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Improved, Crystal-Type Noise Generator

By the Engineering Department, Aerovox Corporation

THE satisfactory repair of modern high-gain electronic equipment, such as amplifiers and receivers, as well as the development of this apparatus, often involves some kind of noise level measurement. The technician's attention is being directed increasingly to this subject by the specifications and performance requirements for preamplifiers, preselectors, boosters, complete audio amplifiers, complete video amplifiers, and communications receivers.

The normal presence of an electrical noise background in high-gain equipment is well-known. Its theoretical aspects have been treated thoroughly elsewhere and will not be discussed here. The technician understands that internal noise arises inherently from current flow and/or thermal action in tubes, resistors, contacts, etc. and that its presence limits the smallest signal which can be amplified or even handled by a system. While electrical noise possesses a number of distinguishing charactertistics, the principal ones are its random nature, the distribution of its energy over an extremely wide band of frequencies, and its characteristic acoustic unpleasantness. Its multi-component waveform contains jagged peaks and amplitude smears.

The residual noise level at the output terminals of an equipment may be measured with an oscilloscope or suitable a-c millivoltmeter. Generally, the input terminals of the equipment are short-circuited, although some specifications may call for measurements with the input open. The residual output signal can contain, in addition to noise, other components due to hum arising within the equipment or oscillation. Obviously, every effort must be made to separate the noise voltage from any other such components if the noise measurement is to be valid. This is not often easy. It is interesting to note, however, that an occasional specification will lump the total residual small output due to all such factors under the generic heading of noise.

A standard method of noise measurement consists of feeding an adjustable-amplitude noise signal into the input circuit of an equipment under test while monitoring the noise-output power of the equipment, and noting the increase in noise-input amplitude required to double the output-noise power. The input noise then equals the internal noise of the equipment; and from these data, a noise factor may be calculated. If a wattmeter is not available, the output-noise voltage may be monitored in lieu of noise power, an increase in output voltage of 1.41 times corresponding to doubling the power. Both receivers and amplifiers are checked in this manner.

The noise test signal is derived from a *noise generator,* of which there are several types. Laboratory versions of this instrument are based upon a special temperature-limited noise-diode tube (example, Sylvania Type 5722). When the plate voltage of this tube is adjusted to the level at which the filament emission is saturated (that is, all emitted electrons are collected by the plate), the shot noise generated by the diode has constant amplitude and its energy is distributed over a wide spectrum. At intermediate plate voltages, the diode noise output is proportional to the d-c plate current. Thus, by providing for smooth variation of the diode plate voltage, a noise signal of continuously variable amplitude may be obtained. The a-c noise component generated by the tube is coupled, through the noise generator output circuit, to the input of the amplifier or receiver under test.

Crystal-Type Noise Generator

The diodes employed in tube-type noise generators are rather expensive. This factor plus the need for both filament and plate power supplies render the tube-type instrument unattractive to the technician and to the low-budget laboratorian.

A much simpler, yet effective noise generator utilizes the inherent

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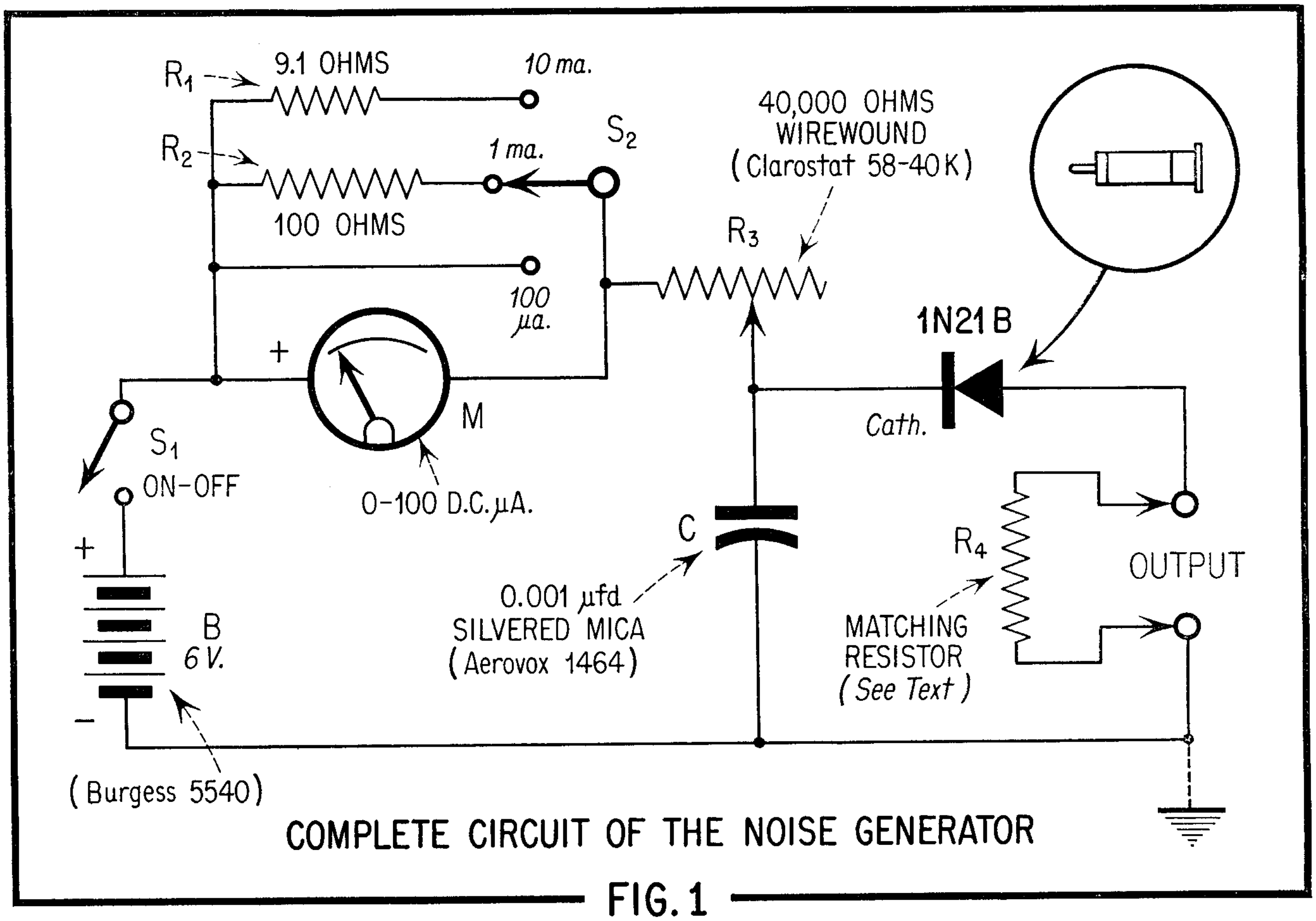


COMPLETE CIRCUIT OF THE NOISE GENERATOR

FIG. 1

noisiness of a d-c reverse-biased point-contact silicon diode. The noise component arising from diodes of this type have been used for testing at frequencies up to 3000 megacycles and higher. The circuit of a noise generator based upon a silicon diode is very simple, inexpensive, and reasonably rugged. It is completely suitable for the comparative measurements which suffice in common service and experimental applications.

Basically, the crystal-type noise generator consists of a point-contact silicon diode, such as 1N21A or 1N21B. (Germanium and silicon junction types are unsatisfactory). The diode is reverse-connected across a battery; that is, with the diode anode negative, and a means is provided for coupling the noise energy, generated by the flow of current through the diode, out of the circuit. Several such generators have appeared in the literature but in general have been makeshift in character and have included no means for dependable control of the noise amplitude.

The circuit of an improved generator is given in Figure 1. In this arrangement, the diode current is adjusted by means of the 40,000-ohm wirewound rheostat, R_3. The current level is indicated by the multirange meter, M. This meter has three ranges, selected by switch S_2: 0-100 microamperes, 0-1 milliampere, and 0-10 milliamperes.

This arrangement for constant monitoring of the current over a possible range of 5000 to 1 enables reasonably accurate re-setting of the output-noise level. The resistance values of the two meter shunt resistors, R_1 and R_2, are based upon an internal meter resistance of 900 ohms. This is the resistance of the Triplett Model 327-T instrument employed in the writer's prototype. Some variation will be necessary when an individual internal meter resistance differs from this 900-ohm value. In any case, the required shunt resistance (in ohms) equals $r_m/9$ for the 1-ma range, and $r_m/99$ for 10 ma. The numerator, r_m, is the internal meter resistance, in ohms.

The a-c noise component due to random fluctuations of current in the diode is transmitted to the OUTPUT terminals through the 0.001-ufd silvered mica capacitor, C. For a-c, this capacitor forms a closed circuit comprising the 1N21B, C, and the OUTPUT terminals.

A non-inductive (good-grade composition or carbon film) resistor, R_4, bridges the OUTPUT terminals to match the input resistance, or impedance, of the device under test. If the noise generator is used, for example, with a receiver having an input impedance of 300 ohms, R_4 will be 300 ohms. Resistor R_4 need not be larger than ½ watt. Since many different input impedances are encountered in amplifiers and receivers, the question will arise as to why a switching arrangement has not been employed here to give the noise generator a wide range of output impedance. The reason for not doing this was to avoid the inherent noise-generating properties of such a switching circuit. In fact, in order to keep all internal noise not arising in the diode, and extraneous pickup at a minimum, resistor R_4, diode 1N21B, and capacitor C must be mounted right at the OUTPUT terminals. This insures the shortest possible leads. When the generator is to operate into a new impedance, Z, a new resistor R_4 equal to Z must be fastened directly across the OUTPUT terminals.

When the device under test has a balanced input circuit, as often is the case in television receivers, two series-connected resistors with their junction grounded can be connected, for impedance-matching, across the noise generator OUTPUT terminals in the manner shown in Figure 2. The value of each resistor is equal to ½Z, where Z is the input impedance of the device under test.

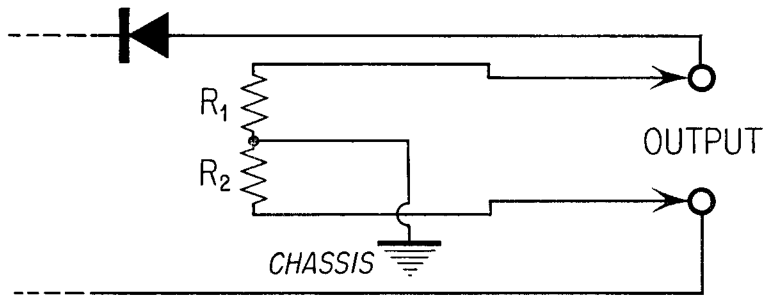
Whether the generator has balanced output (Figure 2) or unbalanced output (Figure 1), its ground must be connected solidly to the ground of the device under test.

Construction

The simplicity of the noise generator circuit removes any complication of construction. By using a 6-volt battery (B) of thin, flat construction, like Burgess Type 5540 (4″ x ⅞″ x 2-¾″), the entire instrument may be housed in a metal radio utility box slightly larger than a standard meter case.

The insert in Figure 1 shows the shape of the 1N21B diode. The metal tip on the left end of this figure is the cathode terminal which is connected to the junction of rheostat R_3 and capacitor C.

The only wiring precaution is to keep all connections between the diode, capacitor, OUTPUT terminals, and R_4 as short as possible. To accomplish this, solder the base of the diode directly to the upper OUTPUT terminal, and solder capacitor C from the tip of the diode to the lower OUTPUT terminal. In order to prevent damage to the diode during this operation, hold with metal pliers the metal part of the diode being soldered. This will conduct the heat away from the diode case. Continue to grip with the pliers until the diode is unmistakably cool to the touch.



ALTERNATIVE CONNECTIONS FOR BALANCED OUTPUT

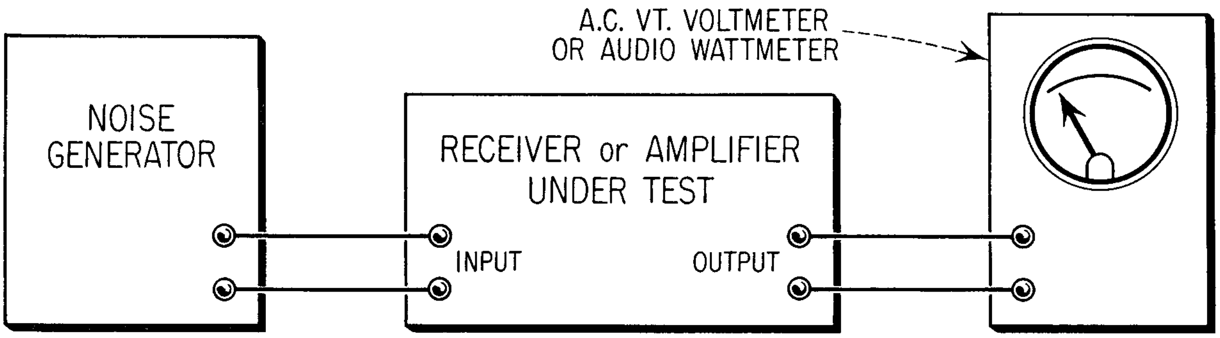
FIG. 2

Operation

Figure 3 shows a typical setup for noise measurements. The following test procedure is recommended: (1) With the noise generator switched-off, note the reading of the output meter (a-c v-t voltmeter or audio wattmeter) when the amplifier or receiver is in operation and its output controls are set for normal operation. (2) Record this deflection of the output meter, due to the inherent internal noise level of the equipment under test, as the "zero level." (3) Switch-on the noise meter and increase its output by adjusting rheostat R_3, until the output power of the amplifier or receiver (when the output meter is a wattmeter) is doubled, or until the output voltage (when the meter is a voltmeter) is increased 1.41 times. (4) Note the reading of the current meter, M. High current values indicate a high noise level in the device under test, and vice versa. After work is done in the device, a decrease in the initial current reading obtained in a repeated step 4 indicates an improvement in the noise characteristic; an increase in meter M deflection shows a worsening of the noise.

In addition to the comparative type of measurement just described, the noise generator output may be calibrated quantitatively. One method is to plot the noise output voltage (E) at the generator output terminals vs meter M readings for a given output impedance, R_4. Either these voltages might be used in subsequent noise tests, or the noise power levels might be calculated: $P = E^2/R_4$ watts. For either voltage or power, a separate calibration is required with each output impedance, R_4.

The technician will find noise measurements advantageous in checking the performance of all-wave receivers, television receivers, and amplifier systems for sound reproduction. These measurements are particularly revealing when used to determine the efficacy of TV boosters, since the latter devices are known to suffer occasionally from prohibitive noise.



NOISE TEST SETUP

FIG. 3