the GENERAL RADIO Experimenter



Since 1915 – Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 32 No. 5 OCTOBER, 1957

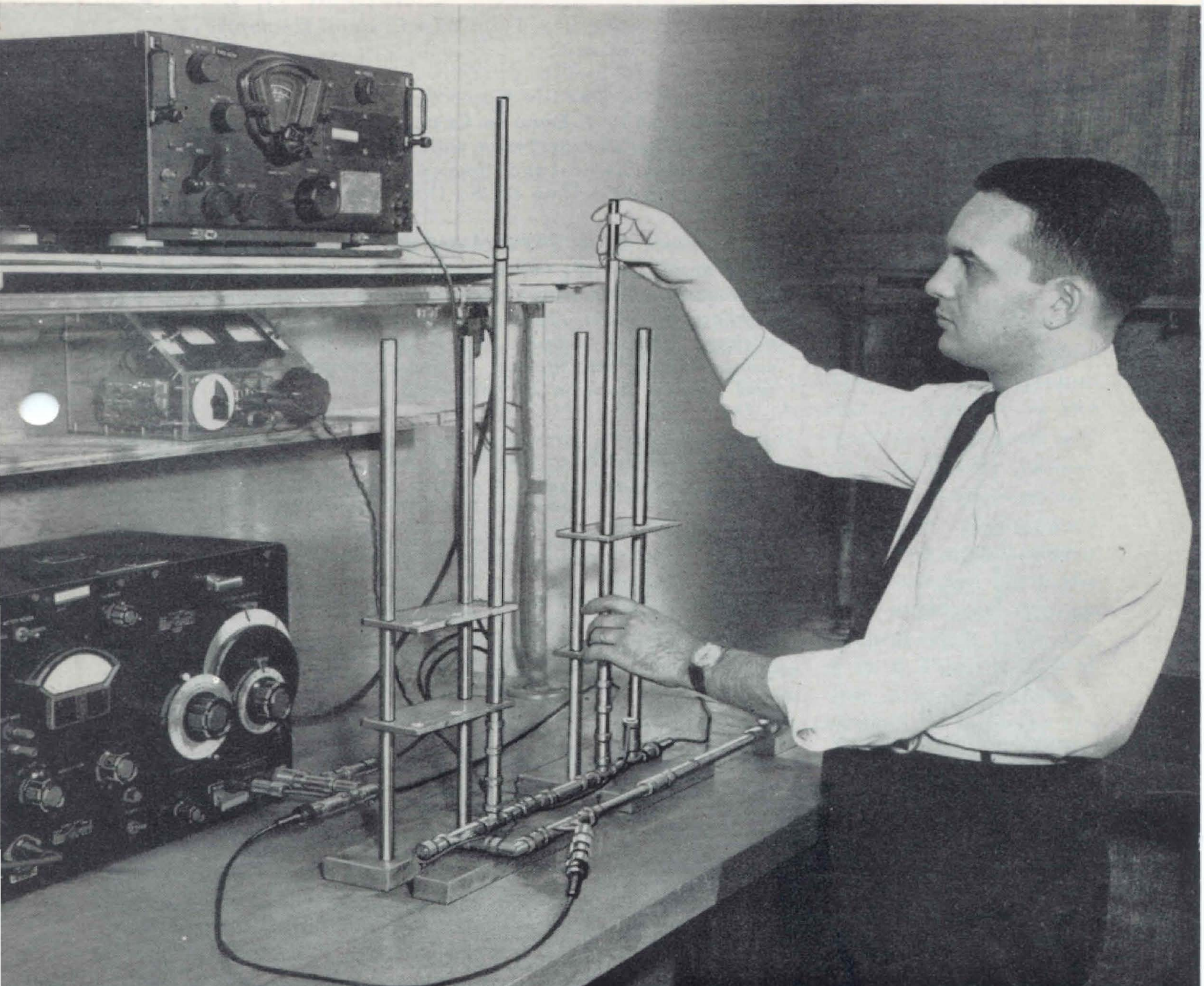

Photo Courtesy Philco Corporation

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the GENERAL RADIO Experimenter

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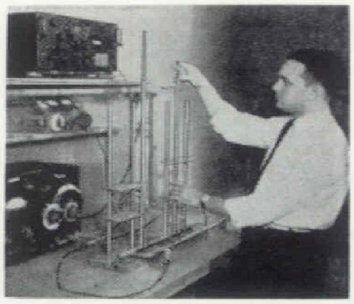
**COVER**



Mario Fortini of Philco Research Division measures transistor performance with Type 874 coaxial-line equipment.

# TRANSISTOR TESTING WITH TYPE 874 COAXIAL ELEMENTS

The excellent electrical properties and ease of interconnection of General Radio Coaxial Elements have led to their use in many specialized testing systems at very-high and ultra-high frequencies. An interesting example is their use by engineers of the Philco Corporation in the evaluation of the high-frequency capabilities of SBDT-12 graded-base transistors.* With this coaxial-line equipment, the transistors have oscillated at frequencies as high as 1100 Mc, as contrasted with an upper-frequency limit of 700 Mc in circuits using conventional lumped-constant elements. Excellent agreement has been obtained between measured results with the coaxial circuits and predictions of transistor performance based on conventional measurements at frequencies below 300 Mc.

The Type 874 Coaxial Elements have been used in the measurement of both gain and impedance, and in the determination of oscillation capability. Standard elements were used for the most part, although a few were modified for specific purposes. These modifications are detailed later in this article.

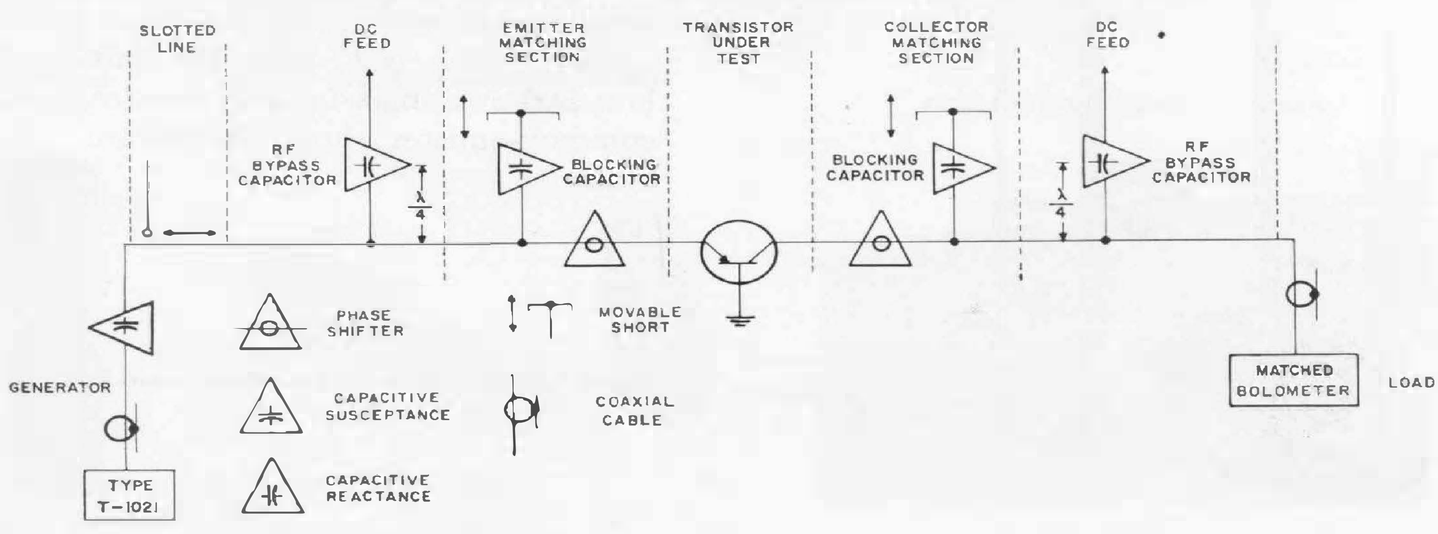
*This work was performed in the Philco Research Division, in a transistor applications group under the direction of James B. Angell, by Donald A. Zettel, a student of the cooperative program at the University of Detroit, working under the guidance of Mario M. Fortini. The work was supported in part by the Signal Corps under contract No. DA-36-039 SC-46040.

## U-H-F AMPLIFICATION

The technique for measuring the unneutralized gain of a graded-base transistor in a common-base connection is shown in Figure 1. The coaxial-line equipment consists of a transistor mount, input and output matching sections, and d-c supply paths for powering the transistor. Each matching section consists of an adjustable-length line and an adjustable shunt stub. Type 874-K Coupling Capacitors in the stubs prevent the stubs from short-circuiting the bias currents to ground. D-C power is applied by means of a feed-through capacitor, which serves as the short-circuiting end of a quarter-wave stub.

Gain is measured with a bolometer and power meter after the input and output circuits to the transistor are matched to the characteristic impedance of the line. Because the transistor has a certain amount of internal feedback, caused chiefly by the collector capacitance and base spreading resistance, precautions are necessary to insure the simultaneous matching of input and output. First the input is matched by means of the input adjustable line and stub with the output terminated in a Type 874-WM 50-Ohm Termination. A signal generator and slotted line are used to indicate the

Figure 1. Functional diagram of the u-h-f amplifier.



matched condition at the frequency of interest. A 50-ohm termination is then connected to the input, and the output circuit is matched, again using the signal generator and slotted line to determine the match. This process is repeated on both input and output until a match is simultaneously achieved at each end of the amplifier section when the other end is terminated in 50 ohms. The gain is measured by first noting the power into a 50-ohm bolometer from a matched generator, and then noting the power output with the matched amplifier inserted between the generator and bolometer.

## U-H-F OSCILLATION

Figure 2 is a photograph of the oscillator arrangement in which the TYPE 874 Coaxial-Line Elements are used. A diagram of the equipment in this setup is shown in Figure 3. The oscillator is in essence a tuned amplifier, as described above, in which the output is connected back to the input through an adjustable line. A TYPE 874-LK10 Adjustable Line is used to adjust the phase of the feedback. A high-pass filter section in the feedback path is necessary to prevent oscillation at some lower frequency.

In practice, the oscillator is adjusted as follows. First the input and output are tuned to some particular frequency, as described in the above section for the amplifier. If a gain greater than unity is observed at this frequency, the feedback path is closed from output to input. The presence of oscillation is detected by a change in the transistor collector current as the phase in the feedback path is adjusted. The frequency of oscillation is measured with a super-heterodyne receiver coupled loosely into a TYPE 874-LR Radiating Line in the feedback path.

In order to determine the maximum frequency of oscillation, the above procedure is repeated at progressively higher frequencies. Normally the process converges very rapidly, since the amplifier gain varies at a rate very close to —6db per octave of frequency in the range of interest.

Oscillation frequencies in excess of 1100 Mc have been obtained on developmental graded-base transistors of the SBDT-12 variety. In general, between 200 and 400 Mc can be added to the maximum frequency of oscillation when the coaxial-line techniques are employed in preference to pseudo-lumped-constant circuits. The maximum frequencies of oscillation determined with the coaxial-line equipment have agreed very closely with extrapolations of gain-versus-frequency plots of the transistors under test, with the gain below 300 Mc measured in neutralized, common-emitter, lumped-constant circuits.

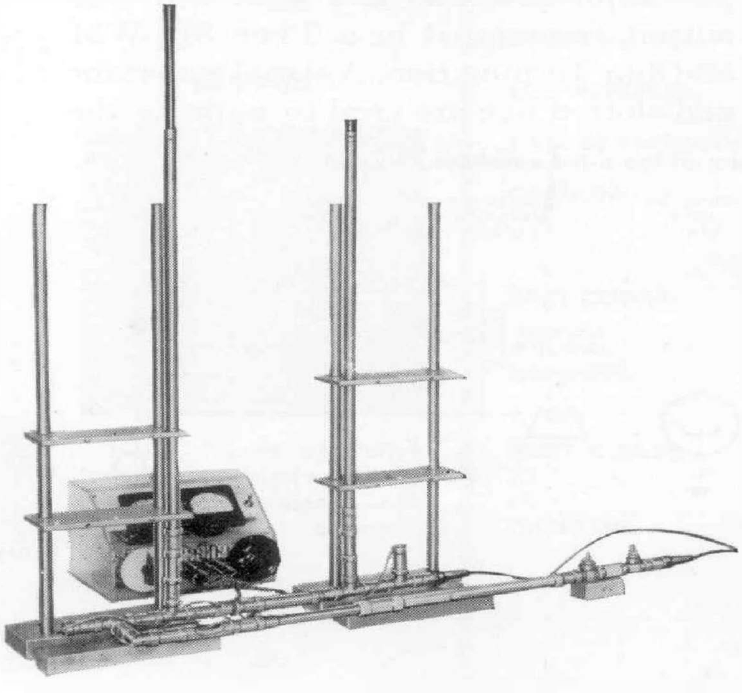


Figure 2. View of the u-h-f oscillator setup.

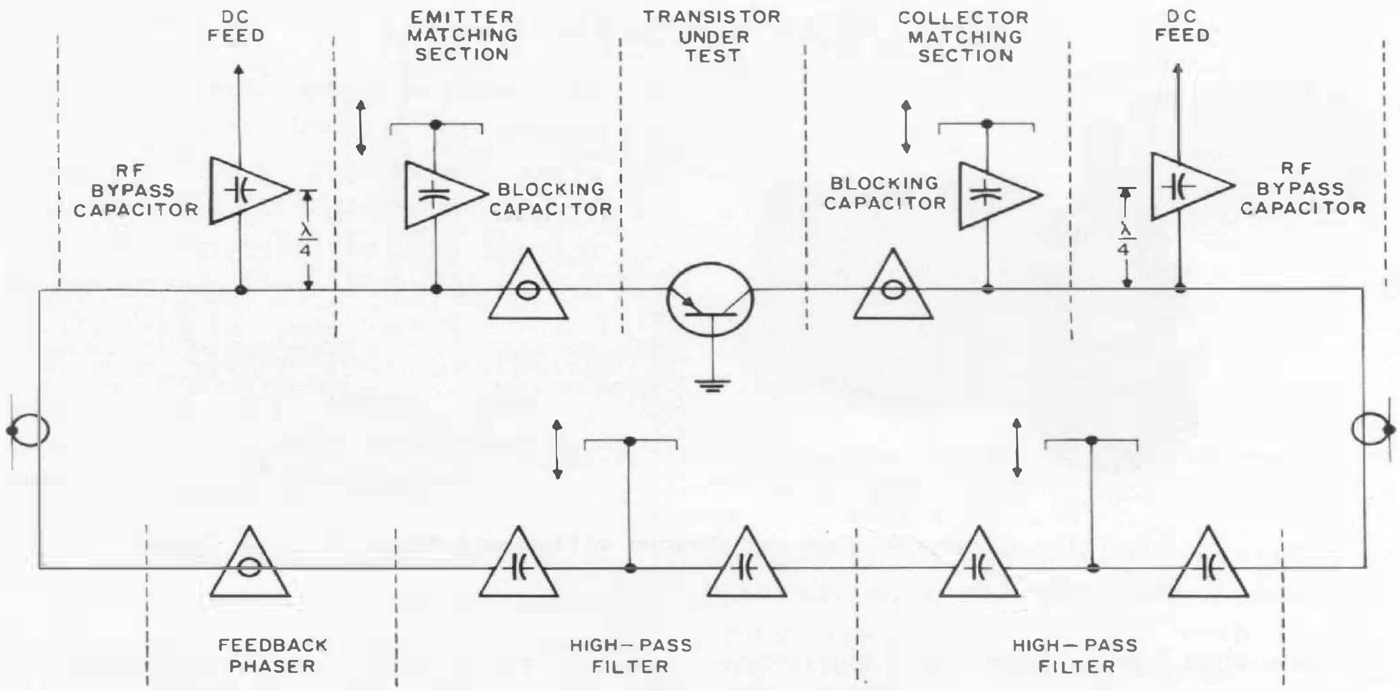



**Figure 3. Functional diagram of the u-h-f oscillator.**

## SPECIAL COMPONENTS FOR U-H-F TESTS

Four special components were required in the above tests. All of these components were readily fabricated from various components of the Type 874 line of coaxial equipment.

The *Transistor Mount* is shown in Figure 4. It was assembled from a modified Type 874-WN3 Short-Circuit Termination and a Type 874-B Basic Connector. A shield at the middle of the mount isolates the input from the output circuit. The base lead of the transistor is grounded to this shield. The transistor can is grounded to the outer conductor of the mount. The emitter and collector leads are tied to the center conductors of the input and output connectors respectively.

*Line Stretchers* were required for both the input and output circuits. It is necessary that these lines be of the shortest length possible for the desired impedance transformation, in order to minimize the possibility of spurious low-frequency modes of operation. The input line stretcher is fortunately achieved, in the thousand-megacycle range, by a partial disengaging of the connectors between the transistor mount and the input matching stub. The output line stretcher

**Figure 4. Transistor mount.**

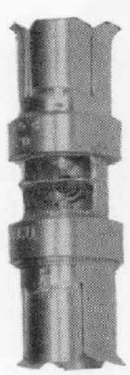


**Figure 5. Modified adjustable line (Line Stretcher).**

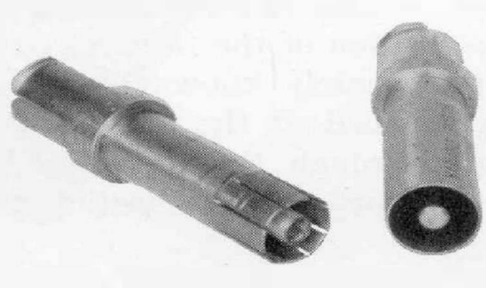
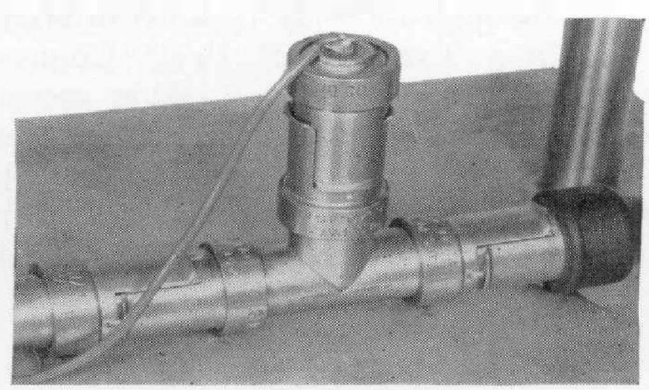


**Figure 7. D-C supply termination.**



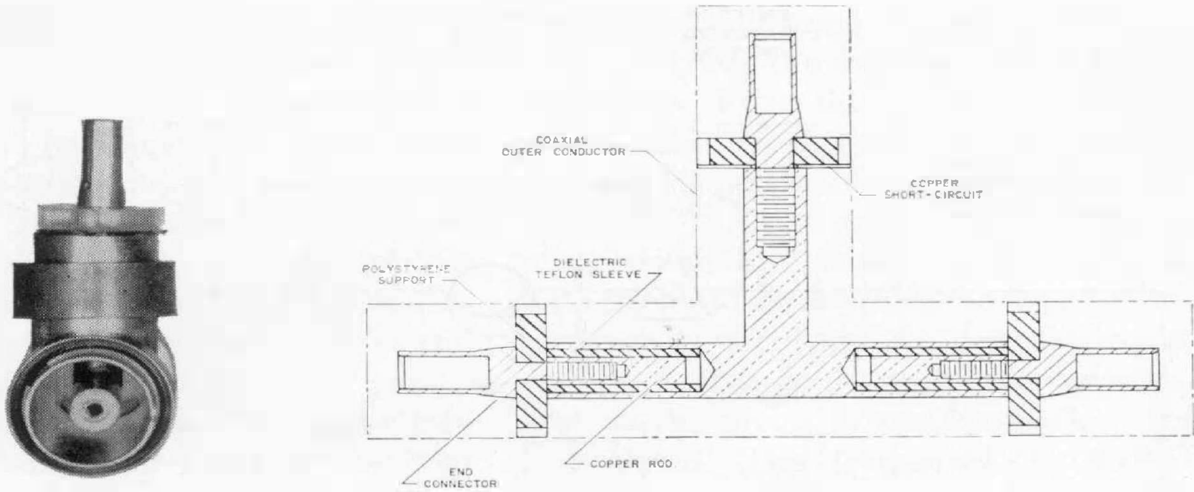



**Figure 6. View and diagram of high-pass filter.**

is somewhat longer, because of the necessity of matching a higher VSWR. The 5-centimeter line stretcher, which is a shortened form of the standard Type 874-LA Adjustable Line, is shown in Figure 5.

*High-Pass Filters* for the feedback path were formed out of Type 874-T Tee Connectors. Each of the filters includes a series coupling capacitor in both the input and output center conductors, together with a shunt stub, whose length is adjusted to resonate with the series capacitors at a frequency somewhat below the intended frequency of oscillation. The series capacitors were formed by use of a thin sleeve of Teflon, as shown in Figure 6; the area of this coaxial capacitor was adjusted to produce a capacitance of 5 $\mu\mu$f, which gave the desired impedance level at the cutoff frequency.

The *d-c feed element* consists of a feedthrough 1500-$\mu\mu$f, disk-ceramic capacitor in a Type 874-B Basic Connector, as shown in Figure 7. This mount provides a short circuit to high-frequency current at the position of the capacitor. A quarter-wave stub is formed from an appropriate length of line with the capacitor at its end; thus the addition of the d-c power does not affect the a-c configuration. In order that the d-c power be kept from the signal generator and the bolometer when amplification is measured, Type 874-K Coupling Capacitors are used in the input and output circuits. For the oscillator, only one blocking capacitor is required in the feedback path in order to keep the collector supply isolated from the emitter supply; the capacitors in the filters normally provide this isolation.

## ADMITTANCE MEASUREMENTS

The Type 874 Coaxial-Line Equipment has also been used for the determination of short-circuit input and output admittances of transistors in the u-h-f range. The impedance measurement at the terminal of interest is made through the use of the slotted line and a transmission-line chart, by measurement of the VSWR, referring back to the position of the transistor terminal. An accurately known short circuit is established at the other transistor terminal through the use of a half-wavelength short-circuited section of coaxial line.

# MORE NEW CAPACITORS

In a recent[1] issue of the EXPERIMENTER, new designs for laboratory standard mica capacitors were announced. These design improvements are now extended to the less-precise, lower-priced TYPE 505 Capacitors and to the decade capacitors in which TYPE 505 Units are used. In the decade capacitors a new switch, and in the decade assemblies a redesigned cabinet, offer additional advantages.

**Figure 1. View of Type 505 Capacitors showing the two case sizes and the arrangement of terminals.**

## TYPE 505 CAPACITORS

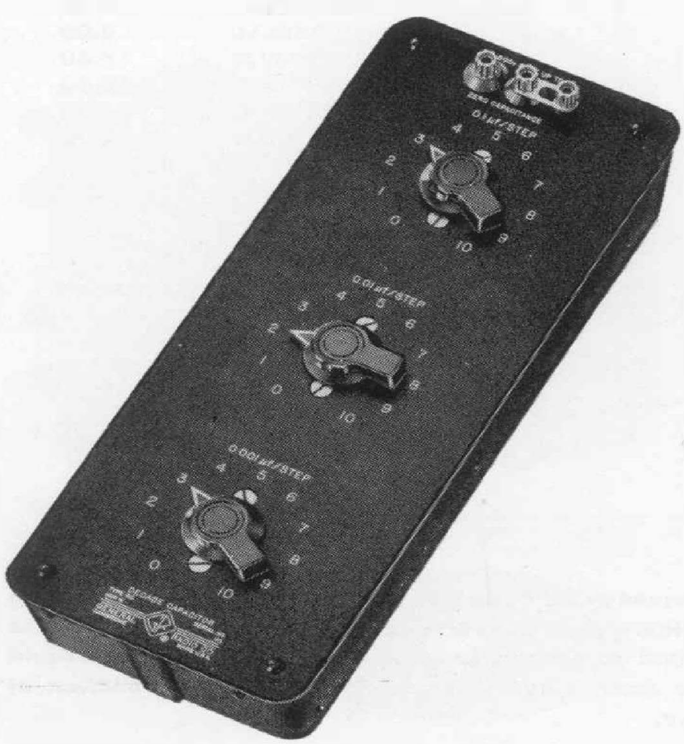
The silvered-mica electrodes and other improvements embodied in the new TYPE 1409 Standard Capacitors[1] are now available in the TYPE 505 Capacitors, and these units are now manufactured to new and considerably improved specifications of tolerance and dissipation factor. The capacitors are housed in low-loss molded-phenolic cases and are equipped with both screw- and plug-type terminals and with flanges for mounting. They are used both as laboratory "secondary standards" and as circuit elements in measuring equipment as, for example, in a number of General Radio bridges in the 1-percent-accuracy class.

Dissipation factor of these units, in the 1000-$\mu\mu$f and higher sizes, does not exceed .0003. The losses in the phenolic case increase the dissipation factor slightly for units of 500 $\mu\mu$f and smaller. Leakage resistance is 5000 megohm-microfarads or 100,000 megohms, whichever is the lower. The first figure represents the performance of the mica, while the second represents the phenolic case and is controlling below 0.05 $\mu$f.

The same high-quality silvered-mica sheets are used in the construction of the TYPE 505 Capacitors as are used in the TYPE 1409 Standard Capacitors. Accuracy of adjustment is $\pm$ 0.5%, in contrast to the 0.1% adjustment of the TYPE 1409. The lower accuracy and the less-expensive packaging result in a unit that sells at a price substantially lower than that of the 1409[1], but whose characteristics and stability are entirely adequate for many laboratory, production-line, and instrument applications.

[1] Easton and McElroy, "New, Silvered Mica, Standard Capacitors, TYPE 1409," *General Radio Experimenter*, 32, 2, July, 1957.

**Figure 2. Panel view of the Type 1419-K Decade Capacitor.**



## SPECIFICATIONS

**Accuracy:** ±0.5% or ±3μμf, whichever is the larger.

**Temperature Coefficient:** Approximately +0.0035% per degree Centigrade between 10° and 50° Centigrade. Calibration is made at 23° C., at a frequency of 1 kc.

**Dissipation Factor:** 0.0003 for 1000 μμf and higher; 500 μμf, 0.00035; 200 μμf, 0.0004; 100 μμf, 0.0006.

**Frequency Characteristics:** See plots below. Series inductance is approximately 0.055 μh for units in small case and 0.085 μh for large case. Series resistance at 1 Mc is approximately 0.03 ohm for small case and 0.05 ohm for large case, varying as square root of frequency above 100 kc.

**Leakage Resistance:** Greater than 100,000 megohms, when measured at 500 volts, except for the Types 505-T, 505-U, and 505-X, for which it is greater than 50,000, 25,000, and 10,000 megohms, respectively.

**Maximum Voltage:** See table. At higher frequencies the allowable voltage decreases and is inversely proportional approximately to the frequency. These limits correspond to a temperature rise of 40° Centigrade for a power dissipation of 1 watt for the small case and 2.5 watts for the large case.

**Terminals:** Screw terminals spaced ¾ inch apart. Two Type 274-P Plugs are supplied with each capacitor. High terminal (inside foil) is marked H.

**Mounting:** Mica-filled, low-loss phenolic cases.

**Dimensions:** See sketch. Over-all height, 1⅝ inches for large case, 1 inch for small case, exclusive of plugs.

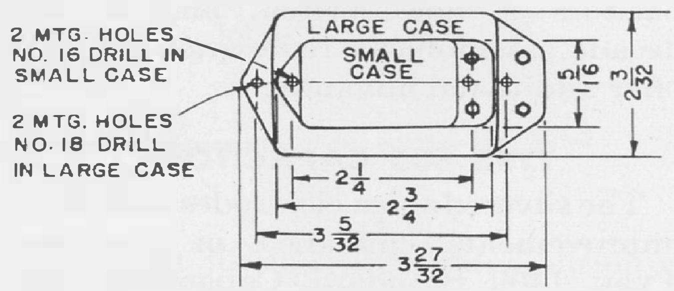



**Figure 3. Dimension sketch of Type 505 Capacitors.**

| *Type* | *Capacitance* | *Maximum Peak Volts* | *Frequency Limit for Max. Volts* | *Weight in Ounces* | *Code Word* | *Price* |
|---|---|---|---|---|---|---|
| **505–A** | **100 μμf** | 700 | 12Mc | 4 | CONDENALLY | **$ 8.00** |
| **505–B** | **200 μμf** | 700 | 7 | 4 | CONDENBELL | **6.50** |
| **505–E** | **500 μμf** | 500 | 3.5 | 4 | CONDENCOAT | **6.00** |
| **505–F** | **0.001 μf** | 500 | 2 | 4 | CONDENDRAM | **6.00** |
| **505–G** | **0.002 μf** | 500 | 1.1 | 5 | CONDENEYRE | **6.50** |
| **505–K** | **0.005 μf** | 500 | 500kc | 5 | CONDENFACT | **6.50** |
| **505–L** | **0.01 μf** | 500 | 320 | 5 | CONDENGIRL | **8.50** |
| **505–M** | **0.02 μf** | 500 | 200 | 6 | CONDENHEAD | **9.00** |
| ***505–R** | **0.05 μf** | 500 | 100 | 11 | CONDENCALM | **13.50** |
| ***505–T** | **0.1 μf** | 500 | 50 | 12 | CONDENCROW | **16.50** |
| ***505–U** | **0.2 μf** | 500 | 25 | 13 | CONDENWIPE | **24.00** |
| ***505–X** | **0.5 μf** | 500 | 10 | 15 | CONDENWILT | **52.50** |

*Mounted in large case.

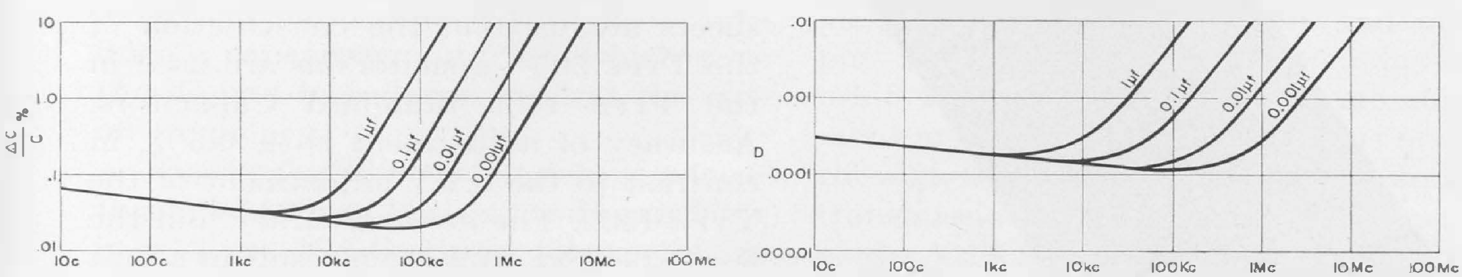



**Figure 4.** ***(Left)*** **Change in capacitance as a function of frequency for Type 505 Capacitors. These changes are referred to the values which the capacitors would have if there were neither interfacial polarization nor series inductance. Since the capacitors are adjusted to their nominal values at 1 kc, the 1-kc value on the plot should be used as a basis of reference in estimating frequency errors.** ***(Right)*** **Dissipation factor as a function of frequency.**

## THE TYPE 980 SWITCH

By the use of an appropriate switch, four individual capacitor units can be paralleled in various combinations to provide a decade sequence from 1 to 10. The new Type 980-P1[2] Switch, replacing the former Type 380-P3, is designed for this purpose. The switching sequence is designed for the use of a 1-2-2-5 series of capacitance values. This combination was selected from the several available ones to utilize for the decades the same nominal capacitance values that are stocked as individual units. The operating principle of the switch is the same as that of its predecessor, employing sequential paralleling action by means of leaf springs, which contact the common rotor by the action of shaped cams. The outstanding characteristics of this new switch are the low capacitance, extremely low dielectric losses, and very high leakage resistance, all obtained by the use of cross-linked (thermosetting) polystyrene in the supporting structure and shaft.

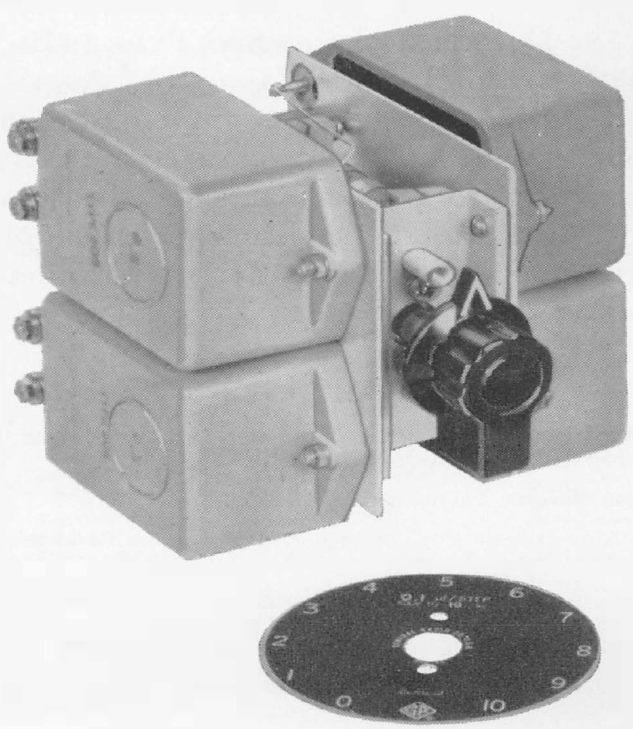
[2]Actually in use for several years, but not hitherto announced in the *Experimenter*.

| *Type* | | *Code Word* | *Price* |
|---|---|---|---|
| **980-P1** | **Switch** | SWITCHBIRD | **$11.00** |

## THE TYPE 980 DECADE CAPACITANCE UNITS

The new switch and the improved Type 505 Capacitors are combined to make the new Type 980 Decade Capacitors. The low losses of these "decades" make them suitable for use in a-c bridges, resonant circuits, and filters.

**Figure 5. View of the Type 980-F Decade Capacitance Unit.**



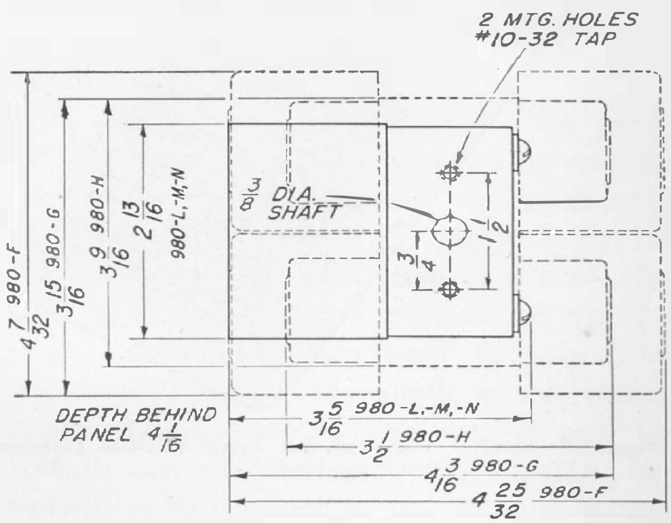



**Figure 6. Dimension of Types 980-F, -G, and -H Decade Capacitor Units.**

In a resonant circuit, for instance, the $Q$ of 3000 is sufficiently high relative to losses in practical inductors that the capacitor loss can usually be ignored. The high leakage resistance makes them useful in many d-c circuits. Two new decades are now available, the Type 980-G and Type 980-H, with capacitance steps of 0.01 μf and 0.001 μf, respectively, in addition to the older Type 980-F, which has 0.1-μf steps.

## SPECIFICATIONS

Electrical specifications are the same as those for TYPE 505 Capacitors.

**Dimensions:** See sketch.

**Net Weight:** TYPE 980-F, 3 pounds, 12 ounces; TYPE 980-G, 2 pounds; TYPE 980-H, 1 pound, 10 ounces.

| *Type* | | *Code Word* | *Price* |
|---|---|---|---|
| **980-F** | **1.0 μf in 0.1 μf steps** | ACUTE | **$128.00** |
| **980-G** | **0.1 μf in 0.01 μf steps** | AVOWD | **60.00** |
| **980-H** | **0.01 μf in 0.001 μf steps** | AWAIT | **45.00** |

## TYPE 1419-K DECADE CAPACITOR

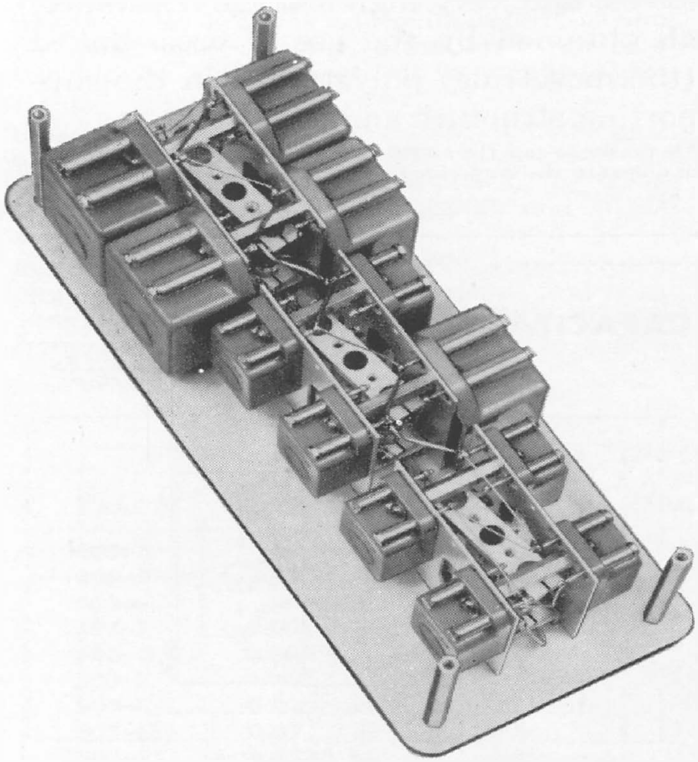


**Figure 7. Interior view of the Type 1419-K Decade Capacitor.**

An assembly of individual decade units, traditionally referred to as a "decade box," is a basic and popular piece of laboratory equipment. The TYPE 219-K Decade Capacitor, a fixture in the General Radio catalog for a great many years, is now replaced by a new and improved model, TYPE 1419-K.

The previous model used for the .01 μf- and .001 μf-per-step decades high quality, molded mica capacitors specially made by a leading manufacturer; the new model uses the TYPE 505 Capacitors, described above, throughout. The new, low-loss switches are, of course, used. The result is a threefold reduction in dissipation factor on these decades. As to stability of capacitance value, observations to date suggest constancy of capacitance, well within 0.1% for a period of several years and quite probably indefinitely, since no systematic drift in capacitance value approaching this figure has as yet been observed.

The TYPE 1419-K is housed in an aluminum cabinet, similar in design and appearance to the companion TYPE 1432-Decade Resistors and TYPE 1419-A Polystyrene Decade Capacitor.[3] As with all G-R laboratory components announced recently, three terminals are provided to permit use as a grounded two-terminal device or with case only grounded and both active terminals above ground.

## SPECIFICATIONS

**Dimensions:** (Length) $14\frac{1}{4}$ x (width) $5\frac{1}{2}$ x (depth) $6\frac{3}{16}$ inches, over-all.

**Net Weight:** 11 pounds, 9 ounces.

[3] "New Decade Capacitors with Polystyrene Dielectric," *General Radio Experimenter*, 31, 2, July, 1956.

| *Type* | | *Code Word* | *Price* |
|---|---|---|---|
| **1419-K** | **1.110 μf in 0.001 μf steps** | CREEK | **$255.00** |

NOTE: Other previously listed TYPE 980 Decade Capacitance Units and TYPES 219 and 1419 Decade Capacitors are still available. These include the TYPE 219-M Decade Capacitor and the TYPES 980-L, -M, and -N Decade Capacitance Units.

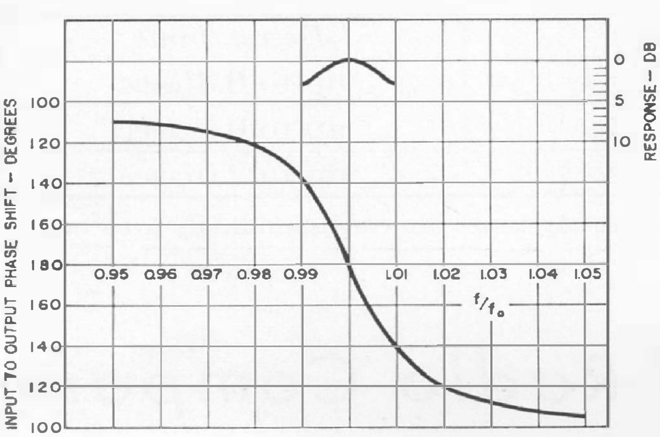
# REDUCING TRANSFORMER NOISE WITH THE SOUND-LEVEL METER

Users of General Radio equipment often devise ingenious ways of applying their instruments to specialized problems. A good example of this ingenuity is reported by Mr. Theodore R. Specht, design engineer, Transformer Division, Westinghouse Electric Corporation in Sharon, Pennsylvania.

Mr. Specht was faced with the problem of determining whether the vibrations in a transformer core had resonant modes or were random. If the core is resonant it will vibrate in modes that cause high sound levels about the core. A combination of the General Radio vibration-measuring equipment and an oscilloscope, as shown in the block diagram in Figure 1, were used to make the determination.

A Type 759-P35 Vibration Pickup and an integrating-circuit Control Box convert a Sound-Level Meter to a vibration meter. The Type 760-B Sound Analyzer, which is a narrow-band, tunable amplifier, is used to evaluate the fundamental or any one of the harmonics of the vibration under study. In this case, the fundamental is twice the transformer test frequency.

**Figure 2. Amplitude and phase response of the Type 760-B Sound Analyzer.**



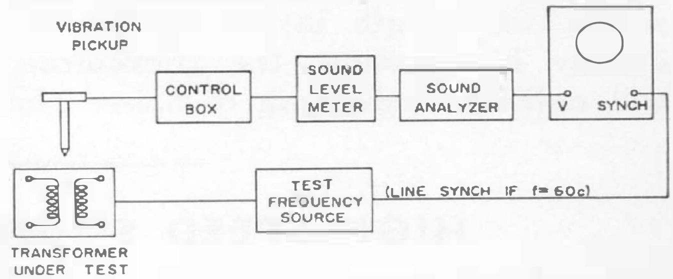



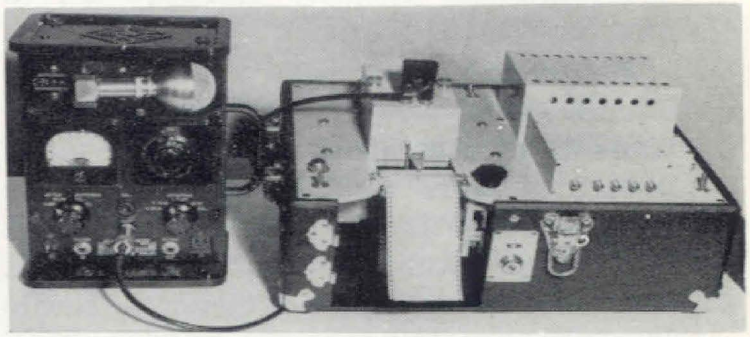

**Figure 1. Block diagram of the vibration-measuring system.**

The output of the analyzer is applied to the vertical deflection plates of the oscilloscope. A linear horizontal time sweep synchronized by the test frequency source is used. If the test frequency is 60 cycles, the oscilloscope can be synchronized internally by line synchronization.

If the analyzer is tuned to the peak of the vibration fundamental or one of its harmonics, its output will be nearly inverted in phase with respect to its input. From the response curve of the analyzer, shown in Figure 2, it can be seen that if the analyzer is tuned to within 0.2 db of the peak of an input signal the phase of this signal will be within ten degrees of being exactly inverted with respect to the output signal of the analyzer.

Since relative phase measurements are desired, the problem of determining absolute phase shift in the complementary equipment is ignored. The vibration probe is placed at different core locations, and the resulting oscilloscope patterns show phase differences of the vibrations at these locations. If the transformer core is mechanically resonant, the vibration pattern will follow one of the usual modes with zero or 180° phase difference between various places. Design changes must be made if resonance is present. If the vibrations are out-of-phase at different locations separated by distances much less than a half wavelength in air for the frequency in question, the transformer will radiate a minimum of noise. The Sound-Level Meter used in the "normal" fashion may then be used to determine the effectiveness of design changes by a measurement of the sound level at a standard distance from the operating transformer.

## HIGH-SPEED SOUND-LEVEL RECORDER



Sound Apparatus Company, manufacturers of Graphic Recorders, has recently improved its Dynamic High-Speed Sound-Level Recorder, Model SL-2, with special emphasis on sound, noise, and vibration measurements. Design features include adjustable writing speed by a patented electronic feedback system; push-button selection of chart speed; scale functions in linear, decibel, or loudness (phon) are available.

The photograph shows Model SL-2b connected to the General Radio TYPE 1551-A Sound-Level Meter. With this simple setup the most complicated acoustical measurements can be recorded rapidly and accurately.

Descriptive literature is available from Sound Apparatus Company, Stirling, N.J.

## VARYING THE RISE TIME OF THE UNIT PULSER

The occasion sometimes arises when it is desirable to be able to vary the rise time of a test pulse. This is particularly important when testing circuitry that is designed to handle pulses which may have a wide variety of rise times. A simple external modification can be made to the TYPE 1217-A Unit Pulser to permit the selection of a number of predetermined rise times. To do this, simply connect a trimmer capacitor between the cabinet ground and the OVERSHOOT screw adjustment. With this setup the following can be developed:

| *Pulse Width* | *Rise Time* | *Decay Time* |
|---|---|---|
| 1 μsec | up to 0.25 μsec | up to 0.3 μsec |
| 2 μsec | up to 0.5 μsec | up to 0.5 μsec |
| 5 μsec | up to 1.0 μsec | up to 2.0 μsec |

With increased pulse width the limits for rise and decay times are correspondingly greater.

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