the GENERAL RADIO Experimenter

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VOLUME 30 No. 2 **JULY, 1955**

THE TYPE 1603-A Z-Y BRIDGE

A New Approach to Audio-Frequency Impedance Measurement

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Anyone who has balanced an impedance bridge has probably experienced the frustration of trying to measure an impedance outside the range of the available bridge. The losses in the unknown may be too great, its impedance too high or too low; whatever the reason, the null balance cannot be obtained. Combining the unknown with another impedance element may be the solution; sometimes another instrument is available; but as often as not the measurement is abandoned without any useful information being obtained.

The new Type 1603-A Z-Y Bridge possesses the almost unbelievable characteristic that it can be balanced for *any* impedance connected to its terminals. From short circuit to open circuit, real or imaginary, positive or negative, a bridge balance can be obtained with ease. Clearly, high accuracy cannot be maintained over an infinite range. Nevertheless, good accuracy is obtained over a very wide range and, even in the ranges approaching zero impedance or zero admittance, the ability to get an answer of any kind is often very valuable.

The customary types of impedance bridges, Maxwell, Hay, Schering, etc., evaluate, more or less directly, the inductance or capacitance of an unknown

Figure 1. Panel view of the Type 1603-A Z-Y Bridge.

circuit element together with its resistance, Q, or dissipation factor. Determination of the corresponding reactance or susceptance values of the unknown then requires a computation in terms of the angular frequency ω.

The new bridge is designed for the audio-frequency range, nominally from 20 cycles to 20 kilocycles. It measures directly the quadrature components of a complex impedance $Z = R + jX$, or a complex admittance $Y = G + jB$. The unknown Z or Y may lie in any of the four quadrants of the complex plane since this bridge can measure both *positive* and *negative* values of R and G as well as X and B.

The basic circuit is the familiar resistance-capacitance bridge but is used here in a manner which is believed to represent an entirely new approach to the impedance measurement problem at audio frequencies. It bears, however, a family resemblance to the radio-frequency bridge described by Sinclair.[1,2]

Theory of the Bridge Network

The Z-Y bridge employs a substitution technique whereby an initial balance, without the unknown element, is followed by a final balance with the unknown in circuit. The difference in setting of the controls between these two balances measures the complex components of the unknown. Bridge balance is attained by the adjustment of a pair of resistive elements, one in each of two opposite bridge arms.

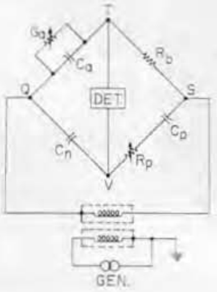

Figure 2. Basic bridge network.

Figure 2 shows the basic bridge network in which the balancing controls are the rheostats R_p, calibrated in ohms of resistance, and G_a, calibrated in mhos of conductance. If R_{p1} and G_{a1} are their initial balance values, the equations for this preliminary balance are:

$$R_{p1}C_n = R_bC_a \tag{1}$$

$$G_{a1}R_bC_p = C_n \tag{2}$$

It will be seen that this initial balance is independent of frequency and, furthermore, will have no sliding zero, since neither of the balancing controls occurs in both equations.

For measuring its impedance, the unknown $(Z = R_x + jX_x)$ is inserted in series into the P arm of the bridge between R_p and the bridge vertex V. The final bridge balance then yields the new values R_{p2} and G_{a2}. It follows that the unknown resistance is given by:

$$R_x = R_{p1} - R_{p2} = \delta R_p \tag{3}$$

at all frequencies. Note that R_x can be negative if R_{p2} exceeds R_{p1}. The unknown reactance

$$X_x = \mathrm{K}(G_{a1} - G_{a2}) = \mathrm{K}(\delta G_a) \tag{4}$$

where the bridge constant

$$\mathrm{K} = \frac{\mathrm{R}_b}{\omega C_n} \tag{5}$$

The unknown reactance is inductive if G_a is decreased in the final balance, or capacitive if G_a is increased.

For measuring its admittance, the unknown $(Y = G_x + jB_x)$ is connected across the A arm of the bridge in parallel

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[1] Sinclair, D. B., "A Radio-Frequency Bridge for Impedance Measurements from 400 Kilocycles to 60 Megacycles," *Proc. IRE*, Vol. 28, p. 497, November, 1940.

[2] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Megacycles," *General Radio Experimenter*, Vol. XVII, No. 3, August, 1942.

with G_a and C_a. The final balance yields the new values G_{a3} and R_{p3} so that the unknown conductance:

$$G_x = G_{a1} - G_{a3} = \delta G_a \tag{6}$$

at all frequencies and can be negative if G_{a3} exceeds G_{a1}. The unknown susceptance

$$B_x = \frac{R_{p3} - R_{p1}}{\mathrm{K}} = \frac{\delta R_p}{\mathrm{K}} \tag{7}$$

is inductive if R_p decreases or capacitive if R_p increases in the final balance.

Note that in the two types of measurement the functions of the two balance controls are transposed. In the measurement of Z, the change in R_p gives directly the real component R_x, and the change in G_a determines the imaginary component X_x, while in the measurement of Y, the change in R_p determines the imaginary component B_x and the change in G_a gives directly the real component G_x.

A given scale on the R_p control can obviously be made direct reading in both R_x and B_x by the proper choice of the bridge constant, K, Equation (5). Similarly the G_a control can be made direct reading in both G_x and X_x. Inspection of the equations shows that, if these common dial scales are to be calibrated in ohms and micromhos, the required value of K is 10^6. If *complete* coverage is desired, it follows that the resistance range must be the reciprocal of the conductance range. In the Type 1603-A Z-Y Bridge, K equals 10^6, and identical ranges of 1000 ohms and 1000 μmhos have been chosen for the complex parameters of the unknown. To permit measurement of positive and negative values of R_x G_x, X_x and B_x, initial balance must occur at mid-range of both control scales.

From equation (5) it is seen that the bridge constant, K, is a function of frequency. By means of a three-position switch, the fixed parameters of the bridge network are selected to keep each of the products R_bC_a and R_bC_p constant and, simultaneously, to give K a value of 10^6 for any one of three convenient reference frequencies: $f_o = 100$ c, 1 kc or 10 kc. When the bridge is operated at the corresponding reference frequency, the dial scale for the imaginary component will be direct reading in ohms or μmhos. The R and G scales are direct-reading at *any* frequency.

When the operating frequency, f, differs from the selected reference frequency, f_o, the imaginary components are given by:

$$X_x \text{ (in ohms)} = \frac{f_o}{f} \text{ } (\delta G_a \text{ in } \mu\text{mhos}) \tag{8}$$

$$B_x \text{ (in } \mu\text{mhos)} = \frac{f}{f_o} \text{ } (\delta R_p \text{ in ohms}) \tag{9}$$

A balance of this bridge can be obtained in terms of *impedance* at any given frequency, f, if R_x and $X_x\left(\frac{f}{f_o}\right)$ are *both* below 1000 ohms. If either of these quantities exceeds 1000 ohms, an *impedance* balance is impossible. However, by connecting the unknown in parallel in the A arm, an *admittance* balance can be obtained, as the following simple consideration will show. If either component of the complex impedance

$$R_x \pm \mathrm{j}X_x\left(\frac{f}{f_o}\right)$$

exceeds 1000 ohms, the scalar value of this impedance must exceed 1000 ohms, and the scalar value of the corresponding complex admittance, as well as each of its components, must be less than 1000 μmhos.

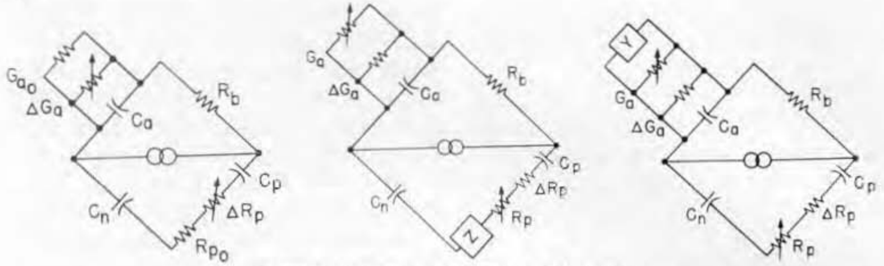


Figure 3. Normal operation of the Z-Y Bridge

Figure 3a. Initial balance obtained with controls ΔG_a and ΔR_p.

Figure 3b. Measurement of impedance. Final balance obtained with controls G_a and R_p.

Figure 3c. Measurement of admittance. Final balance obtained with controls G_a and R_p.

Conversely if *either* of the quadrature components G_x or $B_x\left(\frac{f_o}{f}\right)$ exceeds 1000 μmhos, an *admittance* balance is impossible, but an *impedance* balance can be made.

Thus either a Z or a Y balance is always possible and we have a truly universal bridge with an infinite range. The familiar equations for translating impedance to admittance components, or vice versa, can, of course, be used if desired.

In a given impedance balance it will be seen from Equation (8) that, if δG_a turns out to be less than 100 μmhos when f_o is 1 or 10 kc, a shift to the next smaller value of f_o will increase the required δG_a ten fold and thereby enhance the precision with which the reactance, X_x, is evaluated. Similarly, in a given admittance balance, Equation (9), if δR_p is less than 100 ohms when f_o is 100 c or 1 kc, a shift to the next larger value of f_o will increase the precision with which the susceptance, B_x, can be measured.

Conversely, an increase in f_o, if possible, may serve to bring within limits an "off-scale" value of X_x, while a decrease of f_o, if possible, may bring within limits an "off-scale" value of B_x.

Under these conditions, the f_o selector switch functions, in effect, as a multiplier for the X or B scale ranges, but *not* for the R or G scale ranges which are fixed at 1000 units each for all values of both f and f_o.

Operating Features

The user will appreciate the convenience of zero-centered scales on the two balancing controls which, in the final balance, read directly the values of δR_p and δG_a, and eliminate the subtraction indicated in the equations.

Each balance control consists of two separate rheostats. There are two *main* controls designated as G_a and R_p in Figure 3. These have identical linear scales, each zero-centered and calibrated to $\pm$1050 units in each direction to provide some desirable overlap. They are preset to their respective mid-scale values G_{ao} and R_{po} prior to making the initial balance with the two auxiliary controls ΔG_a and ΔR_p. Final balance is then made with the two main dials, which indicate directly the values of R_x (or G_x) and δG_a for Equation (8) (or δR_p for Equation (9)). The frequency ratios in these equations are indicated on the main dials.

In operation designated as *normal*, during the initial balance the two main control rheostats are removed from the circuit by switching and are replaced by two fixed resistors duplicating their mid-scale values G_{ao} and R_{po}, thus avoiding a preliminary centering of the main dials. This feature is a great convenience in making measurements over a range of frequency, since a quick readjustment of the initial balance can be made on the auxiliary dials for each new frequency.

If the Z or Y components of the unknown produce only small main dial displacements (readable with limited precision) in the final balance, a *reversed* operation technique can be used. In this case *all four* balance controls are in the circuit during the initial balance, which is made with the two main controls after the two auxiliary controls have been set to give the desired range of measurement. The final balance is then made solely on the two auxiliary controls whose incremental displacements, on expanded scales, permit more precise measurements.

For this purpose, the auxiliary dials are calibrated in the same units as the main dials and have full scale ranges of 120 units for ΔG_a and 140 units for ΔR_p. They are purposely made nonlinear to permit maximum precision in the measurement of a few ohms or a few micromhos.

By selecting the appropriate arrangement of the detector terminals of the bridge, the operator may measure: (1) the *grounded* Z or Y value of the unknown with one terminal grounded and the ground capacitance of its high terminal in parallel with the unknown element, (2) the *direct* Z or Y value with the ground capacitances of both terminals removed, or (3) the *balanced* value of Z or Y with both ground capacitances of the floating unknown element existing in delta across it. This valuable feature is not possessed by many types of impedance bridges.

The generator is isolated from the bridge network by an internal shielded transformer. (Fig. 2.) A similar external transformer (not provided) is required for the detector input if the balanced value of the unknown is desired. The Type 578 Transformer is recommended.

Figure 1 shows the panel arrangement of this bridge. The two G_a controls are on the left and the two R_p controls are on the right. Switching is arranged for maximum convenience, which permits the unknown to remain

Figure 4. Impedance components of "black box" as a function of frequency.

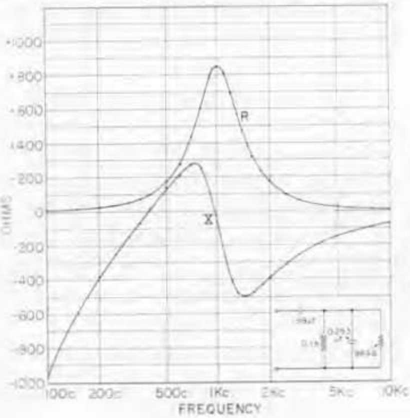
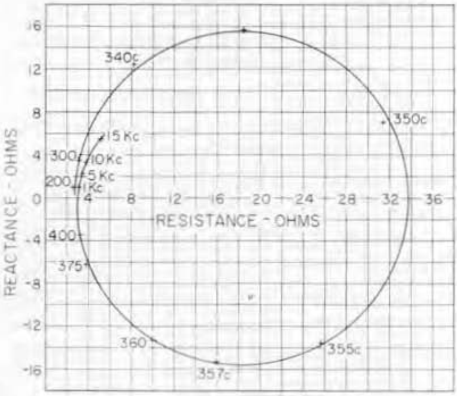


Figure 5. Reactance vs. resistance for a typical loud speaker.



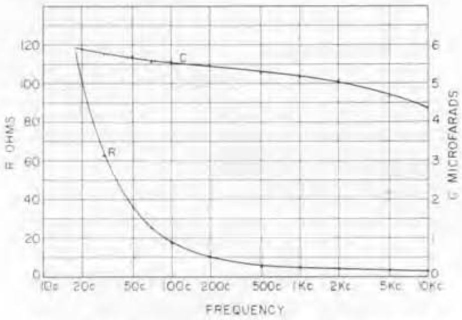


Figure 6. Impedance parameters of an electrolytic capacitor.

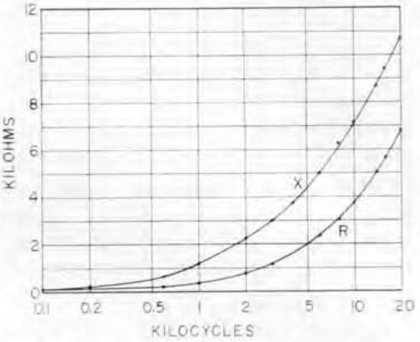


Figure 7. Impedance components of tape recorder head as a function of frequency.

attached to a single pair of terminals at all times. The function of the f_o selector switch (upper left on panel) has already been described. A six-position switch (upper right panel) provides for (1) normal initial, (2) reversed initial and (3) final balance for either Z or Y measurements. It disconnects the non-grounded terminal of the unknown for all initial balances. In addition, it shifts the bridge position of the unknown to permit Z or Y measurements, keeping the same unknown terminal grounded in all positions.

Residual Errors

Any impedance bridge is subject to certain residual errors because its resistive components cannot be made completely non-reactive, and its reactive components cannot be made to have zero losses. Furthermore, stray ground capacitance exists at each vertex of the bridge which is not directly grounded. This capacitance is not significant, of course, if the opposite vertex is grounded.

In this Z-Y bridge, see Figure 2, the bridge vertex V is grounded for impedance measurements, while the bridge vertex T is grounded for admittance measurements. Hence the residual ground capacitance at the vertex S appears across the P arm for Z measurements and across the B arm for Y measurements. To neutralize this capacitance, a small voltage of appropriate phase and magnitude is introduced at this junction S. The transformer capacitance and the ground capacitance of the vertex Q are in parallel with either C_a or C_n, where they are insignificant.

Other significant residual impedances are the small inductances of the windings of the two main rheostats. These have been neutralized at mid-scale and at the extreme scale limits by placing appropriate capacitors across each half of these rheostat windings. The remaining (reduced) errors reach a maximum at the ±500 scale points. Correction data, significant only at high frequencies, are supplied.

The over-all accuracy of measurement depends not only on the influence of bridge residuals but also upon the resolution of the control dials and on the sensitivity of the null detector. Since the bridge constant K is a function of frequency, it should be noted that the absolute values of a measured X_x or B_x, but not R_x or G_x, depend directly upon the accuracy with which the frequency, f, of the generator is known. Nominal accuracy of the bridge is ±1 %.

APPLICATIONS

This new and versatile bridge is simple, convenient and rapid in operation and should find many useful applications in addition to the obvious measurement of R, L and C components. Among these are:

A. The Typical "Black Box" Problem

The two-terminal circuit network, containing a resistor, an inductor and two capacitors, was measured as an impedance from 100 c to 10 kc. Figure 4 shows the variation of R and X with frequency.

B. Analysis of Electro-Acoustic Transducers

Figure 5 shows the unclamped impedance circle for a small 2-ohm, 2-inch loud speaker measured directly, without a transformer, and demonstrates a major acoustic resonance, without a baffle, at about 350 cycles.

C. LF Characteristics of Electrolytic Capacitors

Measured values for a small electrolytic capacitor, when translated into series resistance and capacitance, Figure 6, show the progressive drop of C with increasing f and the rapid rise in R below 400 cycles.

D. Tests for Linearity of Components

A frequency run of a tape recorder head, Figure 7, showed it to be nonresonant at least up to 20 kc.

E. Resonant Frequencies of Inductors and Transformers

Figure 8 shows the susceptance variation of a 5 henry inductor with increasing frequency. This inductor first became capacitive at f_1, reverted to inductive at f_2, and became capacitive again at f_3, which is not an exact harmonic of f_1.

F. Transformer Parameters

The open and short-circuited impedance of transformers can be measured thereby yielding leakage reactance, self and mutual inductance, and coefficient of coupling; for example, this bridge has been used to measure the leakage reactance of Variac® autotransformers.

G. Audio Transmission Networks

The input and output impedance of filters and other audio frequency trans-

Figure 8. Susceptance variation of a 5-henry inductor at frequencies where distributed cpacitance produces resonance effects.

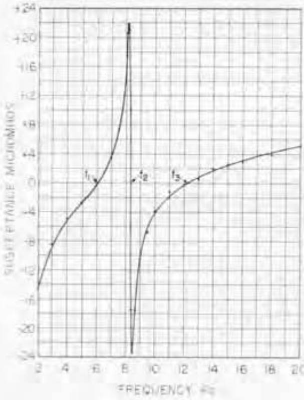
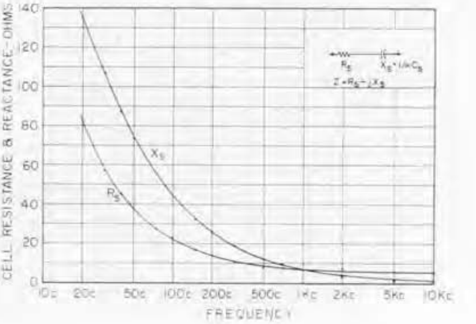


Figure 9. Impedance components of a Balsbaugh cell (110$\mu\mu$f empty) filled with tap water. Since the electrodes of this particular cell were not designed for use with water, the data are not indicative of the actual constants of the water, but are presented here only as an example of this type of measurement.



mission networks, together with their complex characteristic impedance, can be obtained.

H. IMPEDANCE OF BATTERIES

The internal impedance of batteries can be measured provided that their resistance is less than one kilohm.

I. CONDUCTIVITY OF LIQUIDS

This bridge should be particularly useful for measuring the a-c conductivity of electrolytic solutions. Irrespective of dielectric constant, the reactive component of the test cell impedance can be balanced. Figure 9 shows data taken on tap water using a Balsbaugh cell.

J. ELECTRO-CHEMICAL RESEARCH

Circular arc plots of solids or liquids having lossy polarizations in the audio-frequency range can be obtained. Data that have hitherto been difficult to procure in this region are now easily taken.

K. FEEDBACK LOOPS

The ability to measure a negative resistance with this bridge is illustrated by the data in Figure 10 which show the variation, with frequency, of the input impedance of an amplifier with cathode follower network.

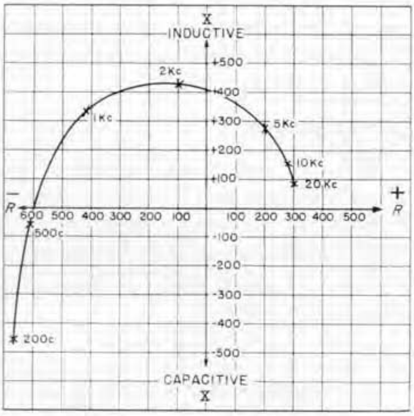


Figure 10. Input impedance of a feedback circuit showing negative resistance characteristic.

— IVAN G. EASTON

— HORATIO W. LAMSON

NOTE: The circuit and method of measurement for this bridge was devised by Ivan G. Easton, Administrative Engineer. Horatio W. Lamson, Engineer, collaborated in the final design. — EDITOR

SPECIFICATIONS

Frequency Range: 20 cycles to 20 kc.

Impedance and Admittance Range: If the absolute resistance is less than 1000 ohms and the absolute reactance is less than 1000 $\frac{f_o}{f}$ ohms, the unknown is measured as an impedance. If the absolute conductance is less than 1000 micromhos and the absolute susceptance is less than 1000 $\frac{f}{f_o}$ micromhos, the unknown is measured as an admittance. Under certain limited conditions, a choice of Z or Y measurements is possible.

Accuracy: For real components, R or G: $\pm(1\% + [2$ ohms or 2 micromhos$])$ for the main dials; components of less than about 100 ohms (or 100 micromhos) can be measured on the auxiliary dials within $\pm(1\% + [0.2$ ohm or 0.2 micromho$])$. For imaginary component, X or B: $\pm\left(1\% + \left[\frac{2f_o}{f}\text{ohm or }\frac{2f}{f_o}\text{ micromho}\right]\right)$ for the main dials; $\pm\left(1\% + \left[0.2\frac{f_o}{f}\text{ ohm or }0.2\frac{f}{f_o}\text{ micromho}\right]\right)$ for the auxiliary dials. To obtain this accuracy in the measurement of small quadrature components at the higher frequencies, correction data, supplied in the operating instructions, must be applied. The absolute measurement of X and B, but not R and G, involves the frequency error of the exciting generator.

Maximum Applied Voltage: 130 volts rms.

Accessories Required: A calibrated oscillator or other suitable a-c generator, and a null detector. The TYPE 1210-B Unit Oscillator and the TYPE 1212-A Unit Null Detector are recommended.

Accessories Supplied: 2 TYPE 274-NCO Shielded Cables, for connections to generator and detector.

Mounting: Aluminum cabinet and panel. Black crackle finish. Carrying handle provided.

Dimensions: Panel: (Width) 12½ × (height) 13½ × (depth) 8½ inches, over-all.

Net Weight: 21½ pounds.

Type		*Code Word*	*Price*
1603-A	**Z-Y Bridge**	CATER	**$335.00**

NEW PULSE AMPLIFIER INCREASES UTILITY OF UNIT PULSER

Designed primarily as a companion instrument for the Type 1217-A[1] Unit Pulser, the Type 1219-A Unit Pulse Amplifier offers a specific solution to the problem of producing pulses with many different characteristics of duration, duty ratio, and impedance level at higher power levels. In combination, the Unit Pulser and Unit Pulse Amplifier constitute a pulse generator approaching the wide range of durations and repetition rates characteristic of the Unit Pulser, but with the power-output characteristics usually associated with more expensive and specialized pulse generators designed to fit limited fields of application. Through the economies of standardized unit design, this versatile combination is lower in price than many narrow range pulsers designed for medium power output.

When it is driven by any available source of either positive or negative pulses, the Unit Pulse Amplifier will produce pulses of current with magnitudes up to 600 ma. This pulse of current can drive internal loads to produce either positive or negative voltage pulses, or can be used to drive a load external to the instrument. The internal load resistors are chosen to terminate a wide variety of transmission lines in their characteristic impedances.

General Design Considerations

The main objective in the design of the Type 1219-A Unit Pulse Amplifier was to obtain a maximum value of current into the load while retaining as many of the desirable wide ranges of duration and repetition rates of the Unit Pulser as possible. It was obvious at the outset that some maximum duty-ratio limitations had to be imposed if the amplifier were to produce a usefully high output power at moderate cost. A current between ½ and 1 ampere, giving an adequate voltage for direct deflection of a cathode-ray tube with the lowest normally encountered transmission-line terminating impedance, was desirable. General considerations of power supply design, economical packaging, heat dissipation, and vacuum-tube availability led to the final choice

Figure 1. Panel view of the Type 1219-A Unit Pulse Amplifier.

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[1] Frank, R. W., "Pulses in a Small Package", *General Radio Experimenter*, Vol. XXVIII, No. 10, March 1954, pp. 1–7.

of peak current as 600 ma for very low duty ratios and 500 ma for duty ratios in the neighborhood of 0.1. The maximum duty ratio was set at 0.2 by plate dissipation in the output stage.

The auxiliary considerations of drive, bandwidth, and output circuit were chosen to make the unit as universally applicable as possible. Minimum output impedance was set at 50 ohms, and convenient values of output impedance, ranging up to 150 ohms for positive output pulses and 570 ohms for the negative pulses, were provided by internal switching. With pulses of long duration and low values of output impedance, a capacitive output coupling system would be bulky and would limit the output voltages. To overcome this problem, the output switching system was designed to permit both negative and positive output pulses to retain their d-c component relative to chassis ground.

For maximum flexibility, provision is made for both positive and negative driving pulses. A panel switch connects an amplifier-inverter stage into the circuit when positive drive is used. With this arrangement, it is possible to drive the amplifier from almost any pulse source.

To increase further the flexibility of the instrument, a switch has been provided which will reduce the output current by a factor of approximately 2.5, so that it becomes possible to operate the instrument safely at duty ratios up to 0.5 with an output current of 200 ma. Two desirable features are gained by this mode of operation; it is possible to obtain a square-wave output, and the rise and decay times are improved.

Figure 2. The Unit Pulser and Unit Pulse Amplifier, as set up to pulse a Type 1218-A Unit Oscillator at 1400 megacycles.

As with any power amplifier where a maximum duty-ratio restriction is necessary to obtain the desired peak-power output, it is possible, by incorrect choice of the input time durations and repetition rates, to overload the output amplifier stage and therefore to damage it. The necessary protection for the output tubes and power supply is afforded by a 100-ma fuse mounted on the front panel. A neon panel lamp does double duty as pilot lamp and blown fuse indicator, since, in the event of a serious overload which will blow the fuse, the lamp is extinguished.

Circuits

The basic circuitry of the Unit Pulse Amplifier is conventional, as shown by the elementary schematic of Figure 3 and consists of a power stage using two paralleled 5763 power pentodes (V-3, V-4), a driver employing a Type 12AU7 (V-2), and, for positive input pulses, an amplifier-inverter stage (V-1). Two internal power supplies of 300 volts and 260 volts for the output tubes and drivers, respectively, are provided.

A single 12-position output switch, S-4, controls the internally available output impedances and output pulse polarity. Four positions of this switch select output pulses that are positive with respect to chassis ground at impedance levels of 50, 75, 100, and 150 ohms. In this class of operation the two output tubes are used as cathode followers, and their 300-volt power supply has its negative side on chassis ground. For pulses with negative polarity the remaining eight switch positions are used to provide internal loads with impedances ranging from 50 to approximately 570 ohms. The loads in this case are placed in the plate circuit of the 5763's, and the positive side of the 300-volt power supply is grounded to chassis. The output stage for negative pulses thus approaches a current source, and the output impedance is linear and independent of tube characteristics.

For negative pulse input, the input polarity switch connects the input terminals directly to the driver stage. In this use, the power amplifier is a two-stage unit and provides an output pulse of excellent shape (see Figure 4) in which the input pulse duration is faithfully reproduced. For a large-amplitude negative pulse, ultimate rise and decay times for the output stage are .050 and .030 μsec respectively. Pulses as brief as .050 μsec at the half-amplitude points have been faithfully reproduced. When the duty ratio switch is in the 0.5 position, the rise and decay times are improved to .030 and .020 μsec respectively (see Figure 7a).

The amplifier-inverter stage is connected to the input terminals and supplied with plate voltage when the input polarity switch is in the *Positive Input* position. This stage then provides a negative pulse to turn off the driver upon the application of a positive driving pulse. Some care must be exercised to preserve the good shape characteristics inherent in the driver-power amplifier system. An excessive positive driving amplitude will cause the output pulse to be stretched by up to 0.4 μsec and will cause a small hump of the order of 3% of the pulse amplitude to appear before the late transition (see Figure 7c).

Since the output system is direct-coupled, the input signals at the grid of the driver and amplifier must be applied through coupling capacitors. These signals must appear negative or positive with respect to the cathode potentials of either the driver or amplifier. If the input were applied relative to chassis ground rather than referenced to the negative supply, any noise or hum on this supply would add to the signal. This would unnecessarily complicate the design of the driver-power supply. Note that, in Figure 4, the input signals are referenced to the *driver supply* negative rather than to chassis ground by virtue of an insulated low input terminal. Best performance will always be obtained by floating the ground of the input system on this post. This does not preclude obtaining synchronizing

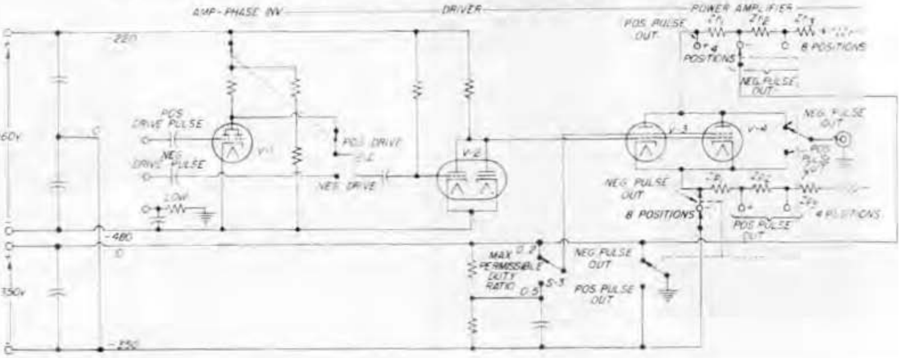


Figure 3. Elementary schematic circuit diagram of the Unit Pulse Amplifier.

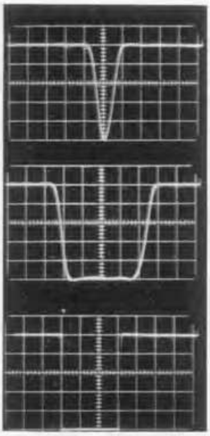


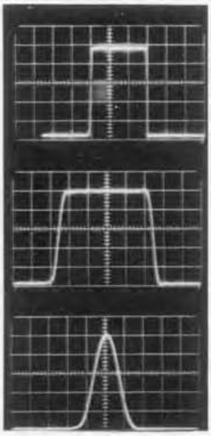
Figure 4

Negative output pulse

0.1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 0.1μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 0.5μsec

1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 3μsec

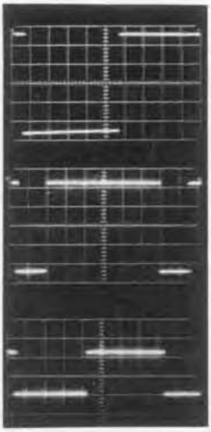


Positive output pulse

1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 3μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 0.5μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 0.12μsec



Negative output pulse

200μsec/cm P.R.F. = 200c
50Ω 25 volts T_p = 1000μsec
(Note slope of bottom)

133μsec/cm P.R.F. = 1kc
570Ω 270 volts T_p = 200μsec

1kc square wave
50Ω 10 volts

pulses, etc., from the driving source, since these signals are generally obtained through coupling circuits whose low-frequency impedance is negligible.

The two internal power supplies are of the full-wave-doubler variety, which make most efficient use of the power transformer copper and to which selenium rectifiers lend themselves so well. Large rectifier de-rating figures have been used to insure long life. Adequate filtering is provided by two-section R-C units for both driver and output supplies. The hum on the output pulse is less than 1%.

Some Notes on Operating Characteristics

In any specific use, careful consideration must be given to two important effects that are encountered with (1) pulses of high duty ratio and (2) pulses of long time duration. The characteristics of the TYPE 1219-A under these conditions are given in Figures 5 and 6 below.

Figure 5 shows the effect of high duty ratios on output current. This information is tabulated on the panel. The effect is due to power supply regulation, and it is an advantageous one because it permits a more economical use of the output tubes for the low duty ratios most commonly encountered. Without the protection of decreasing power supply voltage at higher duty ratios, either the range of duty ratios or the peak current at the lower ratios would have to be decreased.

Figure 6 shows the characteristics of the output pulse with regard to maximum permissible pulse durations for negative drive. Here the criterion selected was a droop of 10% in the "tube on" portion of the pulse. The ramp-off may be due to any one or a combination of three effects: (1) discharge of the internal power supply, (2) insufficient

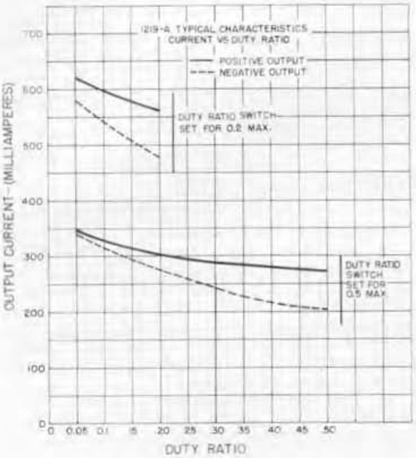


Figure 5. Effect of duty ratio on output current.

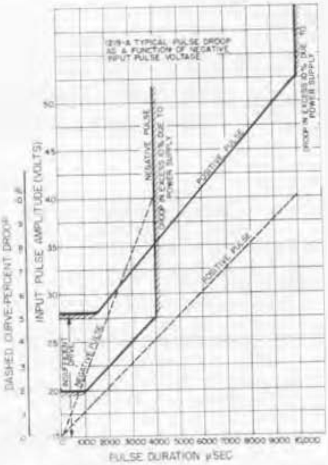


Figure 6. Output pulse characteristics as function of maximum permissible pulse duration.

driving amplitude which will cause the driver tube to come back on prematurely, or (3) a combination of low driving voltage with an external blocking capacitor in the driving pulse generator. Figure 6 shows that, with a driving voltage in excess of 27.5 volts, the first effect will predominate, and a ramp-off of 10% will be reached with an output pulse of 4000 µsec. The rate of ramp-off is very nearly linear so a 1000-µsec pulse will have a droop of 2.5% due to this effect, etc. (dotted curve). Interaction between the driver and main power supplies holds the droop for positive pulse outputs down, so that, with input amplitudes in excess of 55 volts, positive output pulses up to 10,000 µsec may be obtained. As the driving voltage is lowered below its maximum value, the effect due to discharge of the driver coupling circuit predominates, and the 10% ramp-off figure is reached sooner. For example, with only 25 volts available, the output pulse droops by 10% at 3000 µsec.

With positive input pulses, the driver stage supplies an adequate voltage to permit the maximum durations shown in Figure 6 to be reached.

Figure 7 illustrates two additional minor characteristics of the Pulse Amplifier which are of interest when the unit is used to produce brief pulses. The effects are time delay and a tendency for the input pulse to be stretched when the inverter-amplifier stage is overdriven by a positive input pulse. Figures 7, a and b, illustrate the time

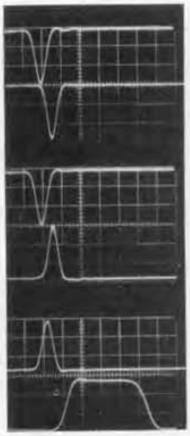


Figure 7
Time delay and overdrive effects

Input Neg.	50v		0.05µsec
Output Neg.	25v	50Ω	0.05µsec
Input Neg.	50v		0.05µsec
Output Pos.	20v	50Ω	0.05µsec
Input Pos.	50v		0.05µsec
Output Pos.	30v	50Ω	0.4µsec

(Note stretching caused by overdrive)

delay effect for both negative and positive outputs with a brief negative input pulse; the time delay through the Pulse Amplifier is of the order of 0.05 μsec. In Figure 7c, a high-amplitude positive pulse is used to overdrive the pulse input stage, and the output pulse is "stretched" by approximately 0.35 μsec. The stretching effect is reduced by reducing input amplitude.

— R. W. FRANK

SPECIFICATIONS

Output Pulse: The open-circuit output pulse voltage is between 10 and 250 volts and is the product of the combination of impedance and available current listed below.

(1) Impedance:

a. Positive pulse: 50, 75, 100, 150 ohms, all ±10%

b. Negative pulse: 50, 75, 100, 150, 200, 250, 300 ohms, all ±10%; 570 ohms ±20% designed to permit *maximum* output voltage.

(2) Output Current: This quantity depends upon the position of the duty-ratio selector switch and upon the duty ratio.

DUTY RATIO	**OUTPUT CURRENT (ma)**			
	POSITIVE PULSE		NEGATIVE PULSE	
	DR Sw 0.2	DR Sw 0.5	DR Sw 0.2	DR Sw 0.5
0.05	620 ±10%	350 ±15%	575 ±10%	330 ±15%
0.1	580 ±10%	325 ±15%	550 ±10%	300 ±15%
0.2	550 ±10%	300 ±15%	475 ±10%	275 ±15%
0.5	—	250 ±15%	—	225 ±15%

(3) Transition Times: The transition times depend on the transition times, magnitude, and polarity of the input pulse, as well as on the settings of the output impedance, polarity, and duty-ratio switches. These characteristics are summarized in the table below.

(4) Maximum Pulse Duration: The maximum duration of the pulse depends only on the tolerable ramp-off during the "on" period. If 10% is chosen, then the maximum "on" period for positive pulses is 10 mμsec and for negative pulses 4 mμsec; with the Type 1217-A, the maximum for negative pulses is 1 mμsec, for positive pulses, 10 mμsec.

(5) Pulse Shape: Overshoot less than 5% of amplitude on any output switch position.

(6) Noise: Hum on the output pulse less than 1% of pulse amplitude.

(7) Input Pulse: The maximum duration of the output pulse is to some extent determined by the input pulse voltage, and tolerable droop.

Input	MAXIMUM DURATION TO 10% DROOP	
	Positive Output	Negative Output
Negative 30 v	2000 μsec	4000 μsec
Negative 55 v	10,000	4000
Positive 10 v	10,000	6000

The droop is approximately linear, hence the

INPUT PULSE			OUTPUT CHARACTERISTIC				
			DUTY RATIO Sw 0.2		DUTY RATIO Sw 0.5		
Polarity	Amplitude	Rise and Decay Time	Rise Time	Decay Time	Rise Time	Decay Time	OUTPUT Switch
Negative	30 v	2 mμsec	50 mμsec	30 mμsec	40 mμsec	20 mμsec	Negative, 50 Ω
Negative	30 v	50 mμsec	50	50	60	50	Negative, 50 Ω
			100	100	30	90	Negative, 570 Ω
			80	80	60	70	Positive, 50 Ω
			180	110	110	80	Positive, 150 Ω
Negative	50 v	1217-A Pulser	60	90	40	80	Negative, 50 Ω
			100	120	90	110	Negative, 570 Ω
			90	120	70	100	Positive, 50 Ω
			180	160	120	130	Positive, 150 Ω
Positive	2.5 v	1217-A Pulser	60	240	40	160	Negative, 50 Ω
			110	240	80	160	Negative, 570 Ω
			90	180	90	120	Positive, 50 Ω
(Minimum necessary drive)			180	240	130	160	Positive, 150 Ω
Positive	25 v	1217-A Pulser	50	80	40	60	Negative, 50 Ω
			90	110	100	100	Negative, 570 Ω
			90	110	60	80	Positive, 50 Ω
(Pulse stretching 0.3 μsec)			180	150	110	110	Positive, 150 Ω

maximum durations for 5% droop are ½ the above figures.
Input Impedance: Approximately 50 kilohms shunted by 30 $\mu\mu$f.

Power Supply: 105–125 volts, 50–60 cycles.
Input Power: 75 watts, full load, 115-volt line.
Dimensions: (Width) 10½ × (height) 5⅝ × (depth) 6¼ inches over-all. **Net Weight:** 8½ lbs.

Type		*Code Word*	*Price*
1219-A	**Unit Pulse Amplifier**	ACRID	**$175.00**

U. S. Patent 2,548,457

A REGULATED POWER SUPPLY FOR UNIT INSTRUMENTS

To provide the ultimate in performance from General Radio Unit Instruments, a voltage-regulated power unit, the Type 1201-A Unit Regulated Power Supply, is now available.

Although the Type 1203-A Unit Power Supply is adequate for all normal uses of Unit Instruments, there are applications where maximum stability of oscillator output amplitude and frequency is required, where amplifier hum level or pulse jitter must be minimized, or where local line voltage fluctuates so badly that regulation is a necessity. For these and other critical applications, the new regulated power unit is well suited.

The Type 1201-A Unit Regulated Power Supply is identical in size and external construction to the Type 1203-A Unit Power Supply, so that the two are completely interchangeable mechanically for the operation of Unit Instruments. The regulated unit, however, is capable of furnishing higher output current with greatly reduced ripple and noise.

The circuit, shown in Figure 2, is that of a conventional series regulator, using a 5651-type voltage reference tube and a high-gain cascode amplifier.

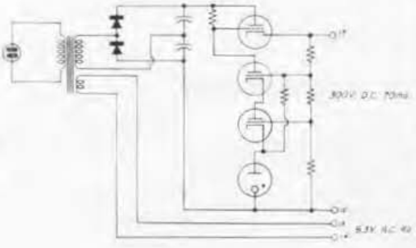
For critical applications, the use of the Type 1201-A Unit Regulated Power Supply will result in improved performance from GR Unit Instruments.

SPECIFICATIONS

High-Voltage Output:
Magnitude, 300 volts dc, ± 1%
Regulation, ± 0.5%
Current, 70 ma, max.
120-Cycle Ripple, 10 millivolts at full load
Heater Output: 6.3 volts, ac; 4 amp., max.; unregulated.
Input: 105 to 125 volts, 50 to 60 cycles, 100 watts.
Tubes: 1 — 12AX7 1 — 6AV5GT 1 — 5651
Dimensions: (Width) 5 × (height) 5¾ × (depth) 6¼ inches, over-all, not including power cord. **Net Weight:** 5 pounds.

Type		*Code Word*	*Price*
1201-A	**Unit Regulated Power Supply**	ASSET	**$80.00**

Figure 1 (right). Panel view of the Unit Regulated Power Supply. Figure 2 (below). Elementary schematic.




K. Adams


W. M. Ihde


R. E. Bard


W. R. Thurston


G. G. Ross


C.W. Harrison

NEW PHILADELPHIA OFFICE

In order to give better service to our customers in the Philadelphia and Camden areas, General Radio has opened a new branch office at 1150 York Road, Abington, Pennsylvania. Mr. Kipling Adams, for nine years manager of the Chicago office, is now manager of the new Philadelphia office.

Mr. William M. Ihde, who has been associated with our Chicago office for five years, becomes manager of the Chicago office and will be assisted by Mr. Robert E. Bard, who has for the past three years been on our Cambridge Sales Engineering staff.

OTHER BRANCH OFFICE CHANGES

Mr. William R. Thurston, well known in the New York area as manager of our district office and as Chairman of the Northern New Jersey Section of the IRE, is returning to the home office at Cambridge to assume new responsibilities with the Sales Engineering group.

Mr. George G. Ross becomes the new manager of the New York office. He will be ably assisted by Mr. C. William Harrison, who for the past two years has been a sales engineer at Cambridge.

NEW DISTRIBUTOR FOR ISRAEL

We take pleasure in announcing the appointment of the Landseas Products Corporation, 39 Broadway, New York 6, New York, as our exclusive representative for Israel.

It is expected that we shall be able to render the best possible service to our friends in Israel through the good offices of the parent concern and its resident branch, the Landseas-Eastern Company, P. O. Box 2554, Tel Aviv, Israel.

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PRINTED IN U.S.A.