



# The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

JUL 24 1958

## A Control System for an FM Signal Generator

CHARLES G. GORSS, *Development Engineer*

The oscillator in an accurate fm system has two rather incompatible requirements impressed upon it. First, it must be stable: its frequency must not change so much as 0.001% under the influence of environment, input voltage changes, or prolonged usage. On the other hand, it must respond cheerfully and faithfully to a command to deviate from its assigned frequency according to an applied modulating wave and return instantly to its preassigned frequency when the impressed voltage is removed. Of course, these demands upon an oscillator in an fm system are not impossible to meet, nor are they new. FM transmitters, employing many different techniques, have fulfilled these requirements for many years. Some of these methods are much too complicated and inflexible for incorporation into a portable signal generator, and therefore have been discounted for this discussion. Instead, a system will be presented which has been developed specifically for use in a crystal controlled signal generator (Figure 1), but whose accuracy features make it equally suitable for use in a transmitter.

### FM Oscillator

Basically the oscillator to be used is a simple triode oscillator with a tuned plate circuit (Figure 2). A conventional reactance tube circuit has its plate tied to the oscillator plate. In this case the 90° phase shift to the grid is such that the current through the tube lags the voltage across it by 90° and the react-

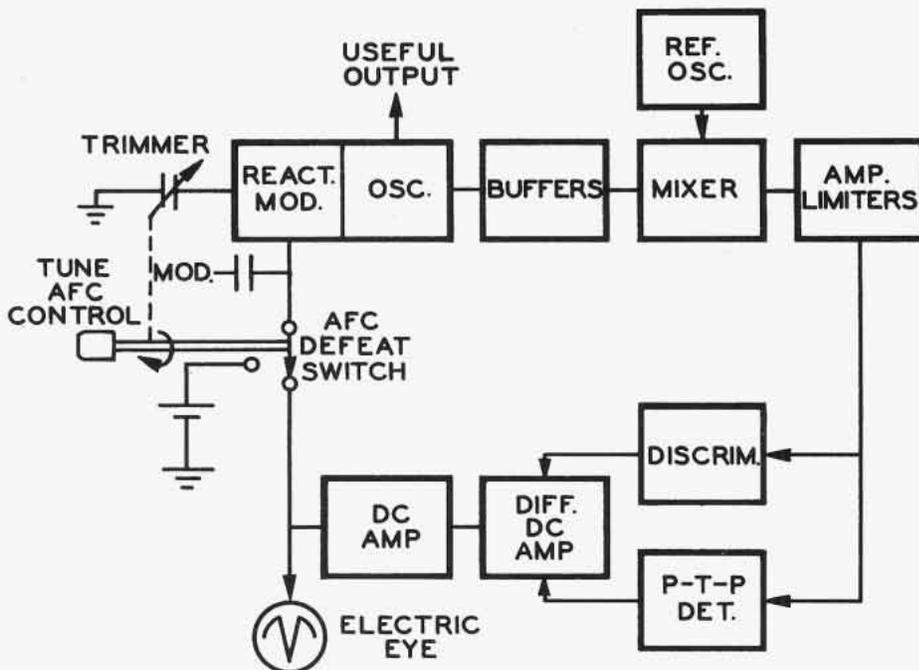


Figure 1. Block Diagram of Overall System.

ance tube looks like an inductance whose value can be varied by varying the control grid voltage. An ac voltage applied to the control grid modulates the oscillator in the prescribed manner by varying the reactance tube inductance.

To keep the center frequency where it belongs, a monitoring device constantly monitors the number of cycles of rf occurring in a unit of time. This unit of time is long compared to a cycle of modulation, but short enough to correct for the factors which will bring about unwanted frequency shifts such as thermal changes, filament voltage drifts, and the slow changes that might occur in component values. Fortunately all of these normal instability factors are measured in seconds or longer, while the modulation periods are no longer than 1/20 of a second. The frequency monitor then applies a dc voltage to the reactance tube grid, bringing about a

steady-state change in inductance which is of the proper direction and amplitude to correct the center frequency.

### Reference Oscillator

The first objective in the frequency monitoring system should be to establish a stable reference to which the oscillator can be compared. A natural choice for this is a crystal oscillator operating near the unknown frequency. The reference oscillator chosen here is a conventional two-tube Butler oscillator (Figure 3) operating on the fifth overtone of a series resonating crystal, which is kept in a temperature-controlled oven for frequency stability. The fm oscillator and reference oscillator frequencies are mixed in a suitable device and the difference frequency is then monitored. Since the unknown varies back and forth with modulation, some offset is required to

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insure that the difference observed is always in the same direction. If this were not done, and should the difference pass through the zero beat, the result would lead to ambiguity because a certain frequency difference would produce the same beat note, whether it were above or below the reference.

A difference frequency of 100 kc was chosen for this system because the widest deviation to be expected would be 75 kc. This allows 25 kc of safety before zero beat is reached. If broader deviation were required, wider separation would have been considered. To consider specific numbers, the frequencies selected for the system are 48 mc for the carrier and 47.9 mc for the reference oscillator.

By adding the reference, the requirements put upon the frequency monitor are greatly relaxed. For example, a requirement of 0.001% maximum error at 48 mc represents a frequency error of 480 cycles. Four hundred and eighty cycles out of the 100-kc difference on the other hand is roughly 1/2%. This is approximately a 500 to 1 reduction in the stability which will be required of the frequency monitoring device. Using this approach, it is obvious that it is desirable to reduce the difference frequency to a minimum which is set by the requirements for modulation.

In practice, it is necessary to separate the carrier oscillator from the mixer where the 100-kc difference is generated, in order to prevent modulation of the carrier oscillator by the 100-kc difference frequency. Two cascaded, grounded-grid amplifiers with capacitive voltage dividers are employed to reduce the net stage gain to unity and increase the isolation. This reduces the incidental AM caused by the 100 kc, to a level well below 1/2%.

**Discriminator**

A counter-type frequency discriminator (Figure 4) is used to measure the IF and produce a dc output proportional to

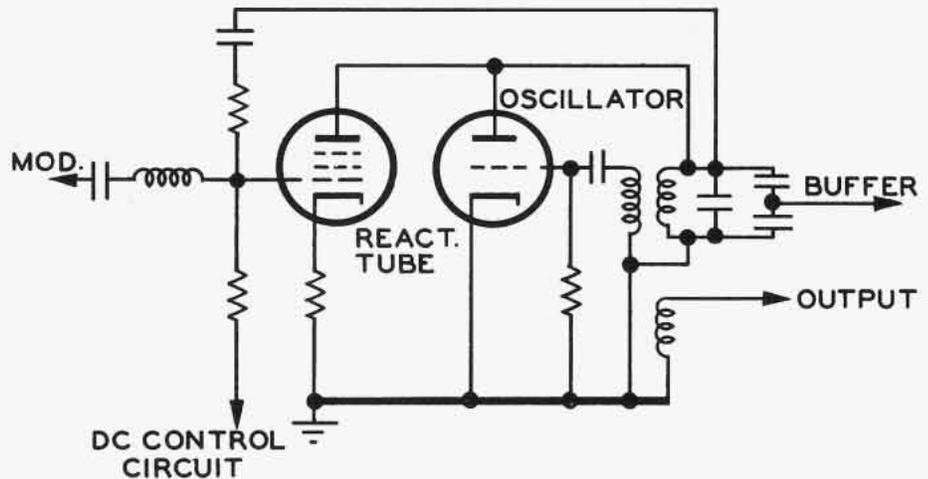


Figure 2. Reactance Tube Oscillator.

this frequency. In this circuit, a low-value capacitor is charged to a fixed voltage on each positive cycle and discharged into a high-value capacitor on each negative half cycle. A resistor connected across the high-value capacitor constantly discharges it. The voltage on the high-value capacitor therefore is directly proportional to the rate at which the charging cycles occur, since each charging cycle delivers a constant charge ( $Q = CE$ ; C being the low-value capacitor and E the fixed voltage to which this capacitor charges).

**Limiters**

To assure constant charging voltage, several stages of limiting are included between the mixer, where the 100-kc IF is produced, and the discriminator.

**Detector**

There is still a possibility of instability in the output of the discriminator, because the output of the limiters can fluctuate slightly with changes in supply voltages and component values. A change in the limiter output will result in a change in discriminator output

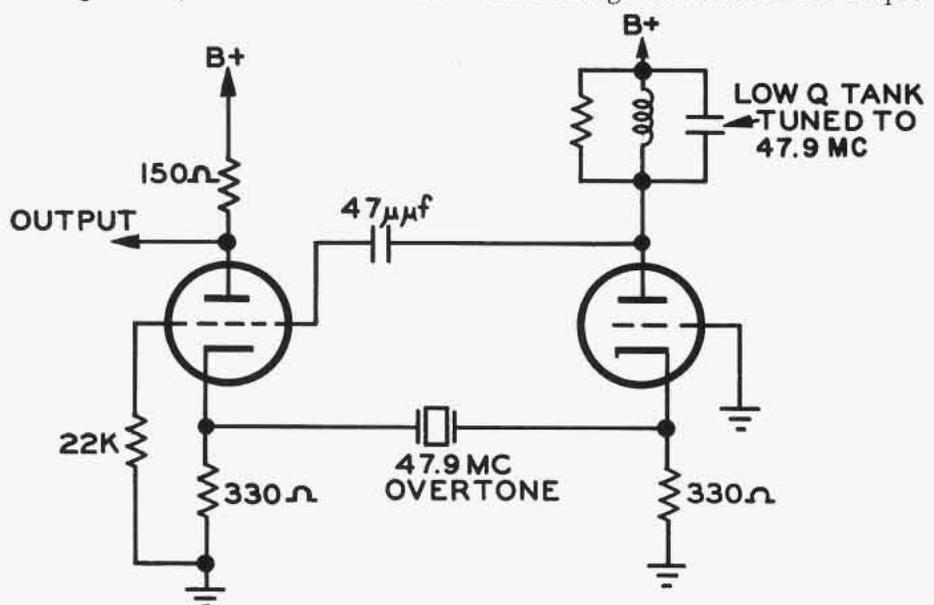


Figure 3. Reference Oscillator.

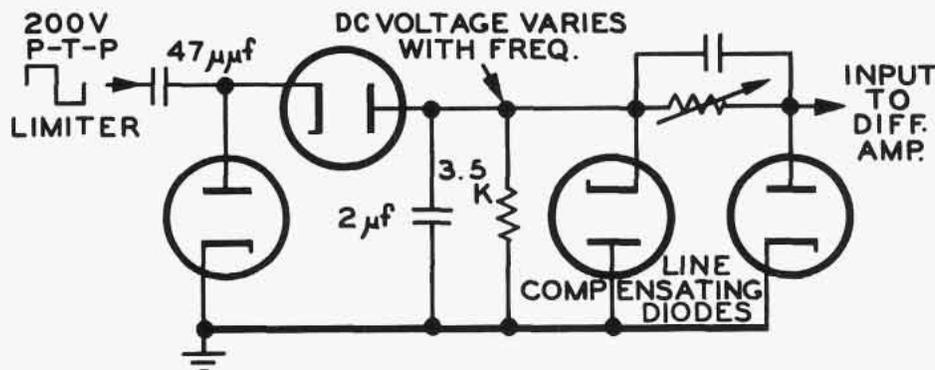


Figure 4. Frequency Counting Discriminator.

which is exactly proportional to the change in limiter output. In order to cancel out any such instability, a peak-to-peak diode detector is also coupled to the output of the limiter. The output of this detector is relatively independent of frequency, but varies directly with peak amplitude.

#### Differential DC Amplifiers

The discriminator output is connected to one input of a differential dc amplifier, and the output of the peak-to-peak detector is connected to the other input of the differential dc amplifier. Since the output of the peak-to-peak detector is much higher than the output of the discriminator, it must be first divided down to match the output of the discriminator. The differential dc amplifier is so designed that only a difference between the two inputs will result in an output variation. If both inputs vary simultaneously, as would result from a limiter output level change, no change in output results. However, should the frequency change, only the output of the discriminator would vary and an output change would appear amplified in the output of the differential dc amplifier.

The output of the differential amplifier is amplified further in another dc amplifier and then coupled back to the grid of the reactance tube. Inasmuch as the output of the last dc amplifier is at a plate voltage level, it is necessary to refer this output down to the grid voltage of the reactance tube. This is accomplished by returning a voltage divider off the plate of the dc amplifier to a negative supply of roughly  $-150$  volts. Since the plate voltage is about  $+150$  volts in this case, a tap about half way down the divider results in proper grid potential with a loss in forward gain of only 6 db.

With the grid connected to the out-

put of the dc amplifier the system will react strenuously against any change in frequency. The forward gain following the discriminator is sufficient to reduce any change in the natural resonant frequency to less than 1/100 of that change.

#### AFC Defeat

As might be expected, there is a flaw in this scheme. When the control circuit is first energized and the supply voltages are building up at various rates, it is possible that the 48-mc oscillator, under the influence of a reactance tube warm-up transient, might be forced down to 47.8 mc. This would result in 100-kc difference between the reference oscillator and the fm oscillator; the same difference obtained with the fm oscillator operating at 48 mc. The trouble here is that the phasing in the system is reversed. Normally an increasing frequency would result in an increasing difference. In this case however, an increase in the fm oscillator frequency will result in a decrease in the 100-kc difference. The system is so phased that a decrease in IF results in a voltage coupled to the fm oscillator which will increase the oscillator frequency, and result in pushing the oscillator back to where it belongs. This is true as long as the frequency never gets lower than 47.8 mc. Should the frequency fall below 47.8 mc, the IF would be higher than the normal 100 kc. The discriminator would then operate as if the frequency were too high, resulting in an output to the reactance tube grid which is in the direction to lower the oscillator frequency. Once this action starts, there is no stopping it until all of the amplifiers and the reactance tube are saturated and can go no further.

To break this deadlock, a momentary switch is added which breaks the AFC loop (Figure 1) and connects the reactance tube grid to a fixed voltage

which is its normal operating voltage. This allows the oscillator to return to a point close to 48 mc. When the loop is closed again, the AFC action returns to normal and the 48-mc frequency is restored.

#### Electric-Eye Indicator

A 6E5 indicator tube is used as an indication of proper operation. When the output of the last dc amplifier is normal, the eye is approximately half open. If the system is out of control, the eye is completely closed. Therefore, anyone observing the eye will get an immediate indication of proper or improper operation of the system. Since the gain of the dc amplifier is quite high it takes little change in frequency to cause the eye to go from the full-open to the full-closed condition.

Another use is made of this indicator. It is desirable that the reactance tube operating point be fairly constant since it is being used for fm modulation. In time, a drift in component values would result in the operating point of the reactance tube being shifted far off to one side of the linear range in order to hold the frequency accuracy, causing the modulation distortion to increase. To correct for this, an oscillator fine trimmer is coupled to the momentary AFC disabling switch in such a manner that the operator can depress the switch button and then turn it, causing variation of the internal trimmer capacitance. Proper frequency is indicated at the point where the eye begins to change from the open to the closed condition or vice versa. The actual frequency range spanned from the full-open to the full-closed condition is so small that exact adjustment to the half-open condition is not possible. This is of no consequence because exact adjustment will be automatically attained when the control loop is restored. What is important here, is that the frequency is close enough so that no large shift in the reactance tube operating point is required. The range of the trimmer is small enough and so centered that one could never reach 47.8 mc. If it were possible to reach 47.8 mc, the IF would again be 100 kc and ambiguity would result. Because the drifts being compensated for are relatively small, a range of more than 100 kc is unnecessary.

#### Voltage Regulation

In order to obtain the desired stability from this system, all dc power sup-

plies are well regulated against line fluctuations and all filaments in the dc amplifiers and discriminator circuit are regulated by a ballast-type regulator. However, even with this regulating system, small variations in frequency result from the small changes in filament voltage and, to a lesser degree, from small changes in dc potentials. To eliminate this problem a simple line voltage compensator (Figure 4) has been employed. The compensator, consisting of two 6AL5 diode sections connected in series, produces a few tenths of a volt as a result of cathode emission; the voltage varying with line voltage. If a part of this voltage is placed in series with one of the dc amplifier grids, and the polarity and level is adjusted properly, all frequency variations due to line voltage can be cancelled. The relationship between filament voltage and this correction voltage is not very linear, but since the 6AL5 tubes are also regulated by the same ballast that regulates the critical stages, their voltage swings very little. A small section of this curve is fairly straight and the correction is quite useful. In practice, the amount of the voltage coupled in series with the grids from the diodes is adjustable and the frequency can be made remarkably independent of line voltage. Since almost all line instability is due to the filament shift, the time constant of the correction is also well matched.

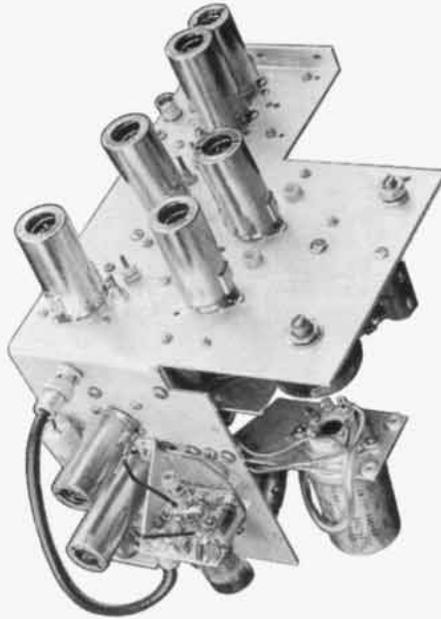


Figure 5. FM Unit for Type 242-A Signal Generator.

#### BRC Type 242-A Signal Generator

In the BRC Type 242-A signal generator, where it is used, the system discussed here maintains a frequency accuracy of 0.0005%. It produces frequency modulation of 75 kc deviation with audio frequencies well over 100 kc, with less than 1% distortion. The

output of the system is added to one of 150 different crystal frequencies. The sum frequency is then multiplied by 4 to produce 1-mc channels running from 400 to 550 mc at a maximum deviation of 300 kc (75 times 4).

Because the Type 242-A is designed to operate in an ambient temperature range of  $-40^{\circ}\text{F}$  to  $+137^{\circ}\text{F}$ , the entire fm oscillator control circuit is contained in a chamber in which the temperature is thermostatically controlled. This would not be necessary at normal room ambient range as the internal thermostat only holds within  $\pm 10^{\circ}\text{F}$ .

#### Conclusion

The general principles and circuitry used in the system described here could be easily applied to any simple channel fm oscillator such as a transmitter. It is obviously not suited to variable frequency operation, but through the use of the adding system employed in the Type 242-A, could be a part of a flexible system.

#### Bibliography

1. "A Crystal-Controlled FM Signal Generator," Gorss, C. G., BRC Notebook No. 16.
2. "Vacuum Tube Circuits," Arguimbau, L. B., Pages 467, 502, and 521.

## Signal Generator Performance

HARRY J. LANG, *Sales Manager*

As designers and manufacturers of laboratory signal generators since 1941, we have come to establish certain standards of performance for this type of instrument which should be of interest to both the designer and the user. While some of these standards may be termed implied and form a nucleus of "unwritten specifications", they are, in many cases, of paramount importance in the selection of a signal generator for a particular application. In this article, an attempt will be made to outline these standards of performance which actually underlie our design philosophy.

A signal generator, in the broadest sense, may be defined as a precise signal source of known, stable, and controllable characteristics. Basically, the device must generate a signal of known frequency, level, and modulation and may be specified in terms of accuracy, settability,

readability, stability, reliability, and convenience.

#### Accuracy

Here we are concerned with the absolute accuracy of frequency, output, and modulation. For a device to qualify as a signal generator, in terms of the current state of the art, frequency accuracy must, in general, be better than 1% at all points within its range. All unwanted spurious outputs should be minimized to a level at least 30 db below the desired output frequency. Output must be directly calibrated to an accuracy of between 1% and 20%, depending upon the region of the frequency spectrum within which the device operates, with accuracy generally decreasing with increasing frequency. Output level must be continuously vari-

able over a range of from roughly 10% to typical system sensitivities to better than 1000% of this value. Basic accuracy must be maintained at all output levels at a constant impedance, and leakage should be negligible at the lowest calibrated output level.

Modulation, whether amplitude, frequency, pulse, or phase, should be directly calibrated to better than 10% and should be continuously variable over a range covering all current system requirements. Unwanted modulation by-products; e.g., incidental fm, or am on fm, must be reduced to a negligible level and the modulation system must operate with specified accuracy over the range of modulating frequencies normally encountered in system operation. Modulation purity, or distortion, must also be minimized to provide a signal that will permit accurate evaluation of



Figure 1. Type 150-A Signal Generator, First FM Signal Generator to be Manufactured by BRC.

the distortion products generated within the system under test.

### Settability

Here, again, we are concerned with the fundamental characteristics of frequency, output, and modulation with basic requirements dictated by the system to be tested. Settability may be generally specified at better than 10 times basic accuracy and modified by special system requirements. For example, narrow-band, crystal-controlled communication receivers require frequency settability in the order of 0.001%.

The matter of repeatability of settings also becomes extremely important since, in many cases, the generator as a development tool, is used to sense minute changes in circuit characteristics rather than absolute values. Furthermore, since certain specialized applications may require individual calibration of generators to a fraction of their generally specified accuracy, the calibration accuracy that can be obtained will be directly determined by both settability and repeatability.

### Readability

While this characteristic is closely related to both accuracy and settability, it is important to note that sufficient calibration points must be provided to permit direct interpolation to specified accuracy at all points within the operating range. Conversely, the use of an excess number of calibration markings may be misleading and imply a level of accuracy inconsistent with generator performance.

### Stability

A signal generator, to perform its intended function, must provide specified

accuracy independent of external conditions encountered in normal operation. Factors which must be considered in signal generator design, include the following:

#### 1. Input Power Supply.

Since all commercial sources of power provide regulation in the order of 5%, and further, since laboratory or production line applications may be further aggravated by local load conditions, signal generators must be designed to operate with minimum line input variations of  $\pm 10\%$ .

#### 2. Ambient Temperature.

Since both factories and laboratories may experience ambient temperatures varying between 50°F and 100°F, adequate compensation must be incorporated into the generator design to provide specified accuracy over this range.

#### 3. Vibration.

Since many generators will be operated in plants where vibration from heavy production machinery will be encountered, every effort must be made to reduce variations in frequency and output as well as spurious modulation from this source.

#### 4. Operating Cycle.

Since most generators are not operated on a continuous duty cycle, adequate provision must be made to minimize the warmup time required to obtain specified performance.

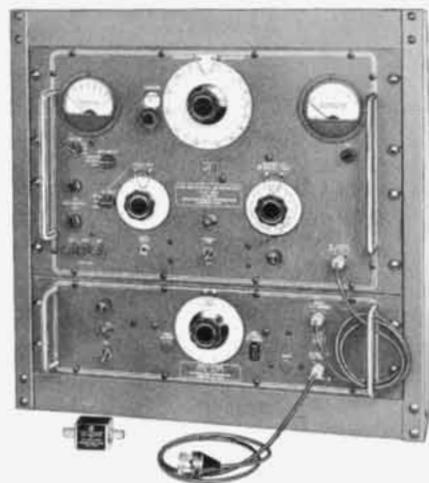


Figure 2. Rack Mounted View of the Type 202-F Signal Generator and the Type 207-F Inverter.

### Reliability

Though the area of reliability is currently under continuous discussion in the field of military electronics, it is

sometimes under-emphasized with respect to commercial equipment. Downtime and repair expense are not always catastrophic in the case of commercial test equipment, but they do represent lost value to the user. A well-designed signal generator should provide a minimum of ten years reliable service with only the need for occasional replacement of tubes and certain other minor components that may have a shorter life cycle. Rugged mechanical design, coupled with adequate derating of electrical components, is necessary for reliable service.



Figure 3. Type 240-A Sweep Signal Generator.

### Convenience

A well-designed signal generator should permit simple, rapid, foolproof operation by using personnel. All controls and dials should be legibly marked to show their function; dial scales should be direct reading and readily visible under laboratory conditions with a minimum of eye strain. All front panel controls should be grouped functionally and should be human engineered for ease of adjustment. The use of correction charts and nomographs should be avoided.

While this discussion of signal generator performance is not intended to be all-inclusive, we have tried to outline the major considerations given to the design of our products in this field: these considerations being an outgrowth of experience, gained over the years, in

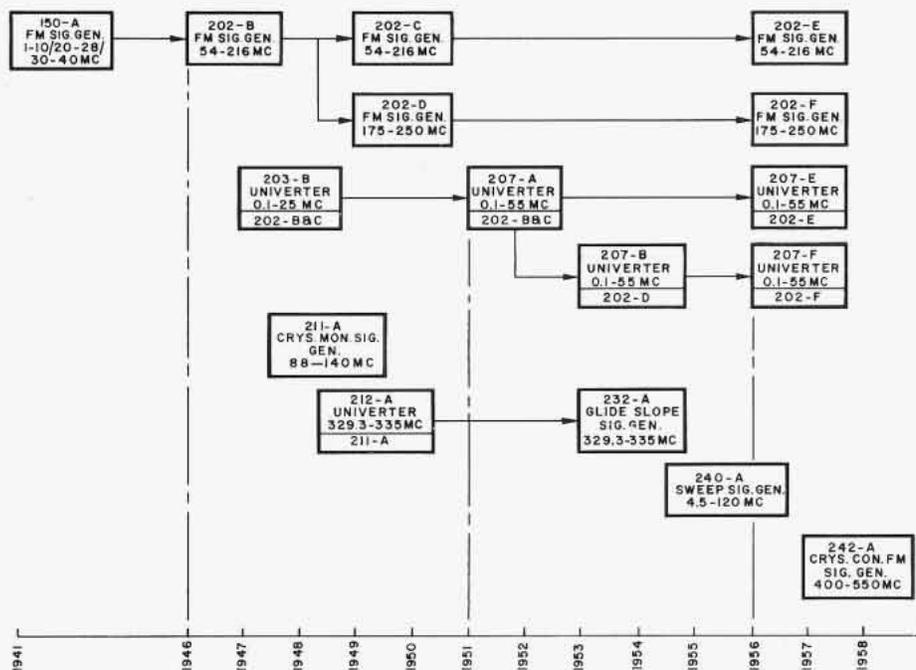


Figure 4. Development and Evolution of BRC Signal Generators.

signal generator design. In 1941, BRC produced the first commercial FM Signal Generator, our Type 150-A (Figure 1). We have continued to specialize in the field of FM and now produce our Types 202-E and 202-F (Figure 2) FM-AM Signal Generators in which we have attempted to provide instrumentation to meet the ever-changing requirements of current day systems. The Types 207-E and 207-F Univerters are companion accessories for these generators and provide extended frequency coverage. Sweep Signal Generator, Type 240-A (Figure 3), offers signal generator performance in a wide-band sweep source. The Type 211-A Crystal Monitored Signal Generator and the Type 232-A Glide Slope Signal Generator are specifically designed for the testing and calibration of aircraft ILS and Omni-Range systems. Our latest, the Type 242-A Crystal-Controlled FM Signal Generator provides fm outputs with crystal accuracy. Figure 4 historically traces the development and evolution of these products.

## MEET OUR REPRESENTATIVES

### CROSSLEY ASSOCIATES

HARRY J. LANG, Sales Manager

*The first in a series of articles intended to provide a capsule history and facilities report on the sales representatives who sell and service BRC products throughout the world.*

Founded in 1937, Crossley Associates of Chicago, Illinois, is the oldest engineering sales representative organization in the Midwest specializing in the field of electronic instrumentation. Pioneers in technical customer service, they have helped to establish distribution channels for the entire instrument industry and have developed application engineering techniques and set standards of performance for others in this field.

Alfred Crossley, President and Founder of the company, has been active in the radio and electronics field since 1916 and holds numerous electronic patents. Notable among these is a patent for a



ALFRED CROSSLEY  
President and General Manager

crystal-stabilized oscillator. After filling many key engineering posts in the radio

industry, he entered the field of consulting engineering and subsequently made the transition to engineering sales representation in 1937. Boonton Radio Corporation, in order to provide a new level of customer service to the growing electronics industry in the Midwest, became the first manufacturer to engage the services of the newly formed engineering sales company. Crossley Associates thus became the first representative for BRC products.

Over a period of twenty-one years, Crossley Associates has vastly expanded and modernized both its facilities and services to keep pace with the ever-changing needs of the electronics industry. With headquarters in Chicago, the organization now maintains three branch sales offices in Dayton, Indianapolis, and St. Paul to provide local service for customers throughout the Midwest area. In three modern, well-equipped service laboratories, complete facilities are maintained for the evalua-



Chicago Headquarters Crossley Associates

tion, application engineering, calibration, and repair of all of the products manufactured by fourteen leading producers of precision electronic equipment. Clerical services are provided for the distribution of technical information and a separate department processes all phases of customer orders including placement, expediting, and factory liaison. Direct TWX service between all sales offices and factories offers up-to-the-minute customer information.

Frank Waterfall, the company's Vice President and Sales Manager, joined Crossley Associates in 1946 after post-graduate studies at Indiana University and the University of Minnesota, augmented by extensive instrumentation experience at the Naval Research Laboratory during World War II. Other members of the Crossley family include ten field engineers who devote their entire effort to the solution of customer measurement problems, and an additional twenty office personnel who support all field engineering activities.

A strong believer in education, Crossley Associates maintains scholarship programs with twelve major Midwestern universities. The field engineers operate under a continuous educational program which includes technical field seminars and factory training courses. Two Crossley trainees are currently attending universities to complete and broaden their engineering education.

It is Crossley Associates' policy to apply, sell, and service the finest in precision electronic instrumentation and components for the communications, electronics, and electromechanical meas-

urement fields. Service is perhaps the most important part of the business since it transcends many years beyond the initial sale of a product. Both Crossley and BRC believe they are duty-bound not only to place in the hands of their customers the proper instrumentation for their particular application, but also to ensure that these products continue to provide precise, reliable answers to ever-changing problems in the rapidly expanding field of electronics.

We at BRC proudly salute Crossley Associates for their continuing record of faithful service to our many customers throughout the Midwest.



FRANK WATERFALL  
Vice-President and Sales Manager

## SERVICE NOTE

### Modification of Glide Slope Signal Generator, Type 232-A, For Improved RF Output

Some time ago, BRC received reports of Type 232-A breakdowns which were attributed to loss of rf output. The instruments concerned exhibited a rapid decrease in rf output. This decrease in rf output resulted in the loss of output reserve, and eventually brought about a condition where "red line" operation and consequently satisfactory operation of the signal generator was no longer possible.

After extensive investigation of the problem, BRC engineers traced the trouble to two tubes in the rf generator circuit. It was discovered that if the filament of the rf demodulator tube (V6/6173) is operated above 6.3 volts, the tube will become gassy and load the output tank. Tests also revealed that the plate dissipation in the rf doubler tube (V5/538-B) runs close enough to its advertised limits to reduce the life of this tube.

The following minor circuit changes eliminated this rf output problem and provided satisfactory operation of the Type 232-A Signal Generator.

1. A 2.2-ohm resistor was added in series with the ungrounded filament connection on tube V6 (6173). This resistor is a wire-wound type capable of handling 0.25 watts.
2. Resistors R24 and R25 (10k ohms) were replaced with 18k-ohm resistors. These resistors are composition type, with a  $\pm 5\%$  resistance tolerance and a  $\frac{1}{2}$ -watt power rating.

Owners of Type 232-A Signal Generators are advised that these modifications will be made whenever an instrument is returned for repairs.

## EDITOR'S NOTE

### Q Meter Contest Award

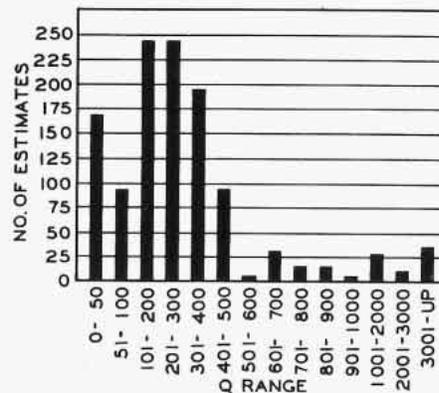
The Q of the coil displayed in the BRC booth at the IRE show is 378. The winning estimate was submitted by Mr. Eugene J. Caron, a project engineer with Radio Condenser Co. of Camden, N. J.

Since Mr. Caron was one of three persons who estimated 378, a drawing was held to determine the winner. The other 378 estimates were submitted by Mr. Chester Warner of Great Neck, N. Y. and Mr. J. Pakan of Forest Park, Ill.

A total of 1198 entries were submitted, with estimates ranging from less than 50 to over 3000. We report, with considerable amazement, that there were twenty one estimates within 1% of the actual measured Q. A list of persons submitting these near misses and a graph showing the distribution of estimates are given below.

Estimate	ESTIMATES WITHIN 1% Submitted By
375	R. Friedman, Polarad Electronics, L. I. C., N. Y.
375	D. W. McLead, Norden Laboratories, White Plains, N. Y.
375	M. Leonard, Columbia University, N. Y. C.
375	C. Briggs, Mass. Inst. of Tech., Cambridge, Mass.
375	F. A. Blackshear, Sperry Gyroscope, Great Neck, N. Y.
375	R. P. Thurston, Waters Mfg. Co., Wayland, Mass.
375	H. C. Hausmann, Arcs Industries, W. Islip, N. Y.
375	W. K. Springfield, IBM, Endicott, N. Y.
375.5	M. Fischman, Sylvania Electric, Bayside, N. Y.
375.6	H. E. Whitted, Western Electric, Winston-Salem, N. C.
376	T. B. Robinson, National Co., Malden, Mass.
376	M. R. Easterday, Bendix Aviation, Kansas City, Mo.
377	M. Freedberg, N. Y. C. Community College, N. Y. C.
377	D. T. Geiser, Sprague Electric, N. Adams, Mass.

- 377.1 R. C. Ferris, Lockheed Aviation, Marietta, Ga.
- 378 C. WARNER, Sperry Gyroscope, Great Neck, N. Y.
- 378 EUGENE J. CARON, Radio Condenser Co., Camden, N. J.
- 378 J. PAKAN, A.R.F. Products, Forest Park, Ill.
- 379 G. Elliott, Rochester, N. Y.
- 380 S. B. Alexander, Emerson Radio, Jersey City, N. J.
- 380 W. A. Palmisano, Army Chemical Center, Edgewood, Md.



Distribution of Q Estimates.

The display coil was measured at 10 megacycles in the BRC standards laboratory on a Type 260-A Q Meter which was previously calibrated against BRC Q Standards. Ten separate measurements were made, the average Q measurement being 378 and the average capacitance measurement being 58  $\mu\mu\text{f}$ .

Mr. Caron visited BRC on May 1 to accept the Q Meter from Dr. G. A.

Downsbrough, President of the company. During his visit, he stopped at your editor's desk and passed along the following information concerning his career in the engineering field. After he received his B.S. in Radio Engineering from Tri State College at Angola, Indiana, he was successively employed in an engineering capacity by Raytheon Corporation, Hazeltine Corporation, and Radio Condenser Co. Mr. Caron joined Radio Condenser Company in 1948 as Supervisor of TV Engineering. He is presently with the Special Apparatus Division of Radio Condenser Company as Project Engineer.

Along with our special congratulations to Mr. Caron, BRC wishes to thank our many friends who visited with us at the IRE show.



Dr. G. A. Downsborough, President of BRC, presents a Type 160-A Q Meter to Mr. E. J. Caron of Radio Condenser Co., winner of the Q Meter contest.

## Engineering Representatives

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