The GENERAL RADIO EXPERIMENTER

VOL. VI. No. 1 JUNE, 1931

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

VOLUME CONTROL IN VOICE CIRCUITS

THE development of circuits and apparatus for controlling the volume or power level in voice transmission circuits has been a gradual and interesting one. In the modern broadcasting station, sound transcription, and talking motion picture studios, the control of the power level in practically all of the audio-frequency circuits is accomplished by attenuation networks built up of resistive branches.

It is possible, of course, to regulate power level by changing the efficiency of a circuit element such as the microphone or one of the amplifiers. An affect of this sort can be realized by varying the biasing voltage of a condenser microphone, by a change in the direct current through the carbon-button microphone, or by regulating the plate and grid voltages of some of the amplifier tubes. This, however, is obviously not good practice because all such elements are designed to give the most effective performance by lack of distortion, lowest noise level, etc., with fixed electrical values.

Resistive networks can be designed to introduce no distortion of themselves and to give at once precise and almost noiseless control of amplitude.

A typical volume control problem that is encountered in a broadcasting or sound studio might be outlined something like this:

It is desired to control the power output of three studio microphones and an incoming telephone line so that any one of the group may be operated independently of the other, and so that two or more may be worked simultaneously into a high-gain speech amplifier. This calls for a "mixer control panel" on which are mounted four resistive attenuation networks of suitable design. These are termed "mixers" and have two important electrical characteristics. One is that they have a constant impedance as seen from its output and the other that they introduce no extraneous noise into the circuit. Figure 2 shows the diagram of such a circuit.

The mixer controls are of the L type. Attenuation is accomplished by decreasing the shunt resistance at the same time increasing the series resistance by a compensating amount. The

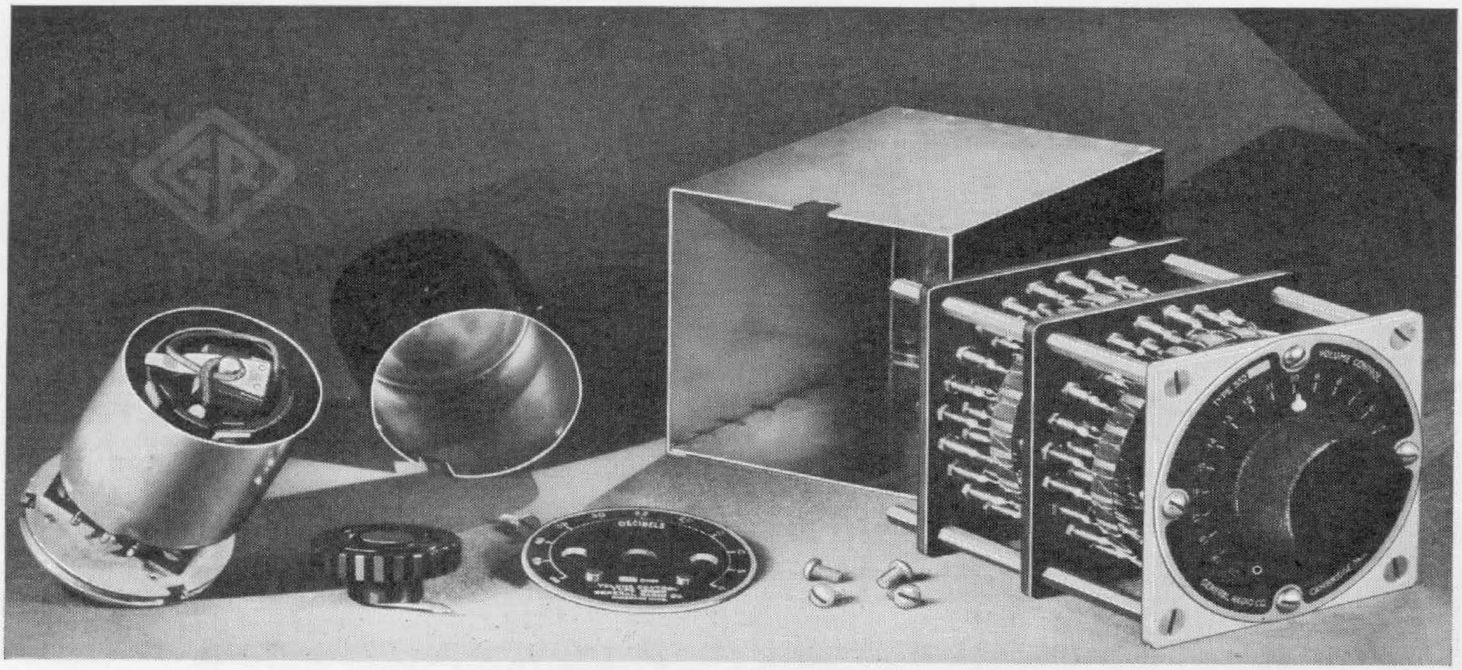

FIGURE 1. General Radio volume controls for recording and broadcast studio use. At the right, the TYPE 552 Volume Control; at the left, the TYPE 652 Volume Control with its dust cover, knob, and dial removed

two switch arms move together and the resistances that they cover for a given angular rotation of the shaft are so chosen that there is no change in the output resistance of the combination regardless of their position. This is very important because if the output impedance did change, all of the remainder of the units would be working into an impedance which varies with the setting of one mixer. Thus their combined output levels would be affected by the setting of any one control.

The impedance of an L-type control on the microphone input side varies widely. This, however, is not important because it simply changes the reflection loss at the junction between the microphone and mixer. Since this loss is taken into account in a properly designed L-type network, it is of no further concern.

In Figure 2 the impedance of the controls is shown as 50 ohms, the four connected in series giving a total impedance of 200 ohms. It is nearly always necessary to have, in the circuit following the mixers, a master gain control. This is to regulate the levels of all of the speech sources together. The customary network for this work is the H-type illustrated. The H-type is chosen because it is possible to obtain good balance to ground of the mixer circuit and the speech amplifier. This balance tends to eliminate to a great extent pickup and cross-talk noises in the leads from the mixer circuit. If the leads are not too long, or if the studio and control room are free from power line disturbances, a T-type network may be used. Both the H- and T-type networks have a constant impedance in both directions. This is also important, because the speech amplifier is designed to work from one definite impedance. A change from this impedance is apt to cause frequency dis-

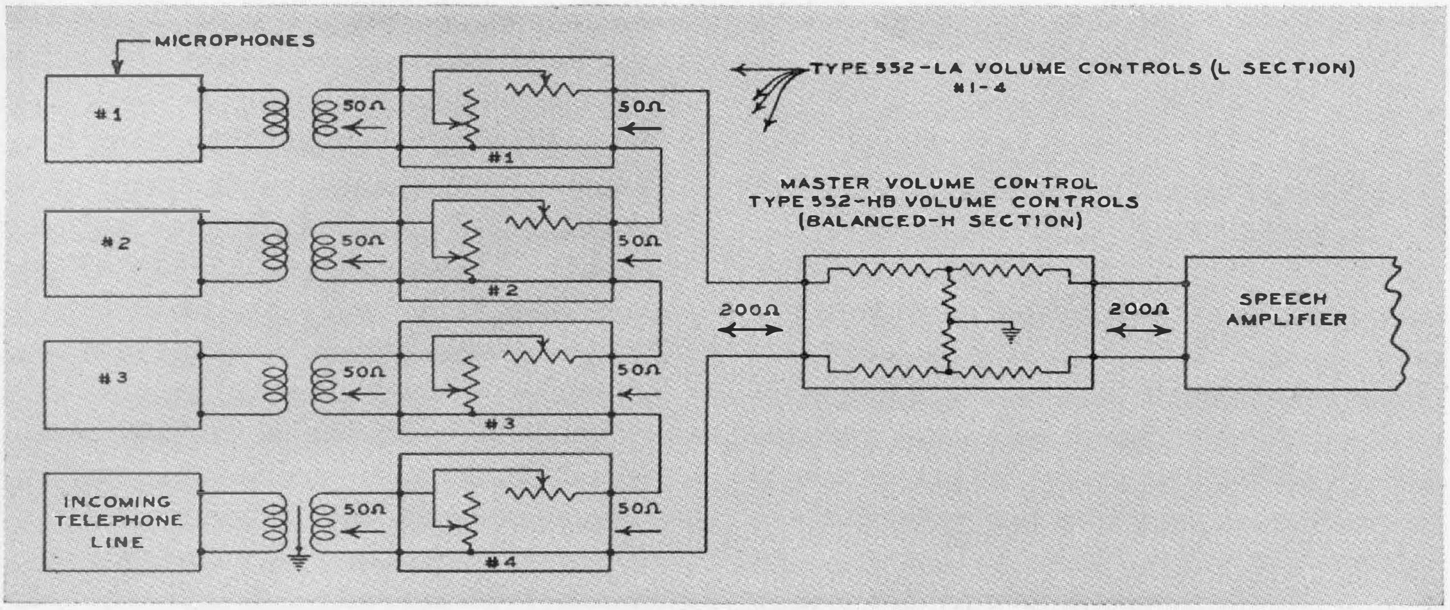

FIGURE 2. Schematic diagram for a typical four-channel mixer and master gain control installation

crimination at the input transformer.

The impedance of the complete mixer circuit is 200 ohms. The impedance of the master gain control is 200 ohms both at the input and output, and the speech amplifier is designed to work from 200 ohms. Thus perfect impedance matching has been accomplished throughout the circuit. The mixer impedance of 50 ohms and the amplifier impedance of 200 ohms have been selected merely because they are common values. The usual output impedance of the microphone circuit is 200 ohms. The proper impedance-matching transformer between this and the 50-ohm mixer has been indicated in Figure 2. If it were desirable to eliminate these transformers or to work at a higher impedance, say 200 ohms, the mixers should be designed for this impedance and connected in the series-parallel arrangement. That is, a pair of 200-ohm mixers connected in series will have an impedance of 400 ohms, and two pairs connected in parallel will have a resulting total mixer impedance of the desired 200 ohms. The usual impedance of telephone lines is about 500 ohms, therefore, a suitable impedance-matching transformer is required here.

As distinguished by mechanical construction there are two general types of volume controls in use. The first is one in which the resistance is made continuously variable by sliding switch contacts across wound wire resistors in the manner of a potentiometer. The other is one in which the control is constructed of a number of small fixed resistors connected to suitable fixed contacts. A switch arm connects these contacts in the proper circuit arrangement and changes the attenuation by discrete intervals. Figure 1 illustrates a balanced-H network of the latter type. Each construction has its own particular advantages. In general, the contact type has a lower noise level, being between 6 and 15 decibels below the slide wire controls. It has a larger contact sur-

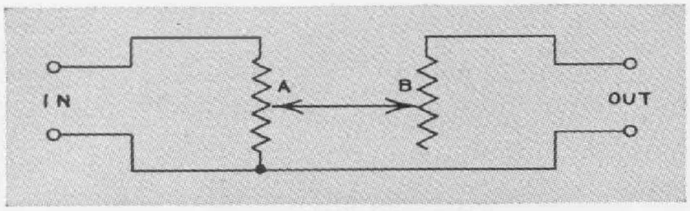

FIGURE 3. This circuit is common in mixer installations

face for the switch and a switch properly designed will wipe the contacts clean of accumulated dust. This is of particular advantage in sound recording work where every effort is made to reduce extraneous noise to the absolute minimum. The calibration of a step-by-step control can be made very accurate without difficulty, and readings can always be exactly repeated. This is important when the over-all efficiency of the system is checked frequently. It is also valuable to be able to do this so that the change in efficiency of the system may be accurately checked when an alteration is made in one of its units.

A step-by-step attenuator should have a considerable number of discrete steps in order to allow for accurate adjustment of the level. The average ear can detect a volume change of about two decibels. It is reasonable, then, that a change per step of this value or a little less should be about correct for a control in a voice circuit. The TYPE 552 Volume Control illustrated in Figure 1 has twenty steps of one and one-half decibels each.

The step-by-step type is almost universally used as a master gain control. As was mentioned previously a relatively complicated H- or T-type network is used in this position. It is of the greatest importance that no failure occur in this circuit since such an accident would probably put a bank of microphones and a speech amplifier out of commission. For this reason this control should be of the most foolproof construction possible.

There are a considerable number of different designs of slide wire volume controls in general use. They differ in mechanical construction but nearly all employ some form of the electrical circuit shown in Figure 3. In this sort of circuit one slider *A* moves along a shunt resistance across the microphone output in the manner of a potentiometer. At the same time a series resistance is introduced into the circuit by a second slider *B* which helps to compensate for the decreasing impedance as seen from the amplifier side as the switches move downward toward zero output. The series resistance also puts some additional attenuation into the circuit. This circuit, or a variation of it, has been in use for a long time and has proved to be reasonably satisfactory.

The principal cause of trouble in a slide wire volume control is the noise which it is apt to bring into the circuit. They are used at places having a very low power level and are followed by a large amount of amplification. For this reason any small noise caused by moving the control is immensely increased and consequently every effort is made to keep it at a low level. There are four important sources of noise in a slide wire control:

1) The contact potential resulting, if the slider and the wire are of different materials. Unlike metals placed in contact with one another in air will generate a feeble e.m.f. which is enough to be very noticeable and annoying under some conditions.

2) Small dust particles getting between the slider and the wire thus causing a momentary increase in resistance or even an open circuit.

3) Ordinary electrostatic pickup in the winding which is usually introduced by hand capacitance.

4) The difference in potential between adjacent turns of wire produces a small click as the slider progresses from one turn to the next.

The contact potential trouble may be corrected by using similar metals for both the resistance wire and the slider.

A good dust cover and an occasional cleaning with carbon tetrachloride helps to correct the difficulty from noise due to dust and dirt. The electrical pickup can be largely eliminated by a shield around the windings and by placing them a little distance from the panel so as to insure a fair separation from the operator's hand. Winding the resistor unit with a large number of turns of small wire reduces the potential difference between turns to a very low value and, if carried to a limit, will practically eliminate the trouble. The limit is when the wire size becomes too fine for ordinary handling and wear.

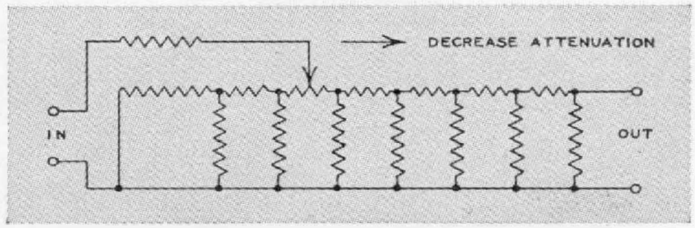

FIGURE 4. The ladder network has several advantages in mixer work. It is used in the new TYPE 652 Volume Controls

The ladder circuit shown in Figure 4 is admirably suited for microphone mixer and other volume control uses.

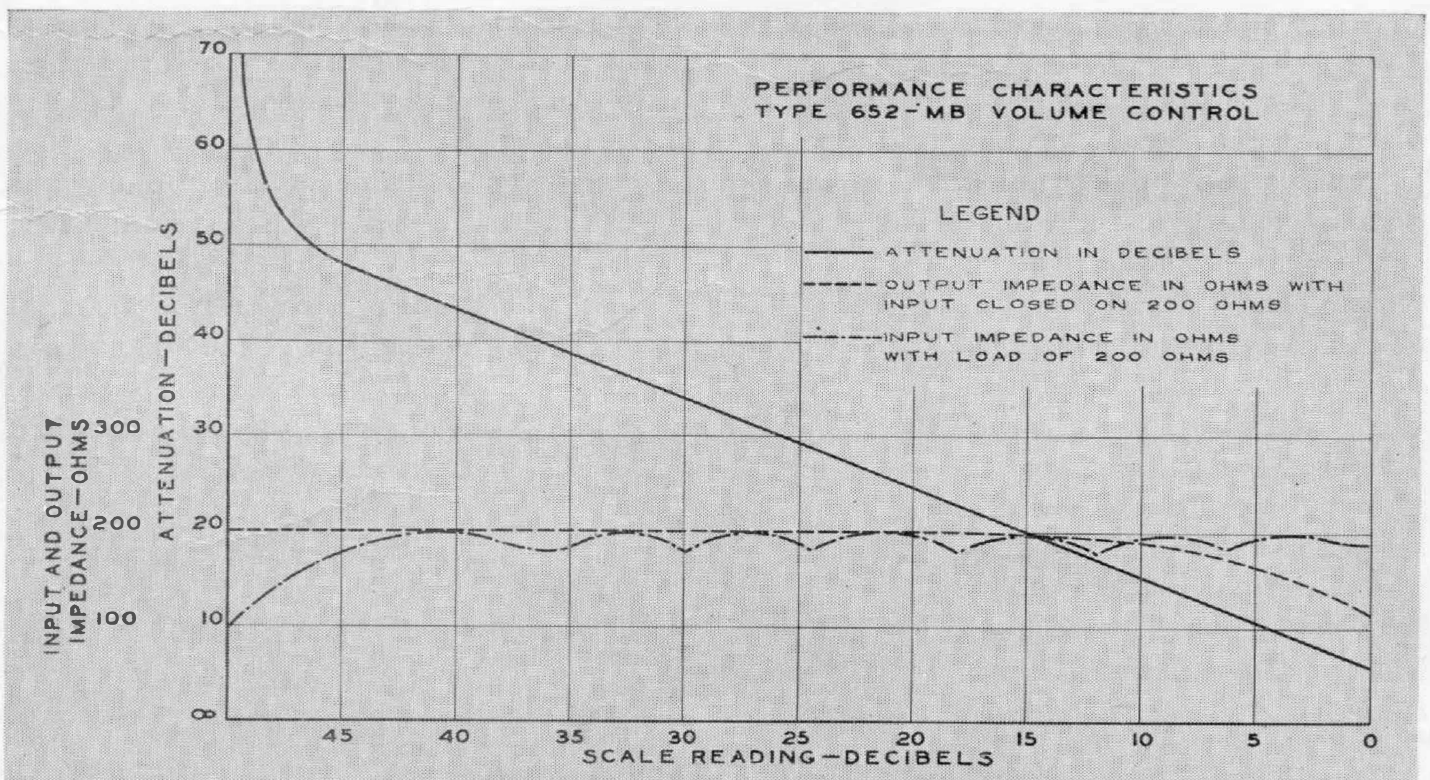

FIGURE 5. Terminal impedances and attenuation for a 200-ohm ladder type volume control as a function of scale reading

FIGURE 6. A dial from a TYPE 652 Volume Control

This type of network has been used for some time in attenuators of General Radio standard-signal generators. Its application in a modified form to volume control devices in audio circuits was suggested by W. Robert Dresser of Paramount News, Inc.

It has been utilized in the new General Radio Type 652 Volume Control illustrated in Figure 1 and in Figure 6. The electrical characteristics of this unit are shown in Figure 5. The photo-etched scale of the instrument is calibrated approximately in decibels of attenuation and is linear.

The linear attenuation characteristic will be noted as being particularly desirable. This straight-line attenuation characteristic continues up to about forty-five decibels, and then increases rapidly and uniformly to cut-off. The minimum insertion loss of the network is six decibels, which is lower than in most controls of this type. The output impedance remains constant over the greater part of the scale and drops to a minimum of 120 ohms. The fact that the impedance does not change from 200 ohms at infinite attenuation is valuable because if several units, such as microphones, are set at zero output they will cause no impedance change in the system.

The input impedance varies around 200 ohms with a total change of only 12 ohms from 0 to 45 decibels. At cut-off the input impedance is 100 ohms. When working from a microphone circuit it is not necessary to keep the impedance constant, providing that the reflection loss is considered in the calibration, but the fact that the impedance does stay so constant suggests that the unit may be used in any circuit where an approximately constant impedance in both directions from a control is necessary.

The ladder type of network requires only one sliding contact. By wiring to the switch by a pigtail connection, the sliding contact at the bearing is also eliminated. The resistance card on which the slider moves has a total resistance of 1200 ohms. This high resistance makes it possible to wind the card with a large number of turns of fine Advance wire. The switch itself is of Advance metal backed by a stiff phosphor bronze strip to insure a firm contact.

ARTHUR E. THIESSEN

The author of the foregoing article is an engineer with the General Radio Company. Volume-control and volume-measurement problems are two of his specialties

MISCELLANY

YOUR ADDRESS AGAIN ▲ ▲ ▲ So heavy has been the return of letters and cards sent out with the April *Experimenter* that our mailing room has been swamped. We had hoped to base the mailing list for this issue on the returned letters and cards, but we are deferring this action for another month.

If you wish to continue receiving the *Experimenter* and have not already indicated your desire to continue, please do so at once. A card mentioning your name and address as it appears on the envelope enclosing this issue will do the trick, if you didn't get a letter or card in April. New readers and those residing in Canada may safely ignore this suggestion.

✦ ✦ ✦

RADIO SHOW ▲ ▲ ▲ Not everyone interested in General Radio instruments visited our demonstration at the Radio Manufacturers' Association Trade Show in Chicago. It is for the benefit of those who did not that the following brief description of our exhibits is presented:

Descriptive articles about each instrument will appear in future issues of the *Experimenter* as well as in a series of catalog supplements. The latter will not, as in the past, be mailed to all of our laboratory instrument customers until the fall when Part 3 of Catalog F will be issued. In the meantime, catalog supplements may be had on request. Ask for them by the number (*e.g.* F-300-X) appearing at the end of each of the following descriptive notes.

Volume Controls — A small wire wound unit for use as a mixing control in the recording or broadcast transmission studio has just been developed. Quietness, uniformity of attenuation variation, and constancy of terminal impedance are its features. (See the article in this issue of the *Experimenter* or send for "F-300-X.")

Standard-Signal Generators — One of the new units is an inexpensive, yet accurate, instrument for measuring receiver sensitivity in production and for maintenance work on high-frequency police and airplane-beacon receivers. Frequency range: 90-6,000 kc.; output range: 1-150,000 microvolts.

The second unit was designed for rapid and precise measurement of sensitivity, selectivity, and fidelity of receivers in the broadcast band. Its important applications are in circuit development work and in making thorough sampling tests on the production line. Output range: 0.1 to 316,000 microvolts.

Both instruments are described in "F-306-X."

Cathode-Ray Oscillograph — The General Radio oscillograph consists of a new tube, a mounting for it, and a power-supply unit for operating the tube from the alternating-current line. Extreme brilliance of the images, long tube life, and alternating-current operation are the principal features. (Send for "F-303-X.")

MISCELLANY — Continued

Output Meters — With the aid of a more sensitive meter, output meters similar to the TYPE 486 Output Meter are now being built with impedances of 8,000 and 20,000 ohms as well as 4,000 ohms. (Send for "F-302-X.")

Audio Oscillator — This is an alternating-current operated oscillator with high output (0.5 watt) giving frequencies of 200, 300, 400, 600, 800, 1000, 1600, 2000, 3000 and 4000 cycles per second. (See "F-304-X.")

Laboratory Amplifier — Operating from self-contained dry batteries, this unit has the stability and high gain necessary for adapting photo-electric cells to photometric and other measurements. (Send for "F-301-X.")

The General Radio Company mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the

GENERAL RADIO COMPANY
30 State Street
CAMBRIDGE A, MASSACHUSETTS