by 7 inches (485 by 180 mm), depth behind panel, 15 inches (385 mm).

Net Weight: 46 pounds (21 kg).

Type		*Code Word*	*Price*
1266-AR	Adjustable AC Power Source, Rack Mount . . .	CANDY	$345.00
1266-AM	Adjustable AC Power Source, Bench Mount .	BAFFY	360.00

SEMINAR ON HIGH-SPEED PHOTOGRAPHY TECHNIQUES AT M.I.T.

The scientific and engineering uses of high-speed photographic measurement techniques will be the subject of a one-week seminar at the Stroboscopic Light Laboratory, Massachusetts Institute of Technology, starting Monday, July 16.

Both theory and laboratory practice will be covered.

Subjects include pulsed stroboscopic lighting, optical high-speed cameras, Kerr cells, Faraday shutters, image converters, etc.

The program is under the direction of Professor Harold E. Edgerton of the Department of Electrical Engineering at M.I.T.

For further information inquire from the Office of the Summer Session, Room 7-103, M.I.T., Cambridge 39, Massachusetts.

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