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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.

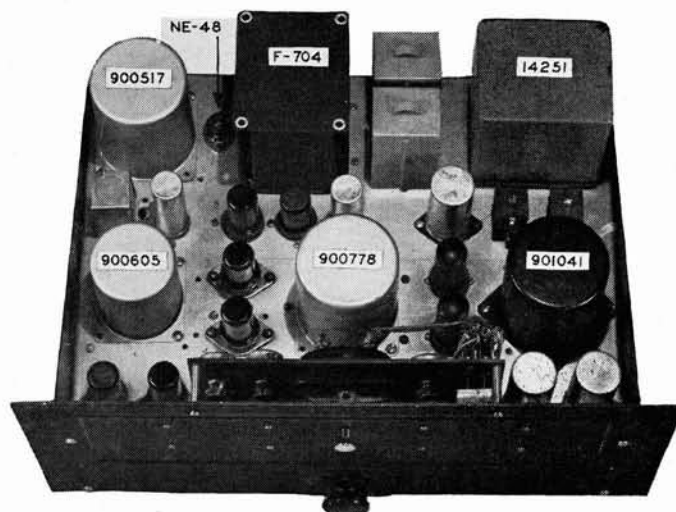
MANY OF THE AAGC's in service are necessarily of compromise design. For example, in extremely portable battery-operated equipment, such as radio mikes or pack transmitters, it is hardly practical to utilize all of the refinements of a high-quality studio control unit. A tiny transmitter cannot devote sufficient filament power or bulk to push-pull control tubes and balancing transformers so that a single-sided system is generally used. This leads to a condition of regeneration or degeneration, depending on the number of stages, and also to creation of severe pop components. The general cure for both of these ailments is the same—the use of an extremely slow attack time around 50 to 100 milliseconds. Although it might seem that this would render the control virtually useless, such is not the case. Tests on high-level input to units incorporating even this imperfect control show that great benefit is derived as compared to similar equipments without any form of automatic control. Without the control, overmodulation becomes serious and causes the "rasping" type of distortion which is disagreeable and at the same time intelligibility is reduced. With the control, the rasping distortion is eliminated, and quality, except for a few slight pops, is generally good. Furthermore, average level may be increased many db when the AAGC is employed.

Dual Controls

Applications wherein extremely wide level variations are likely to occur call for double-action control. Our studio units are of this type and some of these are used without manual assistance as, for example, in news flash booths. The philosophy leading to the development of these dual controls was basically as

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Fig. 5. Top view of ND-333 AAGC amplifier.



follows: with normal input, a limiter type of control would be thoroughly satisfactory. But suppose a speaker were close to the microphone and also had louder-than-normal voice—the microphone output might easily be 20 db or so above normal. This condition frequently exists in practice, especially when the speaker must override a high ambient acoustical noise level. Thus, peak gain reductions of 20 to 22 db are not uncommon, and this is too much for an ordinary limiter since gain rises too rapidly during slight pauses, producing a continual rising and falling effect which removes syllable emphasis and creates an unnatural and displeasing sound. If, however, control adjustment were made slowly in the microphone circuit ahead of the limiter, the rapidly rising gain during pauses would be evident only during the first few spoken words, that is, during the transition period prior to attenuation of average level by the first circuit. Thereafter the input level would be held down to just slightly above normal. If long pauses existed, the input would slowly restore gain towards maximum. Thus the func-

tioning of such a double circuit might be likened to a person's neck and eye action wherein he glances only with the eyes at objects which are to be viewed but momentarily. When prolonged viewing is called for, the neck automatically turns to relieve the eyes of most of their displacement after which the eyes are in better position for continued viewing. The slow averaging of the dual control is thus similar to neck action, whereas the rapid limiting is similar to eye action.

Units employing two controlled stages have served satisfactorily in studio operations for the past twelve years. These operate with the first stage functioning on average level. The second stage, having a rapid attack time, is always available for conventional limiting. Recently, in order to simplify and further improve this double action, designs have utilized a double-time-constant circuit operating in a single controlled stage. Here two radically different time constant RC circuits are operated in series in such manner that a small capacitor is quickly charged by a single peak in the control rectifier. A much larger capacitor is slowly charged, requiring many peaks to

accumulate an appreciable charge. But if a high signal level persists for a sizable fraction of a second, the voltage across the larger capacitor becomes equal to or even greater than that across the smaller, due to the ratio of discharge resistors. Therefore, after only a few short program bursts, most of rectified control potential appears across the small capacitor and recovery rate is rapid—about 0.5 second for 90 per cent recovery. However, after continued peaks most of the rectified potential accumulates across the large capacitor, allowing the rapidly acting circuit to relax in its activity. The resulting recovery rate after prolonged peaks is relatively slow—about 2 seconds for 50 per cent recovery and 8 to 12 seconds for 90 per cent recovery. Again it should be brought out that limiting action, with this type of double time constant circuit, is always available for holding down unduly high level peaks. Such a dual control is desirable for any of the various applications where extreme portability is not required.

The most recent AAGC developed at NBC, Type ND-333 studio control unit, is pictured on Fig. 5. It is operated in place of a regular studio amplifier, having sufficient gain for operation between the mixer output and the program bus.

It has a maximum voltage gain of 81 db, will control programs at as low as -75 VU, and has a maximum output power of around 4 watts at 15 ohms impedance. It is a rack mounted unit, powered from either a house battery supply or the 115-volt a.c. line. All controls except the meter switch are located behind the hinged front panel door in order to reduce the likelihood of undue tampering.

Three different control characteristics are remotely selectable to suit the particular program material, two relays mounted on the chassis providing for this remote selection. The *modified limiting* characteristic previously described is used for all programs of local origin, with the exception of symphony and opera. For these, the *compression* characteristic is available. The *nemo* or *limiting* characteristic is for the programs from outside the studio where the program has previously undergone automatic gain control. Thus, no additional control is introduced for normal level peaks. To achieve this, a connection may be made at the control console's nemo switch in order to select automatically this *nemo* characteristic for outside programs, causing the unit to act like an ordinary amplifier unless some unreason-

ably high peak occurs in the program.

The two controlled tubes in this particular unit are 6SA7's, which should be properly balanced for transconductance. Assuming normally good tubes, this balance is readily achieved by means of a balance checking switch and adjusting system. When the balance switch is pressed, a 60-cps signal is applied in phase to the control grids of the 6SA7's, and the balance potentiometer may be adjusted for minimum output meter reading. Balance checks by this means show that ordinary tubes give excellent balance and produce no audible plop or any discernible dissymmetry on an oscilloscope. Furthermore, correct balance produces the condition of minimum harmonic distortion as indicated on a distortion meter.

Above 50 cps, distortion is extremely low, even for conditions of high input levels and gain reduction. Measured curves are shown on Fig. 6, and these are representative of ordinary good tubes.

After reaching what was believed to be the stage of complete development, one of these controlled amplifiers was placed in studio operation and used on a great many different N. Y. programs with excellent results. Then a complaint

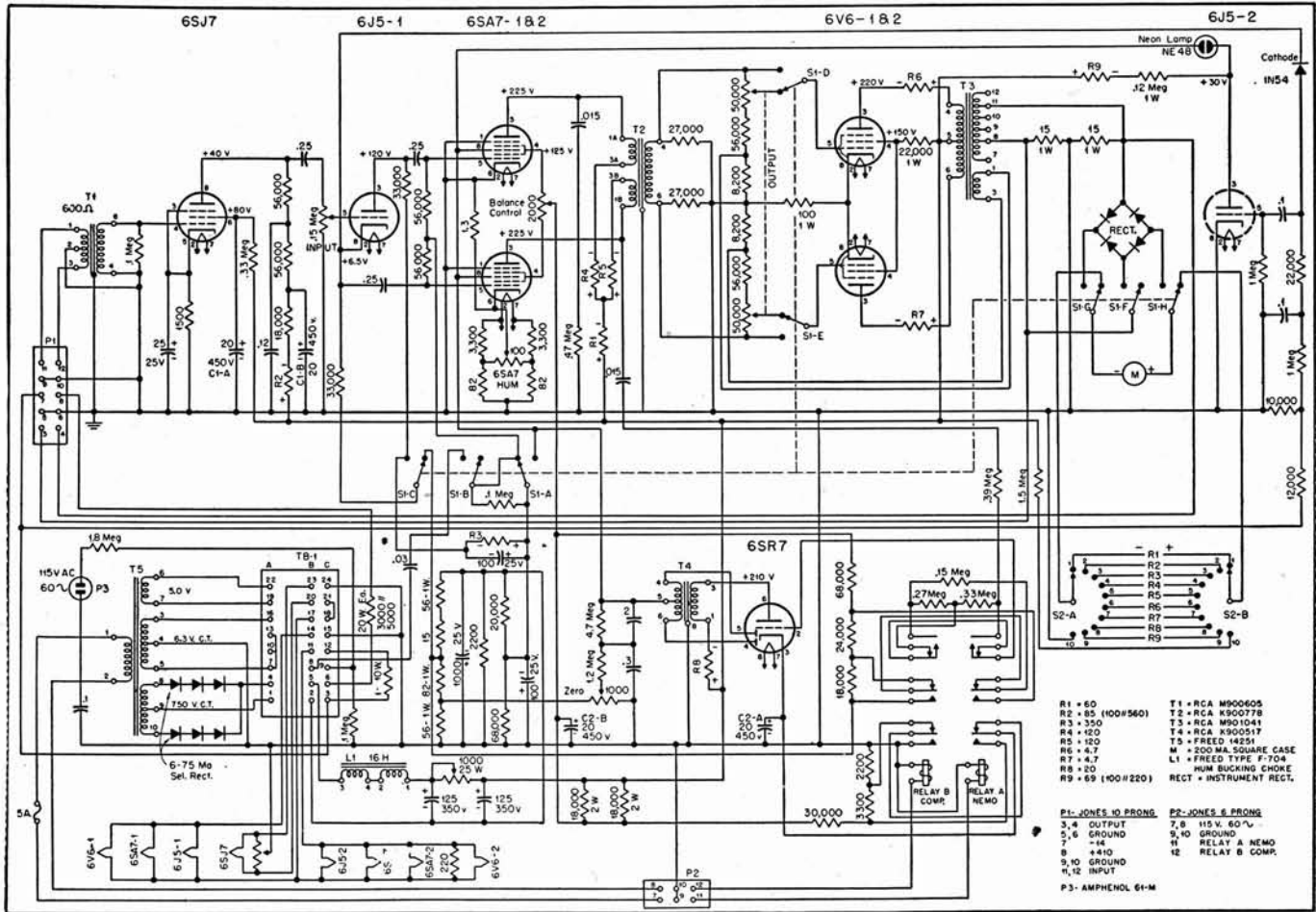


Fig. 7. Complete schematic of ND-333 Automatic Audio Gain Control Amplifier.

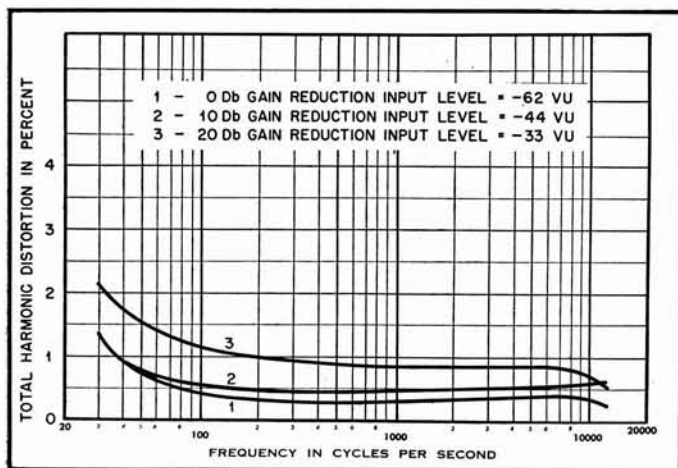


Fig. 6. Harmonic distortion curves for ND-333 amplifier under different operating conditions.

was received which could not be overlooked. The producer on one of the dramatic shows believed that the unit was holding pistol shots down too low in level. He liked its action otherwise but wanted to hear the sound-effect shots louder and have them indicate full scale on the VU meter—the engineer had always been able to achieve this without the automatic control. He agreed that the broadcasting station limiter would reduce most of the excessive peak level but still wanted a more realistic effect in the control and clients booths. Therefore, a short study of pistol shot acoustical characteristics was conducted by viewing oscilloscope patterns. The main portion of the pistol shot proved to be extremely short, in the order of 15 milliseconds. Such a short burst at normal amplitude does not sound loud, nor does it register fully on a VU meter. In order to make it indicate and sound full, the amplitude must be increased several fold. With this in mind, a special circuit was invented and installed in the unit to create the desired effect. Figure 7 is a complete schematic of the ND-333 AAGC, showing the pistol shot accentuating circuit at the upper right portion. A crystal rectifier converts a sample of the high-intensity sound potential to a negative d.c. pulse which is coupled to the grid of a triode amplifier. The crystal is biased to conduct only when the input level is 24 db above threshold, a condition existing only on pistol shots as far as we can determine, assuming some degree of manual control. The negative pulse on the grid results in a positive plate pulse, which in turn ignites the neon lamp and momentarily decommissions the control circuit.

ND-333 Application

The new studio control unit is highly effective and multifold in purpose. It permits 6- to 8-db higher average output onto the telephone lines feeding both

the local and remote broadcast transmitters. It permits a more even over-all control of level, and unless its action is purposely overridden by the control engineer, makes it unnecessary for millions of listeners to continually jump to adjust the volume controls on millions of radio receivers throughout the country. It gives improved television sound through increased transmission level and uniformity. It prevents excessive levels on telephone long lines, which otherwise cause severe distortion. Broadcasters sometimes feel that the long-lines personnel are supercritical of level. It must not be too high or too low or they call master control to insist on something being done about it. At Radio City some of these AAGC units have been available for just this type of emergency. An engineer on a complicated show may have ten or more microphones to keep properly mixed—a producer shouting instruction, a script to follow, and in addition a PA system to control as well as over-all output level. When "long lines" calls master control and they in turn call this one-armed paper hanger two or three times to bring up level or hold down peaks, he becomes slightly confused. Then, in the deliberate atmosphere of the transmission room, someone says "Here's a rubber amplifier for him," silently inserting patch cords to replace the uncontrolled studio amplifier. Calm returns to the master control room, no more calls come from the supercritical long liners, and in the control booth the operator suddenly has no more trouble delivering a sufficiently high level without the VU meter hitting hard off scale. Above all, thanks to Automatic Audio Gain Control, the listener whose baby sleeps upstairs hears every word of his favorite program without worry of a floor walking session.

In conclusion, a great deal of credit and thanks should go to Mr. Raymond Lafferty of the NBC Engineering Development Group for his skill and diligence in the development and application of the ND-333.



Employment Register

EMPLOYMENT OPPORTUNITIES 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 first of the month preceding the date of issue. Replies to box numbers should be addressed to AUDIO ENGINEERING, 342 Madison Ave., New York 17, N. Y.

★ Positions Open

● Positions Wanted

★ **BRAZIL:** We have an opening for an electronic engineer who would like to come to Brazil and become a partner in an old established high-class service organization. Want man with all around knowledge of receivers, amplifiers, test equipment, electronic heating, and general application of electronics. Capital required, about \$5000. São Paulo is the fastest growing city in South America. Genial climate. Food plentiful. Assured future for a good man of about 30. Knowledge of Portuguese not essential. References exchanged. Box 1001.

★ **Wireman,** instrument, capable of building models and occasional short production runs of precision electronic devices. Must be able to work with minimum of supervision. Permanent; write giving salary expected, family status, availability. Box 1002.

★ **WANTED:** Signal Corp Center, Fort Monmouth, N. J. has openings in the following Civil Service positions:

Military Instructors—Microwave relay, radar, radio electronics, fixed station radio, central office techniques, teletype installation and maintenance, repeater and carrier, dial central office maintenance, theory of electricity. \$3100-4600.

Electronic Engineers—Participate in design, development, modification, construction, and testing of electronic equipment—radio, radar, wire communications, instrumentation, sonar, etc. Responsibility depending upon experience and ability. \$3100-6400.

Technical Writers—Write, edit, prepare technical publications, handbooks, circulars, instruction books, etc. Edit and revise scientific manuscripts on radio, radar, electronics, communications, and photography. Write instruction manuals on theory, operation, and maintenance of Signal Corps equipment; determine media and method of presentation of material; prepare charts, graphs, schematic diagrams etc. \$3100-5400.

Applicants for any of these positions should write Chief, Civilian Personnel Branch, Signal Corps Center, Fort Monmouth, N. J., submitting a completed Standard Form 57, "Application for Federal Employment" (obtainable at any first or second class post office) for review before going to Fort Monmouth for a personal interview.