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Calibrating An Inductance Standard

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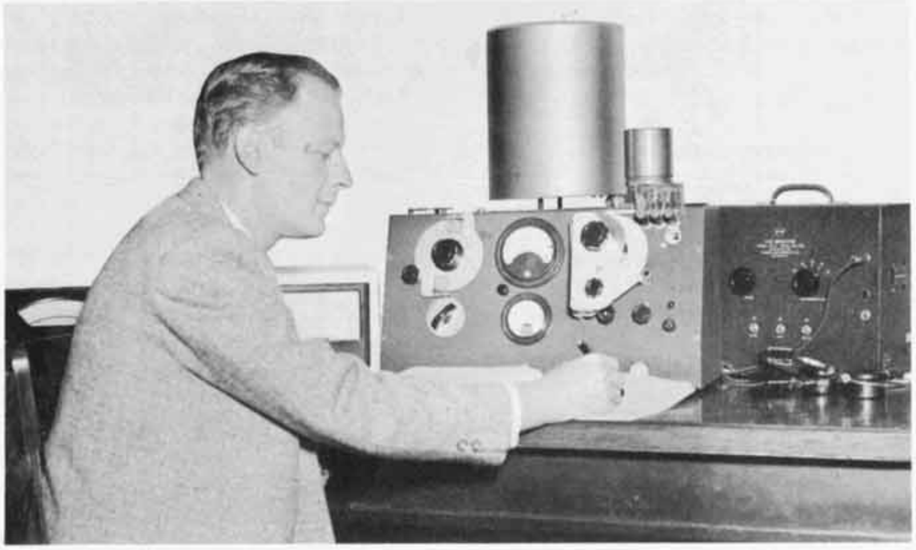

Figure 1. The author shown determining C at a V_o/V ratio, using the modified and specially calibrated Q-Meter.

Definition of Inductance Standard

Ask an engineer for the definition of an inductance standard and he will probably tell you that it is a coil or inductor having an accurately known, highly stable inductance. This is the definition implied. However, a better definition would be, an inductor having highly stable and accurately determined parameters; i.e., inductance (L), distributed capacitance (C_d), and resistance (R).

In such a standard, the parameters L and C_d are readily measured but the accurate measurement of R is extremely difficult. This is true because, in general, the more useful coils have a relatively high Q and consequently a very small value of R. R is so small in fact, that it is often swamped by the losses in any measuring equipment used, and therefore is very difficult to isolate. Since Q is a function of R ($Q = \frac{\omega L}{R}$), it follows that if Q and L can be determined, the value of R is firmly fixed.

Methods for Measuring Q

The problem now is to measure Q. An investigation into the possible methods of measuring Q has been made and the following conclusions drawn:

1. The frequency variation method involves the ratio of the frequency at resonance to the difference in frequency between the two half-power points on the Q-versus-frequency curve. This method was found unsuitable because of the variation of impedance of the Q circuit with frequency and the fact that the resonant frequency is different from the frequency for maximum voltage.
2. Injecting an AM signal into the Q circuit and measuring the attenuation of the side bands was rejected because errors in the amplitude of the side bands are caused both by coupling to the Q circuit and any asymmetry of modulation.
3. Injecting an AM signal into the Q circuit and measuring the phase angle of the detected signal was also rejected due to the error introduced in coupling to the Q circuit and the difficulty in accurately measuring the phase angle.
4. Q as determined from measurements on a BRC G-Meter, Type 192-A, is quite accurate and not difficult to determine, but because the G-Meter provides only two measurement frequencies, 1 mc and 30 mc, this means was found unsuitable as a general method.
5. A variation of the "Q by C" method was found to be most suitable, because the frequency remains fixed for these measurements, and the effects on the Q circuit due to varying frequency are eliminated. Also, the measurement requires basically an injection system, a Q circuit with a variable capacitor, and an oscillator, all of which are available in a Q-Meter.

Q Defined

Up to this point, the term "Q" has been used rather loosely. To aid in this discussion, it might be well to define here the several terms of Q with which we will be dealing:

Q — true Q of the inductor; i.e., $\frac{\omega L}{R}$

Q_e — effective Q; i.e., the Q of the inductor mounted on a Q meter, exclusive of all Q-Meter losses.

YOU WILL FIND . . .

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Q_e — circuit Q; i.e., the Q of the Q-Meter resonant circuit, including the inductor.

Q_i — indicated Q; i.e., the Q of the Q-Meter resonant circuit as indicated by the meter. This value includes the calibration errors of the Q-Meter.

Determination of Q

From the preceding definitions, it is seen that Q_e, the Q that the inductor appears to have when associated with additional circuitry, is the most useful value. If necessary, true Q can be derived from this value. To measure Q_e, a substitution method is used whereby the conductance of the Q circuit is determined first with a well shielded high-Q coil and again with the same high-Q coil plus the inductor being evaluated. The difference between the two determinations is the conductance of the unknown. This can be shown mathematically. Referring to the voltage-versus-capacitance curve (Figure 2) of the Q-Meter tank circuit, the conductance of the Q circuit with the high-Q coil can be expressed as:

$$(1)\quad G_1 = \frac{\omega C_{o1}}{Q_{e1}} = \frac{\omega C_{o1}}{\frac{2\,C_{o1}}{\Delta C_1}\sqrt{\left(\frac{V_o}{V}\right)_1^2 - 1}} = \frac{\omega \Delta C_1}{2\sqrt{\left(\frac{V_o}{V}\right)_1^2 - 1}}$$

The conductance with the two coils is then:

$$(2)\quad G_2 = \frac{\omega C_{o2}}{Q_{e2}} = \frac{\omega C_{o2}}{\frac{2\,C_{o2}}{\Delta C_2}\sqrt{\left(\frac{V_o}{V}\right)_2^2 - 1}} = \frac{\omega \Delta C_2}{2\sqrt{\left(\frac{V_o}{V}\right)_2^2 - 1}}$$

If the ratio $\frac{V_o}{V_1}$ is made equal to $\frac{V_o}{V_2}$, then the conductance of the unknown is:

$$(3)\quad G_x = G_2 - G_1 = \frac{\omega(\Delta C_2 - \Delta C_1)}{2\sqrt{\left(\frac{V_o}{V}\right)^2 - 1}}$$

With the conductance of the inductor known, it is a simple step to compute the effective Q:

$$(4)\quad Q_{ex} = \frac{\omega C_o}{G_x}$$

It should be noted that the inductor should have a Q of more than 100, since the foregoing equations have been derived using this assumption.

While the preceding analysis is straightforward, the actual measurements are involved. From equations (3) and (4) it is seen that because ω is readily determined to a high degree of accuracy using a crystal frequency calibrator or frequency counter, the overall accuracy is dependent upon the determination of C_o, ΔC, and V_o/V and the ability to repeat specific ratios of V_o/V.

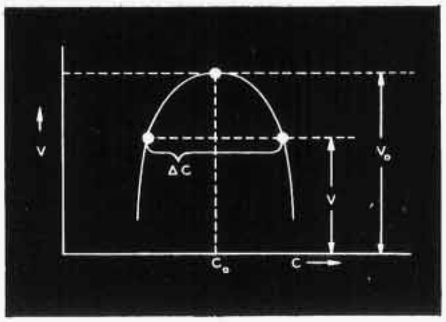

Figure 2. *Voltage versus capacitance curve of a Q-Meter tank circuit.*

To make the measurements we have used a modified and specially calibrated Q-Meter (Figure 1). Additional binding posts have been added to permit mounting two coils; one in the normal manner and the other from the HI post to ground. A means has been provided whereby the Q-Meter B+ voltage is externally regulated and monitored. Direct connection may be made to the cathode of the Q-voltmeter tube. In addition, a calibrated high-ratio gear drive is used to operate the main Q-capacitor and a parallel group of three micrometer type vernier capacitors, having a total range of about $100\mu\mu f$, replaces the usual vernier. This permits the main tuning dial to remain in a fixed position while a wide range of ΔC readings is made.

Voltage Ratio

Setting up the V_o/V ratios necessitates the use of two specialized pieces of equipment; an instrument to provide precise levels of a 1000 cps signal (voltage calibrator) and an instrument to provide several very stable DC voltages (bucking voltage source). The 1000 cps source is used to calibrate the DC source in the following manner: The 1000 cps source is connected to the capacitor terminals of the Q-Meter, whose oscillator is made inoperative by setting between ranges. The DC source is connected through a microammeter to the cathode of the Q-voltmeter tube (See figure 3). Q-Meter zero is accurately set and periodically checked. The Q-Meter B+ supply voltage is also checked periodically to insure stable conditions. The level of the 1000 cps signal is adjusted to give a reading well up the Q scale of the Q-voltmeter. This is the resonance reference $V_o = 1$.

The DC source is then adjusted, in the 1 position, to give a zero reading on the microammeter in the lead to the Q-voltmeter tube, indicating that the voltage is of the same level as the voltage delivered to the Q-voltmeter. The 1000 cps source is now set to give exactly 0.9 of the previous signal and the DC source is switched to the next output and adjusted for zero meter reading. This is repeated for several levels; i.e., 0.8, 0.7, 0.6.

It can be seen that the DC source is now a memory for the various voltages appearing across the Q-Meter tuning capacitor, enabling the user to set and reset precisely to any desired voltage.

With the 1000 cps source removed and the Q-Meter oscillator set to the desired test frequency, the inductor (or inductors) to be measured is connected and the Q-Meter is resonated with the main and vernier capacitors. Capacitor settings are recorded and correspond to the resonating capacitance C_o. The DC source is set to the 1 reference position and the Q-Meter XQ level is adjusted to give a zero reading on the microammeter. The DC source is then switched to the 0.9 reference position and the Q-Meter is detuned on either side of resonance, using the vernier capacitors. The difference between the capacitor settings, at the point on either side of resonance where the current meter reads zero, is the ΔC value for the ratio $V_o/V = 0.9$. These capacitor settings are also recorded, and the procedure is repeated for the V_o/V ratios of 0.8, 0.7, etc.

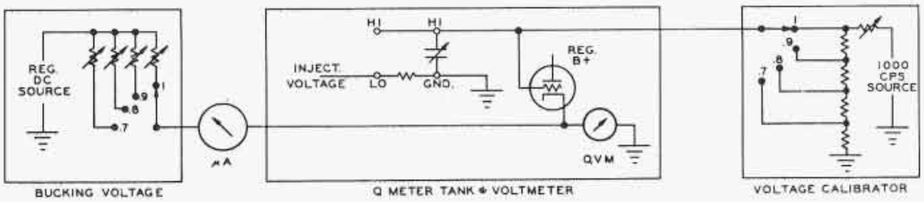

Figure 3. Connections used for setting up V_o/V ratios.

Determining Capacitance

All that remains is to accurately determine the capacitance at the recorded capacitor settings before applying equations (3) and (4).

Modifications made to the Q-capacitors permit settings to be repeated to a very fine degree. This is necessary, because it is required that the Q-Meter be turned off to calibrate the capacitor.

The actual capacitance is measured by connecting a sensitive capacitance bridge to the capacitance terminals of the Q-Meter whose capacitors are set to a previously recorded value. The bridge is then balanced using a precision capacitor. All known corrections to the precision capacitor are applied and correction for the leads from the bridge to the Q-Meter is made.

The preceding is sufficient for the difference in capacitance (ΔC) data, but for absolute capacitance (C_o) data; additional corrections are necessary. A correction for the Q-voltmeter level is required, because the Q capacitance is measured with the Q-Meter turned off. This correction is determined through the use of a second Q-Meter (No. 2). The oscillator of the Q-Meter to be checked is disabled (set between ranges) and the capacitance terminals of this Q-Meter are connected to those of Q-Meter No. 2. Number 2 Q-Meter has a coil connected in its tank circuit and its oscillator is operated at the test frequency. The coil is selected so that some low value of capacitance is required to resonate with it. If the capacitance required is $80\mu\mu f$, then about $40\mu\mu f$ will be supplied by the Q-capacitor of each Q-Meter.

The Q-Meter under test is turned off and its vernier capacitors are used to resonate the tank circuit of Q-Meter No. 2; then it is turned on again, and the process is repeated. The difference in the two settings of the vernier is the capacitance attributable to the Q-voltmeter at the particular voltage (or Q) level. Different voltage levels can be selected by changing the setting of the XQ control on Q-Meter No. 2 and the capacitance correction versus Q level can be plotted as shown in Figure 4.

A final correction to the capacitance values may be necessary. When the Q-capacitor of a Q-Meter is calibrated, some small capacitance existing between the Q-Meter HI terminal and the cabinet (ground) is included in the calibration. A shielded coil connected to the coil terminals of the Q-Meter (shield connected to the LO terminal), causes some of the capacitance to shift from HI terminal to cabinet, to HI terminal to shield. This is called the proximity effect and is exceedingly difficult to define. In all but the most rigorous determinations, this effect may be neglected without seriously affecting the accuracy of the result. Without developing a lengthy and involved procedure for determining this effect, it may be said that generally any shielded coil having overall dimensions similar to the shielded coils manufactured by Boonton Radio Corporation (3-inch diameter shield cans) will produce a proximity effect of approximately $-0.4\mu\mu f$ when mounted on a Q-Meter with the coil base about 1 inch above the Q-Meter top panel. The figure will decrease with a decrease in the shield can diameter or an increase in the distance between the shield can and the Q-Meter.

Recapitulating the capacitance corrections:

C_i – Capacitance indicated by Q-Meter Q-capacitor.
$\pm C_e$ – Correction indicated by precision capacitor.
$\pm C_l$ – Correction for leads from capacitance bridge to Q-Meter.
$\pm C_r$ – Correction for Q-voltmeter level.
$-C_p$ – Correction for proximity effect.

It should be noted that for best results all measurements should be conducted in a temperature and humidity controlled atmosphere so that both the inductor under test and the measuring equipment are not affected by these conditions.

The ΔC values derived using the described procedures are used in equation (3) and a value of G_x is obtained for each V_o/V ratio. An indication of the care and accuracy of measurement is apparent by the degree of coincidence of the several values of G_x for each test frequency. The C_o value measured at each test frequency is used in conjunction with the average G_x value for that frequency in equation (4) to yield the effective Q of the inductor.

True inductance and distributed capacitance of the inductor can be found by applying data obtained from the previous measurements to the following equations:

$$(5)\quad L = \frac{\left(\frac{1}{f_1^2} - \frac{1}{f_2^2}\right)}{4\pi^2 (C_{o1} - C_{o2})}$$

$$(6)\quad C_d = \frac{C_{o1} - n^2 C_{o2}}{n^2 - 1}$$

Where:
C_{o1} and C_{o2} are the capacitances necessary to resonate the coil at frequencies f_1 and f_2 respectively, and n is the ratio of f_2 to f_1.

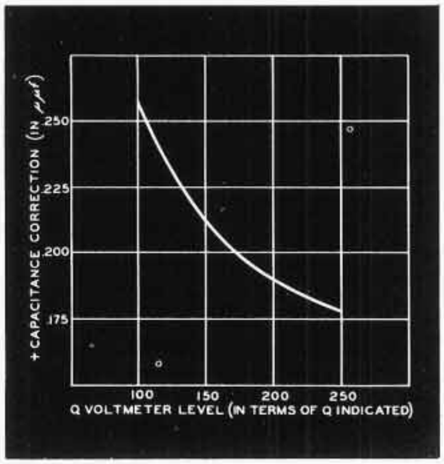

Figure 4. Capacitance correction versus Q-Level curve for a Q-Meter.

All of the true and effective parameters may now be determined by applying the following equations:

$$(7)\quad \text{Effective inductance } (L_e) = \frac{L}{1 - \omega^2 C_d}$$

$$(8)\quad \text{Effective resistance } (R_e) = \frac{\omega L_e}{Q_e} = \frac{R}{(1 - \omega^2 L C_d)^2}$$

$$(9)\quad \text{True } Q = \frac{\omega L}{R} \approx Q_e\left(1 + \frac{C_d}{C_o}\right)$$

BRC Q-Standard, Type 513-A

A specific example of an inductor developed through use of the described methods is the BRC Q-Standard, Type 513-A. The nameplate information for this inductor includes L, C_d, Q_e at three frequencies, and another term, Q_i, at the same three frequencies. In this case, Q_i is the Q that would be indicated by a Q-Meter having average loss and zero calibration error. The Q_i information was derived through an analysis of production indicated Q checks made on Q-Meters manufactured by BRC and relating the result to the measured Q_e value. Of course, in production the procedures just outlined would be impractical, therefore, a comparison method was developed. At each of the three frequencies involved, the production coil is compared to a standard, which has been established using the rigorous method described above. A precisely calibrated Q-Meter is used for the comparison, although its accuracy has only higher order effects on the results.

Suppose that at one of the frequencies, the difference between the production coil and the standard, as compared on a Q-Meter, is given by ΔC and ΔQ. The functions of standard and production coils would then be defined as follows:

Function	Known Standard Coil	Unknown Production Coil
Indicated Q	Q_i	Q_{ix}
Resonating C	C_o	C_{ox}
Effective Q	Q_e	Q_{ex}

Where:

(10) $Q_{ix} = Q_i + \Delta Q$

(11) $C_{ox} = C_o + \Delta C$

(12) $Q_{ex} =$

$$\frac{\omega(C_o + \Delta C)}{\frac{\omega C_o}{Q_e} + \frac{\omega C_o}{Q_i + \Delta Q}\left[\left(1 + \frac{\Delta C}{C_o}\right)\left(1 - \frac{\Delta Q}{Q_i + \Delta Q}\right) - 1\right]}$$

Using the same process to obtain difference data at the other two frequencies, Q_{ex} can be found at each frequency. Distributed capacitance and inductance of the unknown are given by:

(13) $C_{dx} =$

$$\frac{(C_{o1} + \Delta C_1) - n^2(C_{o2} + \Delta C_2)}{n^2 - 1} \text{ and}$$

(14) $L_x =$

$$\frac{\frac{1}{f_1^2} - \frac{1}{f_2^2}}{4\pi^2\left[(C_{o1} + \Delta C_1) - (C_{o2} + \Delta C_2)\right]}$$

Where the subscripts 1 and 2 refer to measurements at 2 frequencies.

To reduce the possibility of errors in manipulation, equations (12), (13), and (14) have been transformed to nomograms for use by production personnel (See Figure 5).

Figure 5. BRC inspector shown using a nomogram to determine the effective Q of a Type 513-A inductor.

A great deal of care has been taken in the physical design and manufacture of the Q-Standards to insure their stability. The coil form is mounted on a copper base, which is fitted to a shield can. The unit is hermetically sealed, evacuated, and filled with an inert gas to a pressure of 1 psi above atmospheric pressure. Leads are brought through the base to banana plug connectors, which may be replaced without breaking the seal. The high potential connector is isolated from the base by a low-loss ceramic seal.

The care taken in determination and production of the Q-Standards is attested to by the fact that not a single coil has been returned for mechanical failure or deterioration of electrical specifications. In some cases, Q-Standard users involved in government work have been required by the cognizant government agency to have their Q-Standards periodically rechecked by BRC. In each such case it has been found that the nameplate information was well within the original specification tolerance and no corrections of any kind were required.

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4. Kang, C. L., "Circuit Effects on Q", BRC Notebook No. 8, Winter, 1956.
5. "A Standard for Q and L", BRC Notebook No. 12, Winter, 1957.

BRC manufactures two Q-Standards; the Type 513-A, discussed in the above article, and the Type 518-A. Each Type 513-A Q-Standard is individually calibrated and marked with its true inductance (L), distributed capacitance (C_d), effective Q(Q_e), and indicated Q(Q_i) at 0.5, 1.0, and 1.5 megacycles. Because these parameters are accurately known and highly stable, this standard may be used for providing precisely known supplementary Q-circuit inductance desireable for many impedance measurements by the parallel method, as well as a means for checking the Type 260-A and 160-A Q-Meters. The Type 518-A Q-Standard on the other hand is a precision inductor designed primarily for use in checking the overall operating accuracy of Q-Meters Type 260-A and 160-A.

A Linear Detector for FM Deviation Measurements

FRANK P. MONTESION, *Editor The Notebook*

With the development of the Type 202 FM Signal Generators in 1946, there arose a need for a device for the precision measurement of frequency deviation. Such a device would be required to provide laboratory accuracy and, at the same time, had to be simple and convenient for direct use on the production line. A detailed survey of available instrumentation revealed that such an instrument was not available and work was carried out at BRC on the development of this laboratory tool, concurrent with the development of the FM Signal Generator.

The result of this project was an early prototype unit, which over the years has undergone constant redesign and improvement to become known as the BRC Type 208-A FM Linear Detector. These instruments have been in constant use in our standards laboratory and engineering and production departments during this period, and are currently used to calibrate the Types 202-E and 202-F, FM-AM Signal Generators.

At the request of several customers who had a need to perform similar measurement of frequency deviation, the Type 208-A FM Linear Detector has been put into production and is now available for sale.

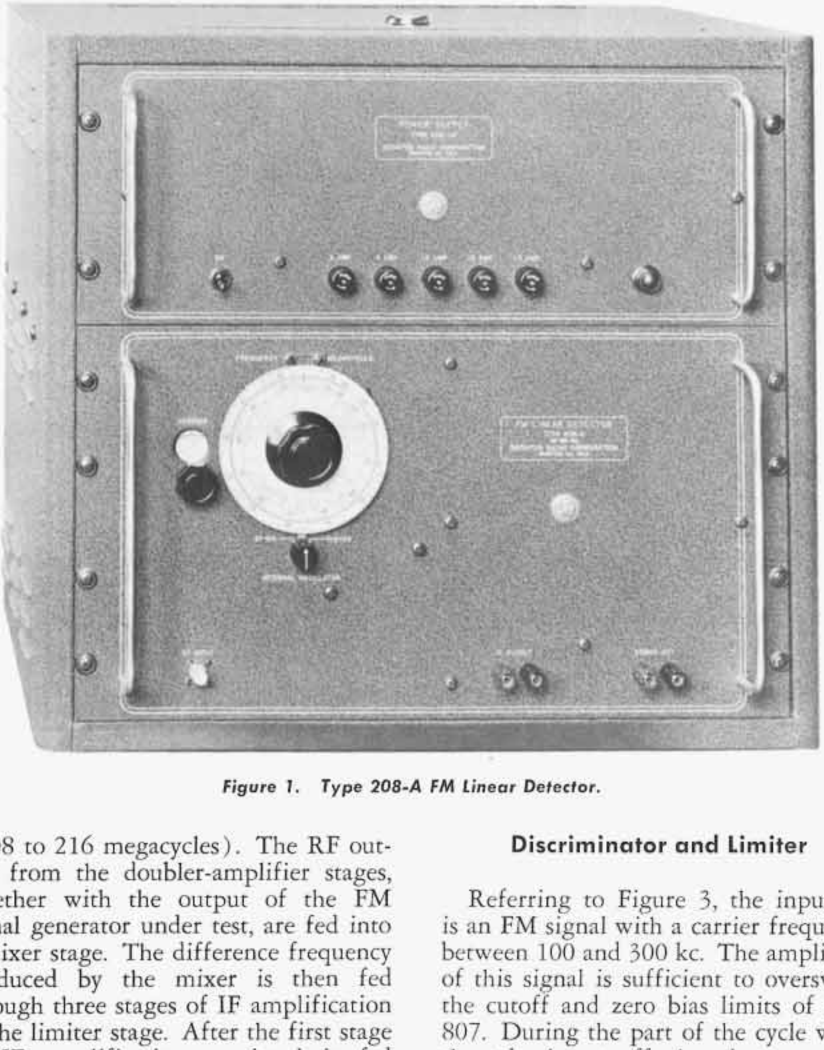

Figure 1. Type 208-A FM Linear Detector.

Operating Principles

The basic circuit elements of the FM Linear Detector are shown in block diagram form in Figure 2. The RF oscillator, doubler, amplifier-doubler, mixer, and RF amplifier stages of the Linear Detector are conventional circuits that operate to produce a signal usable for detection purposes. Actual detection is accomplished in the limiter and discriminator circuits shown in simplified schematic form in Figure 3. A type 6C4 triode, tuned over a frequency range of 27 to 54 megacycles is used as an RF oscillator. The output from the RF oscillator is fed to a Class C frequency-doubling stage tuned to the second harmonic of the oscillator frequency (54 to 108 megagcycles) which drives a Class C stage operating as a frequency doubling stage on the high frequency range (108 to 216 megacycles). The RF output from the doubler-amplifier stages, together with the output of the FM signal generator under test, are fed into a mixer stage. The difference frequency produced by the mixer is then fed through three stages of IF amplification to the limiter stage. After the first stage of IF amplification, a signal is fed through a cathode follower stage to the IF terminals for use in AM measurements.

The limiter stage squares the top and bottom of the signal wave. This square wave signal is then fed to the discriminator where it is converted to a single uniform pulse of current for each cycle. The current pulse rate follows the repetition rate or frequency of the incoming signal.

A low-pass filter is connected across the output of the discriminator to remove undesired signal frequency components and to allow the instantaneous potentials to rise and fall with each discharge of a current pulse. The demodulated output of the detector is a varying unidirectional potential directly proportional to the IF frequency.

Discriminator and Limiter

Referring to Figure 3, the input e_{in} is an FM signal with a carrier frequency between 100 and 300 kc. The amplitude of this signal is sufficient to overswing the cutoff and zero bias limits of tube 807. During the part of the cycle when the tube is cut off, the plate potential will rise to the level of E_B. When the grid is positive, the plate current will rise to a maximum value. Any further increase in positive grid swing will not increase the plate current. It can be seen then that the minimum and maximum values of instantaneous plate potential in tube 807 are held constant, producing an output wave which is squared off, top and bottom, at definite fixed potentials and which is unaffected by possible variations in grid-swing amplitude. This square wave of plate voltage has a repetition rate equal to that of the input signal, e_{in}.

During the part of the cycle when the plate potential of tube 807 reaches its peak value (E_B), capacitor C_1 is charged through diode d_1 of tube 6H6 to a potential equal to E_B. When the plate potential of tube 807 swings toward its lowest value, capacitor C_1 discharges through diode d_2 of tube 6H6 in series with its load, R_3. This action causes one pulse of current to flow through resistor R_3 for each cycle of operation.

The total charge taken by capacitor C_1, once each cycle, is CE. (A small bias voltage in series with the charge diode d_1 effectively overcomes the contact potential of both diodes d_1 and d_2, therefore, the effect of this potential may be discounted.) The portion of this total charge which passes through diode d_2 and resistor R_3 of tube 6H6 is equal to the total charge (CE_B) minus the residual charge (Ce_{pmin}).

With E_B and e_{pmin} held constant, and the time constants of the charge and discharge circuits sufficiently small compared to the input wave period, the total quantity of current flowing through R_3 during each cycle is constant. An increase in the repetition rate (frequency) of the incoming signal will increase the number of current pulses per unit of time, thereby increasing the average value of current flowing through R_3. Conversely, a decrease in the repetition rate of the incoming signal will decrease the average current through R_3. The average potential across R_3 then is a perfectly linear function of the frequency of the incoming signal and the dynamic operation of the detector will result in essentially distortionless detection.

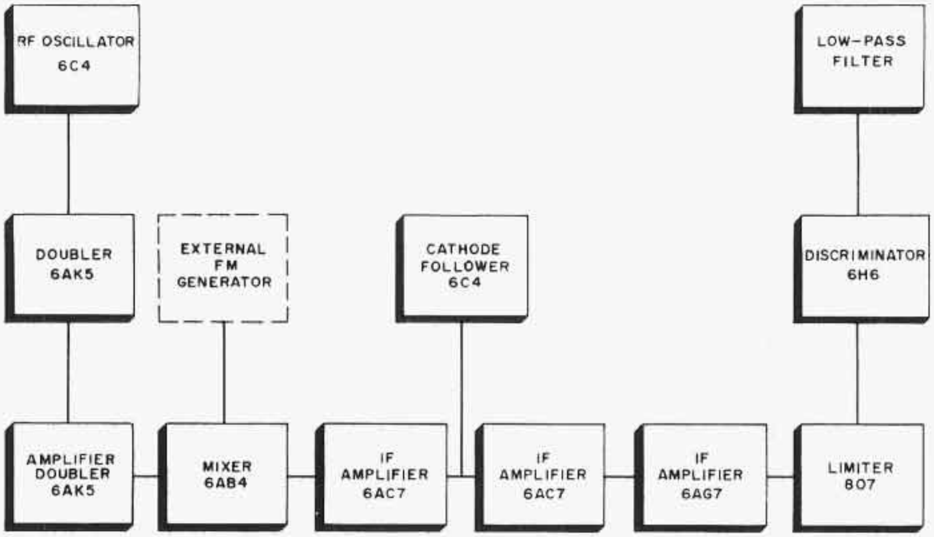

Figure 2. Basic circuit elements of the Type 208-A FM Linear Detector.

Calibration

The Linear Detector is accurately calibrated at the factory to provide a voltage versus frequency deviation coefficient for frequency deviations up to ±300 kc at an intermediate frequency of 350 kc. However, it is advisable, because of component aging, to recalibrate the instrument periodically during normal use. Either of two methods, the Static Method or the Bessel Zero Method, may be used to accurately calibrate the Linear Detector.

Static Method

The Detector is interconnected with an FM signal generator, a frequency calibrator, and an accurate DC measuring device. The generator is connected to the Detector's RF INPUT terminals, the frequency calibrator is connected to the IF OUTPUT terminals, and the DC measuring device is connected to the DEMOD OUT terminals.

With the frequency dials on the signal generator and the Detector set to the same frequency, the DC measuring device will read zero. Advancing the Detector frequency dial to provide 100 kc difference frequency, as indicated by the frequency calibrator, will cause a voltage reading to be indicated by the DC measuring device. This reading is noted and the Detector frequency dial is advanced again until a 200 kc difference frequency is indicated by the frequency calibrator. The voltage reading at the DEMOD OUT terminals is again noted. This procedure is repeated at each 100 kc increment until a 1 megacycle signal is indicated by the frequency calibrator, the output voltage being recorded for each step. The voltage readings obtained are the n plotted on a graph with voltage as the "Y" axis and frequency as the "X" axis. The resultant curve will yield a straight-line section, whose upper and lower limits indicate the frequency points in the frequency spectrum between which linear operation of the Detector should be expected. With the DC voltage for these two frequency deviations known, any deviation (within the linear limits) may be ascertained by using the frequency versus voltage coefficient.

Bessel Zero Method

This method of calibration requires the use of a signal generator, an accurate 10-kc audio signal source, and a heterodyne-type receiver containing a BFO. The RF output of the signal generator is connected to the receiver and the receiver is tuned to the unmodulated carrier frequency of the generator to obtain a beat frequency of several hundred cycles, using the receiver's BFO. This frequency is monitored with earphones or a voltmeter. With the signal generator modulation control set to produce a 10-kc FM modulating signal, the FM deviation control is advanced slowly.

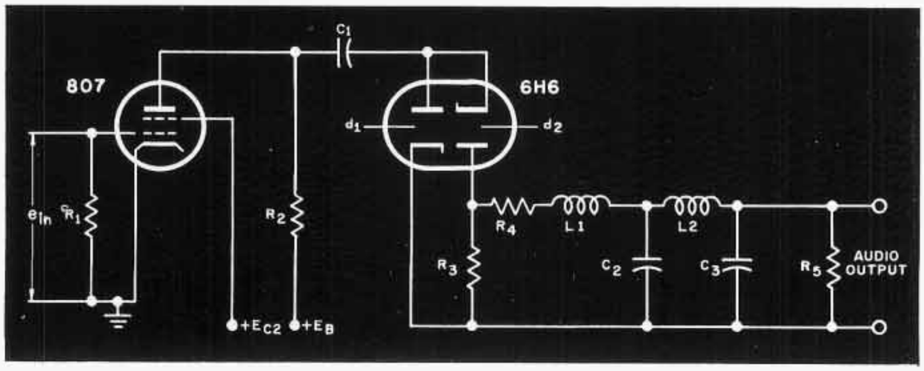

Figure 3. Basic detector circuit.

The beat frequency will disappear at certain points as the deviation is increased. These null points correspond to specific modulation indices, the first several being: 2.405, 5.520, 8.654, 11.792, and 14.931. Frequency deviation values at these null points are then calculated using the Bessel function as follows:

$$B = \frac{\Delta F}{f}$$

Where: B = modulation index
F = frequency deviation (kc)
f = modulating frequency (kc)

After the first null is detected, the receiver is disconnected and the generator signal is fed to the RF INPUT terminals on the Linear Detector. The Detector is tuned to 350 kc IF frequency deviation to insure operation within the linear region. A peak-reading AC voltmeter connected to the DEMOD OUT terminals on the Detector will indicate the voltage output for the deviation calculated for the first null. The procedure is repeated for each null point, and the voltage output obtained for each calculated frequency deviation is recorded. These voltages are then plotted against frequency deviation to produce a curve whose straight-line portion again indicates the linear limits of the Detector.

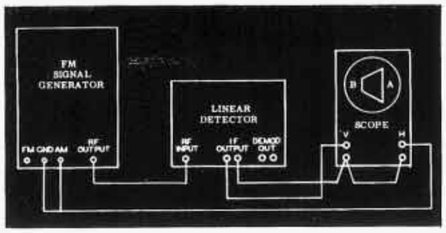

Figure 4. ***Connections for percent AM measurement showing trapezoidal display.***

Application

The FM Linear Detector, as was previously explained, has been designed especially for the measurement of FM frequency deviation. With the instrument calibrated as explained above, its frequency deviation versus voltage output coefficient is known. Measuring frequency deviation becomes merely a matter of multiplying the voltage output reading at the DEMOD OUT terminals of the Detector (produced as a result of the FM signal fed into the Detector) by the frequency deviation versus voltage coefficient.

The Detector may also be used to measure the degree of amplitude modulation of a signal source. For this measurement, an external signal source is mixed with a signal produced by the Detector to provide a difference frequency of approximately 100 to 150 kc at the Detector's IF OUTPUT terminals. This difference frequency is then displayed on an oscilloscope as a trapezoidal pattern, similar to the trapezoidal pattern shown in Figure 4. The lengths of the vertical sides of the pattern (A and B) are then applied to the following equation to indicate the percentage of amplitude modulation.

$$\text{Percent AM} = \frac{A - B}{A + B} \times 100$$

Conclusion

The Type 208-A FM Linear Detector is a precision instrument capable of performing accurate FM and AM measurements in the engineering laboratory or on the production line. It will doubtless become a valuable aid to those customers who have measurement problems of this nature.

BRC Film Gauge Used To Measure Aircraft Organic Finish Thickness

The Glenn L. Martin Company Reports On a New Method Approved by The Navy

At the request of the Bureau of Aeronautics, The Glenn L. Martin Company of Baltimore, Maryland recently prepared a report entitled, "A New Method for Measuring Aircraft Organic Finish Thickness," which describes a new method employing the Boonton Radio Corporation Type 255-A Film Gauge.

The Film Gauge was introduced to The Martin Company by BRC as a means for measuring thickness of metallic plating finishes over nonferrous metal surfaces and its principle of operation was later proposed as a means for measuring aircraft organic finish thickness. The Martin Company subsequently conducted a research program to test the suitability of the Film Gauge for this purpose.

Many finishes were tested by The Martin Company to find a correlation and mode of operation which would prove that practical measurements could be made with the Film Gauge. A correlation was found, preliminary calibrations were performed to confirm it, and a report proposing the new method was issued by The Martin Quality Division Laboratory. This report was later submitted to the Bureau of Aeronautics who gave tentative approval of the method. The method was then evaluated by the Naval Air Material Center Laboratory. Results of this evaluation concurred wih Martin's and full acceptance of the method was published in a report from Naval Air Material Center.

The report prepared by The Martin Company at the request of the Bureau of Aeronautics was prepared by Norman R. Keegan, Chemical-Physical Engineer. In his report Mr. Keegan describes in detail the methods used in determining the accuracy of the Film Gauge for this specific application. Step-by-step procedures are given for operation of the Film Gauge for finish thickness inspection, and special instructions are included for specific applications.

The Martin Report has been reprinted by Boonton Radio Corporation for distribution to interested customers. Copies will be furnished upon request.

EDITOR'S NOTE

BRC Promotions Announced

The appointments of Mr. Frank G. Marble as Vice President and General Manager and Mr. Harry J. Lang as Sales Manager effective July 1st were announced by Dr. George A. Downsbrough, President of Boonton Radio Corporation.

Mr. Marble, formerly Vice President-Sales at BRC, succeeds Dr. Downsbrough as General Manager. Dr. Downsbrough will continue as President, Treasurer, and a Director.

Frank G. Marble

Mr. Marble has been associated with Boonton Radio Corporation since 1951. He served as Sales Manager until 1954 when he was appointed Vice President-Sales.

Prior to his associaion with BRC, Mr. Marble's career covered a broad field of engineering experience. He held design and development posts for seven years with Philco Radio and Television Corporation and Western Electric's electrical research division. Later, he served in engineering administrative positions with Bell Telephone Laboratories and Pratt and Whitney Aircraft Corporation. During the three-year period just preceding his association with BRC, Mr. Marble served as Sales Manager for Kay Electric Company.

In 1934 Mr. Marble received his BS degree in Electrical Engineering from Mississippi State College. He earned his MS in Electrical Engineering from the Massachusetts Institute of Technology in 1935.

Mr. Lang joined Boonton Radio Corporation in 1949 as a production engineer and successively served as project engineer, contracts engineer, and sales engineer. In 1954 he left BRC to study for his master's in Business Administration at the Harvard Business School.

Before returning to BRC, Mr. Lang served as sales engineer in charge of sales for the newly-formed Industrial Products Department of Airborne Instruments Laboratory.

Mr. Lang received his BS degree in Electrical Engineering from the Massachusetts Institute of Technology in 1949. During his studies there, he was an engineering trainee at Western Electric Co., New Jersey Bell Telephone Co., and Bell Telephone Laboratories.

From 1945 to 1946 he was a junior engineering officer with the U. S. Merchant Marine.

Harry J. Lang

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