Fig. 1. Front panel of portable amplifier. Access plate at left end is removed to permit connection of microphone cables.

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Practical, standard engineering provides a design which features compactness, reliability, flexibility, and performance.

New Portable Audio Amplifier for AM-FM-TV

THE FUNCTION of a portable amplifier is to receive the signals from the microphones at a remote-broadcast location, combine them in the desired proportions, and amplify the resulting signal to a level suitable for transmission to the broadcast studio. Since a.c. power is not available at all locations, portable amplifiers must operate from batteries, or from both a.c. and batteries. The electrical performance must be of broadcast quality, although the specifications of most earlier amplifiers are not as rigid as those on studio equipment. As the unit is frequently carried from studio to a remote location, and from one remote to another, it must be light in weight, easy to carry, and of sturdy construction.

In the design of any piece of portable audio equipment, some compromise must be made between the features of the equipment and the size and weight. One of the main determining factors in this compromise is the type of mixing system used. In low-level mixing, the microphone outputs go directly to the mixer system where they are combined and then amplified. High-level mixing, on the other hand, uses an amplifier between each microphone and the mixer system.

Signal-to-noise ratio in a properly designed amplifier is largely determined by what happens at the grid of the first stage. A practical average value of noise in an input stage using a modern low-noise tube is in the order of —125 dbm. This noise can be made to consist essentially of tube and circuit hiss, with the hum appreciably lower in level.

Since broadcast microphones have effective output levels in the order of —50 dbm in moderately loud sound fields, the signal-to-noise ratio at the first grid seldom starts out better than 75 db. In weaker sound fields this ratio is correspondingly degraded.

Now assume that a four-channel, low-level mixing system is interposed between the microphone and the first grid. Such a mixer has an initial loss of approximately 10 db and usually is set by the operator to have a loss closer to 20 db. It is seen that such a mixing system generally reduces the signal-to-noise ratio to 55 db.

These figures are based on the use of the very best type low-noise, low-microphonic input tubes. It can be demonstrated that the use of receiving-type tubes, especially certain types of miniature tubes, will raise the noise an additional 10 to 20 db and change its character from smooth hiss to very annoying hum or to microphonic ringing noises.

Therefore, for portable amplifiers using low-level mixing systems and receiving-type input tubes, it is not unusual to measure signal-to-noise ratios of only 40 or 45 db under standard test conditions approximating a microphone in a moderately loud sound field. Consider what the ratio becomes when the microphone is in a weak sound field. Hardly the background of "dead silence" required by today's new transmitting systems.

When high-level mixing is used, the story is much more attractive since the signal-to-noise ratio seldom goes below that established at the first grid. High-level mixing plus the use of modern low-noise tubes insures the lowest possible noise level at all times.

Consider the output of the microphone in our moderately strong sound field to be —50 dbm. In a high-level mixing system it is first given a boost of 40 db in a low-noise pre-amplifier stage. Then the signal drops, say 20 db, in the mixer. It is still 20 db above microphone level when it is applied to the tube following the mixer. By making the booster stage design the same as that of a low-noise pre-amplifier, the mixer settings can be increased to give a 40-db loss before the signal-to-noise ratio has been reduced below that prevailing at the first grid.

High-level mixing gives other advantages. Since input transformers are used ahead of each tube, the microphone lines may be operated balanced to ground. This gives a noise reducing advantage where the cables are quite long and must run through interference

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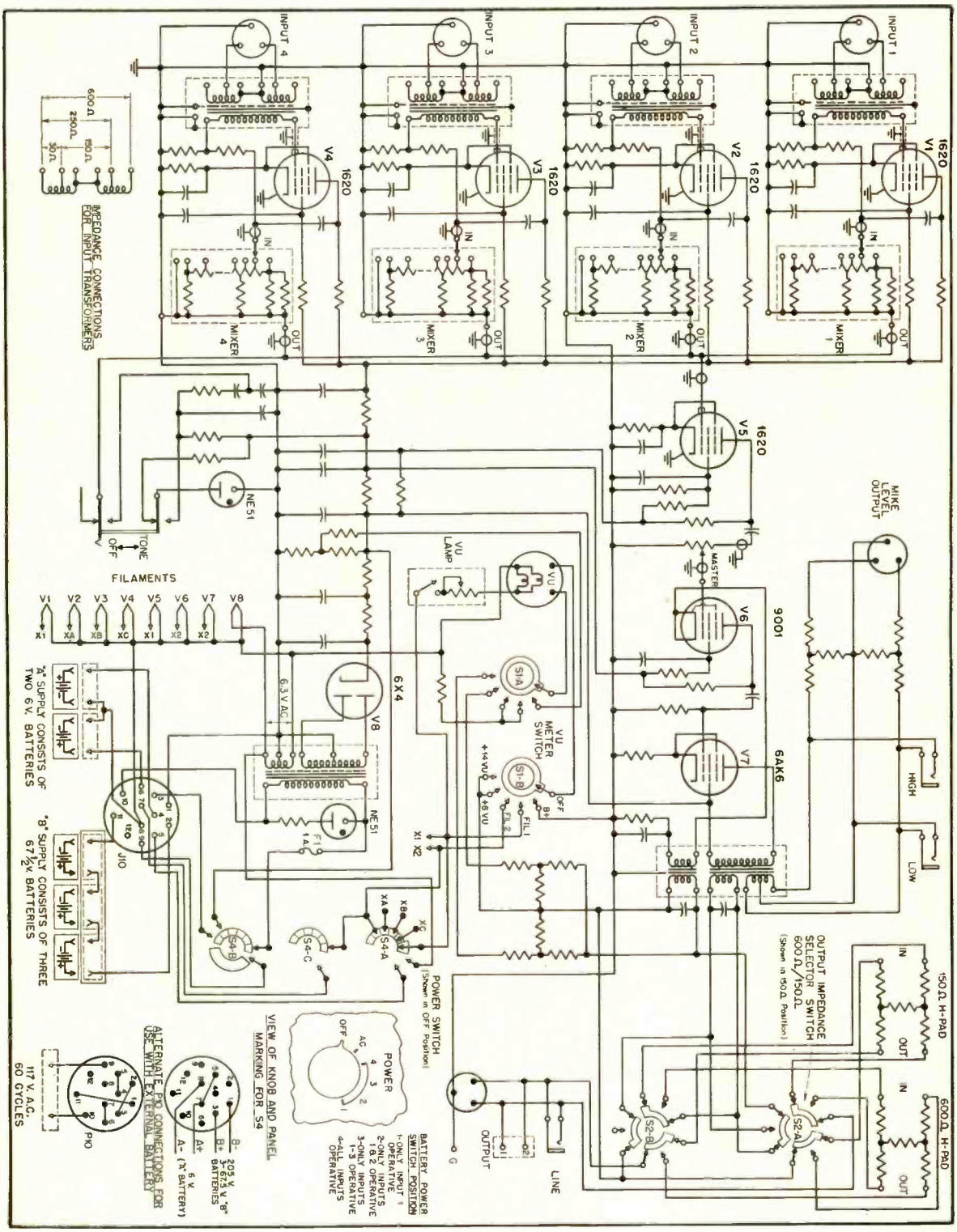


Fig. 3. Schematic of GE Type BA-6-A portable amplifier.

fields. Also, the use of input transformers permits tap changing to match various source impedances.

A. C. and Battery Power Supply

Portable amplifiers which operate from both a.c. and batteries may be divided into two general classifications: (1) Those which have the batteries in a separate case, and (2) Those which have the batteries included in the same case with the amplifier. The advantages of a.c. and battery power in the amplifier case, rather than in a second container, are many. It is safe to assume that most pickup locations have reasonably reliable a.c. power available. However, this power has been known to fail, and in such cases, the inclusion of batteries in the amplifier case where they are *always* available is a great asset.

Because of the additional space and battery power required by the pre-amplifiers of a high-level mixing type of remote amplifier, it is not feasible to include an extended-life complement of batteries in the single-case design. However, lightweight, emergency batteries may be included. In the event of a.c. power failure these would be expected to operate only until the end of the program.

To make this single unit design practical, it was necessary to reduce the power drain to a minimum. In fact, miniature tubes were used throughout the entire amplifier during the early stages of the design because of the reduced heater drain (150 ma for the miniature 9001 tube as compared to 300 ma for the octal base 1620). Type 9001 tubes were employed in the pre-amplifiers and also in the booster and driver stages since this tube makes a very effective high-gain pentode stage, and can also be used as a triode where desired. A 6AK6 tube was used in the output stage and a 6X4 tube as a rectifier. Unfortunately, the hum and microphonics resulting from the 9001 tubes in the pre-amplifier and booster stages were intolerable and these tubes had to be replaced by 1620's, which are especially designed for low-level audio applications. The 9001 was retained in the driver stage, as this stage operates at a level sufficiently high that overall performance is not degraded by the tube. The 6AK6 was chosen since it is the only available tube with a 150 ma. heater which would deliver the required +18 dbm output through a pad of adequate size. The drain on the "B" supply is small enough so that it presents less of a problem.

In addition to the partial use of low-heater-drain miniature tubes, the "A" battery life was further increased by opening the heaters of tubes not in use. Many remote broadcasts use only one or two microphones; therefore the power switch was wired to disconnect the heaters of the pre-amplifier tubes not in use. This switch has five operating positions in addition to the OFF position. The first position permits a.c. operation with all tubes connected, the next four positions are for battery operation with either four, three, two or one pre-amplifier heater connected.

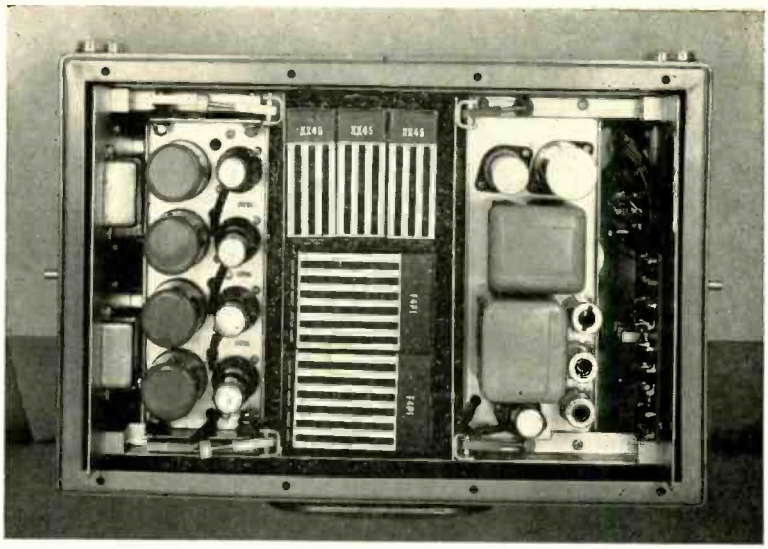


Fig. 2. Portable amplifier with rear cover and battery cover removed.

When the amplifier is operating from its a.c. supply and a power failure occurs, the VU meter pilot lamps and a neon a.c. indicator lamp will go out. The operator then has approximately two seconds in which he can turn the power switch to one of the battery positions without noticeable loss of program level or quality. In the event that a.c. power is restored before the end of the program, the operator is notified by the a.c. indicator lamp and he may then turn the power switch back to the AC position after allowing time for the rectifier cathode to heat. The power changes are not noticeable on the air.

To eliminate the possibility of the internal batteries running down due to the operator forgetting to turn off the amplifier at the conclusion of a broadcast, the batteries are interlocked with the a. c. power cord. This cord must be plugged into the amplifier for the internal batteries to be operative and must be removed to close the case for transit. The power receptacle is also arranged so that external batteries may be used when desired.

Test Tone

A unique feature of the amplifier is the inclusion of a 400-cycle test oscillator for adjusting operating levels. The oscillator is of the relaxation type and employs a 1/25 watt neon-lamp which also serves as a low-drain d.c. pilot lamp when it is not used for adjusting levels. This oscillator provides a direct method for adjusting the level to the control room, eliminates the necessity of setting up a separate microphone near the amplifier, "woofing" the sound peaks and watching the VU meter. Test-tone is also a help where the set up and level check must be made under conditions where "woofing" into a microphone is not desirable. This sometimes happens during a nightclub floor show where quiet is demanded, or in a church where the set-up must be made during part of a service.

Monitoring Circuits and P. A. Feed

In the use of many portable amplifiers, it has been found that sufficient volume has not been provided for headphone monitoring in noisy locations, so two jacks are provided for the phones. The low-level jack is connected across half of an isolated secondary winding and operates at line level which is normally satisfactory for headphone monitoring. The high-level jack is connected across the full winding and allows the operator to monitor at a 6 db higher level, which helps to overcome extremely high background noise.

A third monitoring jack, for two-way talkback to the control room, is connected directly across the line terminals on the line side of the output pad. When the headphones are plugged into this jack, the operator can communicate with and receive program cue from the control room preparatory to going on the air.

The monitoring winding is also connected to a pad which furnishes microphone-level output to a 50-ohm balanced load. The connection is very useful for feeding public address system inputs

or other portable amplifier. In the latter case seven input channels, with sub-master control over four of the channels, may be provided by connecting the MIKE LEVEL OUTPUT of one G-E portable amplifier to one of the inputs of a second portable amplifier.

A full-size illuminated VU meter is provided for convenience of operation. A dimmer control and switch are used to dim the pilot lamps or turn them completely off if it is desired to decrease the drain on the batteries. In addition to two volume-indicating range positions on the VU meter selector switch, there are positions for checking the two "A" batteries and the "B" batteries. This makes it possible to check the condition of the batteries without the necessity of using external meters. The normal operating position of the VU meter selector switch is the +8 VU position corresponding to normal line level. A +14 VU position is also included so that the telephone lines can be fed at a higher level in case of an emergency condition where it may be necessary to override high line noise. Although the amplifier is rated at +18 dbm (+8 VU with a 10 db peak factor), listening tests have demonstrated that quality was acceptable at +14 VU even with reduced battery voltages.

6-DB Output Pad

The output of any amplifier which is intended to feed a telephone line should first go through an isolation pad. Such a pad performs the following functions:

1. Provides an essentially resistive source for the telephone line by minimizing the effects of varying amplifier internal impedance.
2. Provides an essentially resistive load for the amplifier and VU meter by minimizing the effects of varying telephone-line impedance.

The reason for the pad, then, is to minimize the effects of impedance variations in amplifier and line. It follows that the larger the attenuation of the pad the less will be the effect of varying impedances. Use of an adequate loss pad will permit better line equalization, give more accurate VU meter readings and permit the amplifier to function at peak efficiency.

Examination of curves showing the reduction of impedance variations versus pad loss indicated that at least 6 db must be used for high-quality performance. More than 6 db loss would require an excessively large output stage. A loss of 6 db in the isolation pads was therefore indicated.

Either 600- or 150-ohm output transformer connections and isolation pads may be used. Selection is by means of a screwdriver-operated switch. 600 ohms is standard for use on 600-ohm equalized circuits. 150 ohms is used on relatively short, unequalized circuits where the low sending impedance provides a degree of equalization which tends to compensate for the transmission characteristics of the line.

Construction

The Type BA-6-A Portable Amplifier is housed in a lightweight aluminum alloy case 12 inches high by 17⅞ inches long, and 8⅝ inches deep. It weighs approximately 35 pounds, including the weight of the emergency batteries. When operated without internal batteries it weighs approximately 30 lbs. A neat appearance is presented by the grey baked-enamel finish of the case proper and the contrasting blue vinyl plastic-coated fabric applied to both front and rear covers.

Removal of the front cover gives access to the panel, *Fig.* 1, on which all of the operating controls are located. The center section of the panel is finished in blue. The remainder of the panel is finished in satin aluminum. Above each mixer control is a write-in space in which notes may be pencilled and erased. Provision is made to store the a.c. power cord within the front cover.

Removal of the rear cover provides access to the tubes, transformers, and the battery compartment, *Fig.* 2. The batteries are clamped in place by a cover which is easily released by means of four thumb nuts. Spare tubes and fuses are clamped to the inside of the rear cover.

Flush-mounted, snap-in access plates are provided on the sides of the case for access to the input and output connectors of the amplifier. The four input receptacles are mounted on the left side, while the power, line output, and mike level output receptacles, the line output terminals, monitoring jacks, and the output-impedance selector switch are all located on the right side. The access plates are attached to the amplifier by small head chains.

Audio Circuits

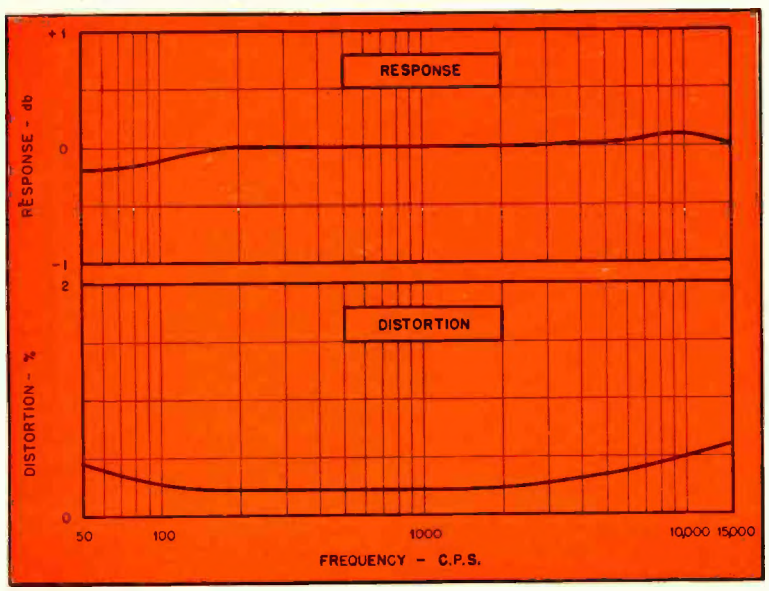
The schematic, *Fig.* 3, shows that the unit consists of four pre-amplifiers, a mixer system, and a program amplifier with booster, driver and output stages. The master gain control precedes the driver stage.

The pre-amplifiers use type 1620 low-noise, low-microphonic tubes, pentode-connected for maximum gain. Inverse feedback is used in these amplifiers to reduce distortion at high input levels. The taps on the input transformers may be adjusted so that the amplifier will operate from 30, 150, 250, or 600 ohms depending upon the type of microphone used. To further reduce microphonic and shock disturbances, the pre-amplifier assembly is cushioned with soft rubber shock mountings.

The four pre-amplifiers feed directly into a high-impedance mixing system which eliminates the need for all transformers between pre-amplifier and program amplifier. The impedance ratio of the ladder network attenuators is 1:2 for minmum loss. High-quality, step-type attenuators are used throughout for smooth, noise-free operation and long life.

Another 1620 is used in the booster stage, as it may operate at a level only slightly higher than microphone level for extreme settings of the gain con-

Fig. 4. Measured performance characteristics of portable amplifier.



trols. A partially by-passed screen circuit is used to provide current feedback, which reduces distortion and raises the input impedance of the booster tube at high frequencies. This effect makes the frequency response essentially independent of mixer adjustments.

The driver and output stage use tube types 9001 and 6AK6 respectively. Inverse voltage feedback is taken from a tertiary winding on the output transformer to the driver stage to minimize the overall distortion and noise. The output impedance is changed from 150 to 600 ohms by changing the two load windings from the parallel to the series connection. The 6-db isolation pads are inserted between the transformer and the output receptacle for both 150- and 600-ohm connections.

Typical performance characteristics are shown in *Fig.* 4. The frequency response is within 1 db from 50 to 15,000 cycles. The distortion is less than one per cent from 50 to 15,000 cycles. Noise is 70 db below the standard output of +18 dbm with the controls in typical operating positions. The maximum gain is 93 db.

The proportions of the amplifier case make it very easy to carry. It is narrow enough so that it will hang freely without bumping into the operator's legs. The amplifier is light enough to be truly portable. The design objective of a single unit amplifier with high level mixing and emergency battery operation has been accomplished.