



Audio Engineering Society,
Box F, Oceanside, N. Y.

AUDIO engineering society

Containing the Activities and Papers of the Society, and published monthly as a part of AUDIO ENGINEERING Magazine

OFFICERS

Theodore Lindenberg, President

J. D. Colvin . . . Executive Vice-Pres. John G. Frayne . . . Western Vice-Pres.
Norman C. Pickering . . . Secretary Ralph A. Schlegel Treasurer

Automatic Audio Gain Controls

J. L. HATHAWAY*

A discussion of the development and application of program-controlled circuits in broadcasting, with a description of a general-purpose AAGC amplifier in regular use.

THE PURPOSE OF THIS PAPER is to cover briefly the history of Automatic Audio Gain Controls at the National Broadcasting Company. With this equipment line levels may be held more constant, the average level increased many fold, and the listening public—both radio and television—subjected less to sudden drastic changes of sound volume. The new automatic control incorporates a number of improved features as compared to those which are currently employed for adjusting gain as a function of program level, thereby eliminating undue volume fluctuations. Such control equipments are not only called Automatic Audio Gain Controls, or AAGC's but compressors, limiters, program regulators, and a number of other descriptive names, some complimentary and some uncomplimentary. Improper maintenance or operation, as well as unsuitable design, accounts for most of those in the latter category, but judging from the fact that there are in the United States thousands of units giving satisfactory daily service, it is obvious that results are generally well worth while. Even in the field of television, sound transmission is greatly improved through the use of a good AAGC, such as the new Type ND-333.

Early Experiments

Laboratory development of Automatic Audio Gain Control systems has been underway off and on for twenty years, sometimes directed toward solving particular operating problems and other times emphasizing control system improvements. Some of the units developed are relatively complex, while others are extremely simple, such as that shown on Fig. 1. Here a small tungsten filament lamp was connected in a low-im-

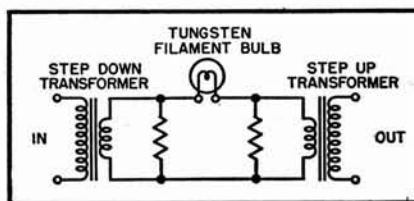


Fig. 1. Earliest form of simple AAGC used in 1929.

pedance circuit so that its resistance variation caused over-all changes of attenuation. Such a tungsten bulb changes resistance by more than 10 to 1, hot to cold, implying a possible attenuation change as great as 20 db. This arrangement *should* be highly effective when preceded by an amplifier of sufficient gain and power handling capacity to heat the filament on program peaks to at least a dull glow. However, its usefulness is restricted by poor timing characteristics. An ordinary small filament has similar heating and cooling thermal lags, and timing determined by these lags has been found completely unsatisfactory for good control. Because heating is *too slow*, around 125 milliseconds, high-level spurts of program are allowed to pass unattenuated and are readily heard. Because cooling is *too fast*, certain desirable program level fluctuations, such as those occurring in speech, are reduced or removed almost completely.

During early experimental work, without known prior art, the importance of utilizing extremely dissimilar gain reduction and gain recovery times was not appreciated. Then in 1934 a circuit was tried having a gain reduction or "attack" time of around 10 milliseconds, together with a recovery time of slightly over one second. After only a short period of careful listening, it was obvious that this combination was superior to anything previously tested, and in fact that first breadboard setup did a worth

while job of controlling gain. Various attack and recovery times were then tried with engineers acting as guinea pigs. When the attack time was greater than about 30 milliseconds, short bursts of high-level peaks were audible, and the over-all effect was not as pleasing as with attack times below 10 milliseconds. In going below 10 milliseconds, there was no appreciable change in over-all effect until the attack time was made less than 200 microseconds. With such a short attack time, the sound quality was the same as that for a time of around 1 millisecond, but on programs of local origin the level was appreciably lower due to extreme crests of high-frequency peaks causing greater gain reduction. The *recovery* time most desirable seemed a matter of properly fitting the particular application. Where greatest possible average level was desirable, rapid recovery—around 1/3 second—seemed best. Where least noticeable effect by the automatic action was called for, a recovery time somewhat greater than 1 second seemed preferable.

Early Application

Shortly after the initial experimentation on time constants, a number of rack mounted units were constructed and placed in service in New York, Cleveland, and Chicago. Some of these served to regulate levels in automatic announce booths whereby news flashes could be placed on the air without waiting for control engineers to reach the studios. Others were for use on regular studio or field pickup programs to aid and supplement the control engineer's efforts in feeding proper level onto the telephone lines. Also a portable unit was used with great effectiveness in the gondola of the stratosphere balloon during its record-breaking flight in 1935, and by the following year we were getting

* National Broadcasting Company, New York.

Automatic Audio Gain Control systems into our special events beer mug and pack transmitter designs. Since then, more or less hand-tailored controls have been employed in a wide variety of applications, including television sound and broadcast transmitters, disc recorders, tape recorders, film recorders, and field and studio amplifiers. Many of these units have different characteristics, sometimes because of the nature of the application, and sometimes because of the difficulties involved in building circuits with optimum characteristics in portable equipment.

Characteristics and Measurements

Many characteristics of Automatic Audio Gain Control—such as frequency response, input and output impedance, signal-to-noise ratio, and harmonic distortion—are similar to those of ordinary amplifiers. It is essential in the measurement of some of these either to block out the control circuit or else to employ a signal level which is safely below the threshold of control. Measurements of recovery and attack times require radically different technique. Recovery time may be determined by watching a VU meter connected to the output of the unit under test and measuring time for it to reach steady state reading after suddenly reducing to normal a tone signal which has been 10 to 20 db above normal. Attack time is readily determined by means of an oscilloscope, preferably one equipped with a P7 screen and a triggered single-sweep circuit. Here, the scope is connected to the output of the Automatic Audio Gain Control and tone applied to the input at just under threshold level. This level is suddenly increased (usually by 6 to 20 db), and the scope displays the over-all effect. *Figure 2* is a drawing made from typical oscilloscope patterns, (A) showing a good AAGC in proper adjustment, and (B) showing either a good one far out of adjustment or a poor one even at its best adjustment. The drawings show tone applied at just under threshold control level, followed at time 0 milliseconds by a 12 db increase. At (A), perfect balance results in complete cancellation of all “thump” or “plop” component, the signal being symmetrical about the axis. After about 1 millisecond, complete stability is reached at a level some 2 db above that at the start. (B) illustrates a condition of misbalance, the dotted line average representing a severe plop component above the axis and lasting for many milliseconds. A plop of this magnitude is readily audible and has a secondary effect—also audible—of depressing the gain to a sub-normal level because of the excessive control potential caused by the misbalance. Thus, for a large fraction of a

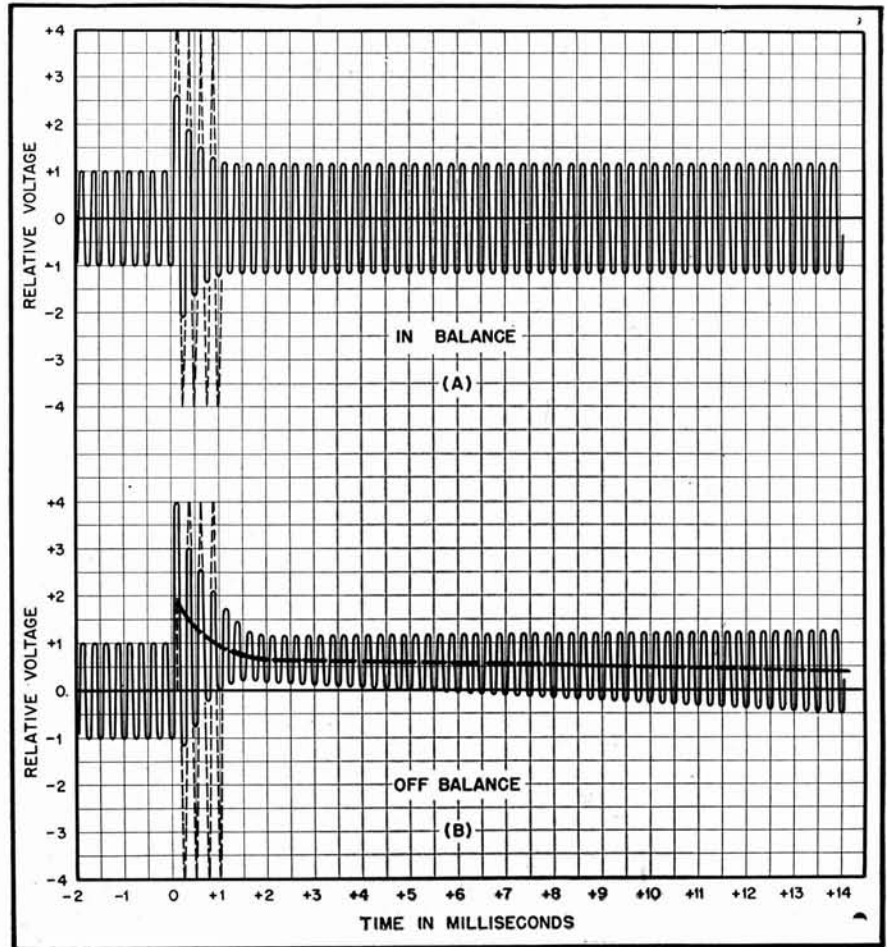


Fig. 2. Drawing made from typical 'scope patterns to show effect of "plop" generation. (A) shows signal passing through well-balanced amplifier as a result of an increase in level of 12 db. (B) shows same signal passing through a poorly balanced amplifier, resulting in an average value differing from the axis, or zero.

second, depending upon the recovery time, the *high*-level input peak has actually caused a *low*-level output. Complete stability should be reached within the recovery time, although this is not shown in the figure.

Unbalances of push-pull tubes or circuit components are responsible for plop generation. Its seriousness in relation to program is obviously a function of program level at the controlling tubes. Thus a given misbalance with low program level might be quite objectionable, whereas it would be completely insignificant if the tubes were operated at higher program level. Therefore, in good AAGC design, with given tube parameters, the program level at the threshold of control must be as high as possible in order to minimize plop. At the same time, it cannot be excessive, since harmonic distortion becomes equally objectionable.

Control Characteristic

“Control Characteristic” refers to the effectiveness of an Automatic Audio

Gain Control in reducing excessive level variations assuming no undue wave form distortion or plop generation. *Figure 3* illustrates three different types of control characteristics. Where complete high-level limitation is called for, as at a broadcast transmitter, it is desirable to utilize a so-called “limiter” characteristic, curve 3. Something less drastic, such as the modified limiter of curve 1, should be employed as a supplementary aid to a control operator, and the unit should, in this application, be located in the circuit following the manual controls, but preceding the volume indicator and loudspeaker so that the operator sees and hears the combination of both manual and automatic control. For operatic and symphonic programs intended for music lovers, the control effect should be much less, as in the so-called “Compressor” characteristic of curve 2.

Amount of Gain Reduction

A common question related to Automatic Audio Gain Control application is “How much gain reduction?” This is

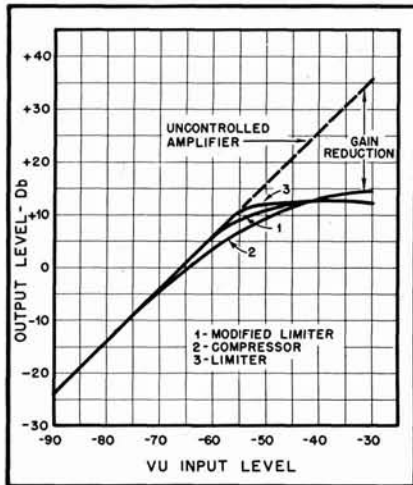


Fig. 3. Typical control characteristics obtained in various forms of automatic amplifier circuits.

not a simple question and a simple reply is too incomplete, some applications calling for greater gain reduction than others. For example, where no manual control is exerted, the extreme input variations can at times account for as much as 20 db of gain reduction. Controls at broadcasting transmitters are not normally subjected to such extreme variations, since manual control has been previously exerted, but even so, surprisingly large variations do exist, as a result of different control operators, different types of programs, and different amounts of telephone lines. This was pointed out two years ago in data taken to chart these variations at our N. Y. broadcasting station. With all adjustments fixed, the number of gain reduction peaks and their amplitudes were counted by a two-man team for several ten-minute periods throughout the day and evening and the results tabulated. Three of these periods are charted on Fig. 4. Two of them depict extremes and

show a surprising difference, the one from Hollywood obviously having passed through a long-peak-ironer before arriving in N. Y. This ironer was more effective some days than others, but generally functioned in dual manner. First it slightly compressed all extremely high levels at each of many repeaters. Second, it eliminated all frequencies above 5 kc, thus accounting for much of the difference between average and peak potentials.

Use With Pre-emphasis

The use of Automatic Audio Gain Control in disc recording circuits has been found highly advantageous because it permits increased level with corresponding improvement in signal-to-noise ratio and at the same time provides for greater reliability. Where the NAB recording characteristic is utilized, a rather special condition results, calling for a special control. In recording with this characteristic, high frequencies are electrically pre-emphasized by a circuit of 100 microseconds time constant, meaning about a 10-db rise at 5 kc and a 16-db rise at 10 kc. If the automatic control is located in the circuit after pre-emphasis, all peaks, including those occasionally caused by extreme high frequencies, are eliminated, which might seem desirable. However, listening tests indicate that this is far from desirable because the program gain control becomes highly unsatisfactory whenever extreme highs exist. This is caused by the level ducking unpredictably during some of the highest passages at the very time the ear expects greatest level. That is, the medium-frequency components which largely determine loudness are suddenly depressed just when they should be the strongest. This condition does not prevail if the Automatic Control is operated prior to pre-emphasis in the circuit. In

this situation a different degradation occurs in the form of occasional high-frequency cross modulation due to overloading by the pre-emphasized components, especially so because of the usual high-frequency recording and reproducing troubles. There is no general rule as to which is the lesser of these two evils, since each leads to degraded sound reproduction. However, tests and usage over many years have shown that a midway condition is entirely satisfactory. For such an arrangement the Automatic Audio Gain Control may be located either ahead of or following the pre-emphasis, whichever is the more convenient. If *ahead*, the amplifier within the AAGC unit feeding potential to the rectifier should be "half way" pre-emphasized. If *following*, the rectifier-amplifier should be de-emphasized "half-way," or about 8 db at 10 kc. This latter arrangement works out very easily in most cases through the use of a single small capacitor shunting the side amplifier or rectifier feed circuit.

To be concluded next month

BALTIMORE GROUP TO MEET SEPT. 6

The Baltimore Audio Engineering Association will meet on September 6 at 8:00 p.m. in the Academy Room of the Emerson Hotel. The main feature of the evening will be a lecture and demonstration by Melvin C. Sprinkle, sponsored jointly by the Peerless Electrical Products division of Altec Lansing Corporation and the Wholesale Radio Parts Co., Baltimore jobbers.



Employment Register

POSITIONS OPEN and AVAILABLE PERSONNEL may be listed here at no charge to industry or to members of the Society. For insertion in this column, brief announcements should be in the hands of the Secretary, Audio Engineering Society, Box F, Oceanside, N. Y., before the fifth of the month preceding the date of issue.

● **Audio Technician.** Employed in audio field at present; experienced in development and construction. Enthusiastic, good troubleshooter and maintenance man; wide knowledge of serious music. Desire position in studio, lab, or custom installation firm. Box 801.

● **Audio, TV Field Engineer.** 10 yrs practical experience in maintenance of professional audio, TV, and radar equipment; design and maintenance custom home music systems. Member AES; Assoc AIEE. Good tech. educ. bkgnd; exc. references; exp. customer relations; extremely conscientious. Presently mgr. TV service lab and field service technician, electronic organs. Desire field work hi-fi audio or TV. Prefer Washington, D. C. area; consider other. Box 701.

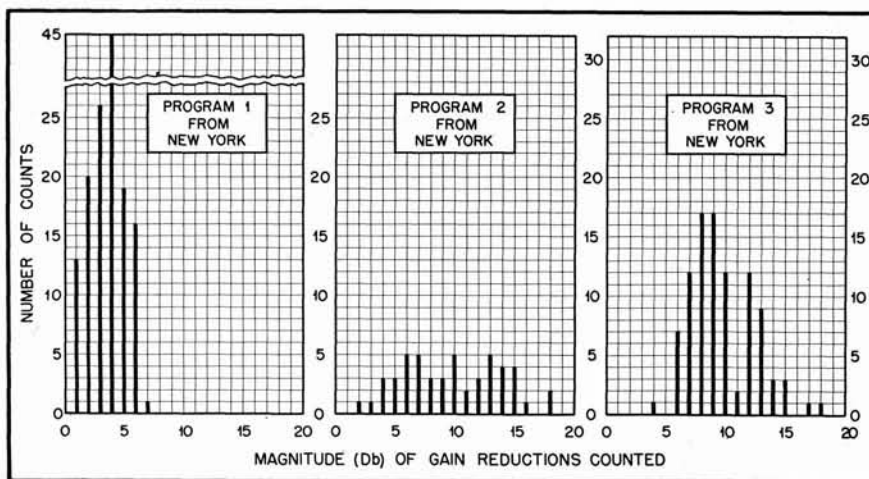


Fig. 4. Actual counts of gain reduction peaks occurring in programs from different sources.