A New Program Distribution System

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PLANNING a system layout of a major sound installation, whether it be for purposes of broadcasting, recording, public address, or any other application dealing with the distribution of many circuits to many other circuits, has for some time been a science occupying the minds of some highly specialized engineers in the audio-electronics industry. Many systems have been designed and built over the years, from installations such as a major broadcasting network might boast, to small "package" systems intended for smaller applications. This article deals with a fairly extensive distribution network for use in a recording installation requiring the receiving and sending of signal over a multitude of circuits.

PRESENTLY USED SYSTEMS

The matter of program distribution is most commonly handled through the use of a 150- or 600-ohm terminated trunk or "bus," as we shall refer to it hereafter, which is bridged at various points by a high-impedance device. In this way no additional termination of any magnitude is placed across the bus, and its level does not drop even with several bridged feeds across it. The bridging impedance used in most applications is of the order of 10,000 ohms or higher, so that if less than twenty bridges are placed across a 600-ohm bus, their combined impedances will equal 600 ohms. This termination in parallel with the existing 600 ohms termination will cause the level on the bus to drop approximately 4 db, depending on the internal impedance of the amplifier feeding it. The loss incurred in an average bridging circuit is about 22 db, under the best turns-ratio-gain conditions of a bridging transformer. This loss must, of course, be made up by subsequent amplification, if the final level required is the same as the bus level itself.

Owing to the necessity of metering the bus program level on a standard volume-indicating meter, the bus level is invariably chosen to be 0 dbm (0.001 watt) or above. VU meter matching pads commercially available make +4 or +8 dbm the most popular levels, especially since the recommended telephone program line level is +8 dbm. Consequently, available broadcast line amplifiers are engineered to deliver +18 dbm (leaving a safety zone for instantaneous program peaks of 10 db above program level) within FCC specified distortion limits. The use of higher output level equipment has up to now been discouraged, since power amplifiers of low distortion ratings were either unavailable to broadcasters or were prohibitive in size, power consumption, and heat dissipation.

It may be prudent to note at this point that the metering of a 600-ohm terminated program line at a level of 0 dbm by a standard VU meter (properly bridged) produces 0.3% rms harmonic distortion at full-scale deflection and even more at lower readings. This is due to the partial rectification of the signal by the meter rectifier. The authors have noted many installations where not one but numerous VU meters were placed across the same program bus at various points, and we wonder whether the facts above should not be carefully considered before subsequent system layouts are designed. Perhaps this may even be the time for manufacturers to release more sensitive volume meters, now that we have entered upon an era when 0.3% distortion becomes more than just a matter of academic interest.

METHODS OF CIRCUIT SELECTION

Typical installations in the broadcast field today find radio lines, recording machines, transmitters, and the like connected to the proper program sources by means of either jacks and patch cords, push-buttons, rotary switches, or lever keys. All these methods require either the necessity of bringing all the available circuits to each recording machine, or the constant attention and attendance of an engineer-operator in a central master control room, who will patch up each feed as required when so requested by telephone or intercommunication system.

THE PROBLEM AT HAND

The system outlined in this article was designed to satisfy the following stipulations: to distribute any one of 50 in-

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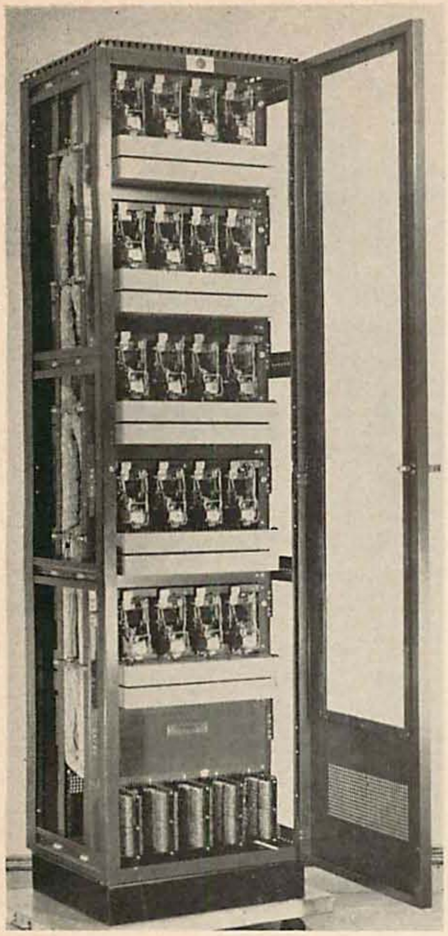

FIG. 1

coming signals consisting of radio lines, studios, tuners, turntables, tape machines, etc., to over 25 recording machines, tape, disk, and film; to make available to key executive personnel at their respective desks all these circuits for monitoring; to allow for practical expansion of facilities in the future, without making present installations obsolete; to facilitate moving of equipment to new locations with the least effort and interruption of operation; to provide adequate master control supervision of all circuits; to centralize all amplifying equipment (except for that directly associated with each recording machine) in one location; to provide the utmost protection from equipment failures.

THE SWITCHING OF CIRCUITS

The actual wiring of each of the more than 25 machines, located in twelve separate rooms over a widespread area, with 50 possible program sources would be prohibitive in cost as well as cumbersome to handle. At the same time the dangers of human error make the master control patched system far from satisfactory. Aside from this, experience with contact-type switching devices has shown that they require periodic burnishing of their contacts, which would become difficult in a widespread system. The system selected consists of a single, broadcast-type, 7-foot rack, into which 40 Strowger stepping selectors are fitted (Fig. 1). These steppers are actuated by telephone dials located on each recording device and permit access to 49 lines, yet require only a single pair of wires to each location. At the same time maintenance is concentrated in a single, easily accessible location.

THE BUS AMPLIFIER

Careful research into available amplifying equipment convinced us that to suit our special needs we would have to build our own. The amplifier had to be small enough to permit the installation of 49 units in a single rack and yet deliver sufficient power to permit the simultaneous recording on all machines at the same time and from the same circuit. In a concentrated effort to eliminate high-impedance bridging, it was decided to operate at an impedance low enough so that a 600-ohm termination would effectively bridge the bus. A 20:1 bridging ratio was found to be sufficient in view of the excellent damping factor of the proposed amplifier. This bridging ratio resulted in the 30-ohm bus which has become standard for our system. The actual level at which the bus was to operate was determined by calculating the needs of the recording equipment and then going backward through the circuit to the bus (Fig. 2). The input of most recording equipment is +4 dbm or above, which permits the use of a VU meter at this point. The loss of the input fader (600-ohm balanced ladder) was found to be 10 db for an average setting of three o'clock, which meant that an effective 600-ohm line level of +14 dbm was needed at each machine for proper input. The loss due to the 20:1 impedance mismatch comes to 13 db, which determines the final level of the 30-ohm bus at +27 dbm (0.5 watt). The fact should be noted that dial selectors located on each executive's desk are equipped solely with a 600-ohm to voice coil transformer, which will deliver sufficient power to a small desk-type speaker unit for instantaneous program feed monitoring without requiring any amplification locally. This is true where the amplifier is used as a bus amplifier and therefore must be bridged. The same am-

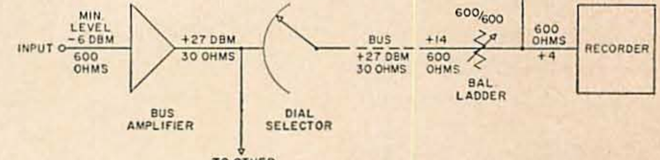

FIG. 2. Block schematic of system.

plifier will deliver 15 watts at 7½ ohms (connecting the output windings parallel) which is more than adequate for common loudspeaker monitoring requirements.

The physical size of each unit (Fig. 3) is 2½ in. wide, 5 in. high, and 13 in. long. This permits the mounting of seven amplifiers on each shelf, and seven shelves, one above the other, in a 77-in. rack panel space with plenty of room left over for terminal blocks at the bottom. Electrically, the amplifier consists of two separate and distinct, single-ended amplifier channels acting as "Siamese twins." They have a common input and output transformer. Each chain consists of one 12AU7 having its two elements cascaded, followed by a single-ended 6V6GT. This chain, together with the opposite, or "Siamese" chain, forms a regular push-pull amplifier. The input tubes are joined by a standard input transformer of sufficiently high operating level, so as to

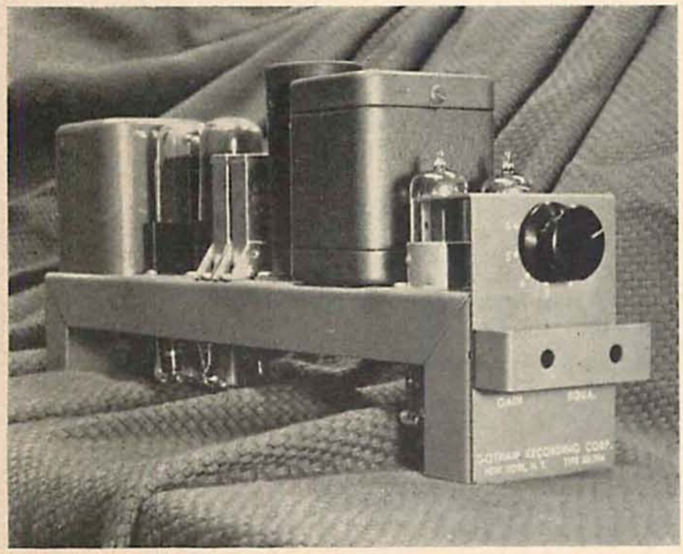

FIG. 3

hold distortion to a minimum at this point. The output tubes terminate in a specially wound transformer having four separate primaries of equal impedance and a split and balanced secondary of 30 ohms. The driver stage is joined by a common cathode resistor which tends to offset any ac unbalance resulting from uneven tube aging (Fig. 4). Also included in the circuit is a high-frequency equalizer capable of a boost of 18 db at 15 kc, to offset losses due to long-distance telephone transmission lines. Through the use of considerable feedback (both negative and positive) it has been possible to largely offset the possible loss of program feed resulting from failure of any tube or any component associated with a particular stage. The maintenance of level through such a failure was considered of utmost importance. Under the amplifier's normal operating conditions, tube aging is to be encountered most rarely. A 6-position switch on each unit connects with a master tube meter which is checked at the start of each day and which

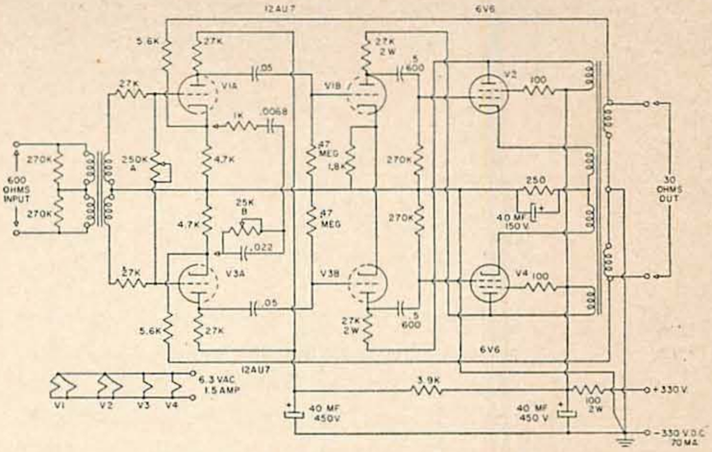

FIG. 4. Circuit diagram of amplifier.

shows such aging before any ill effects may occur. Tube failure, however, is unpredictable. Table I illustrates

TABLE I

Failure	Change in level	IM dist. at +27 dbm	Max. power output below 3% IM, dbm
None	None	0.05%	+43
V-1a or V-3a	None	0.10%	+40
V-1b or V-3b	None	0.10%	+40
V-1a and V-1b	None	0.25%	+40
V-3a and V-3b	None	0.25%	+40
V-2 or V-4	None	0.35%	+37
V-1a, V-1b & V-2	None	0.40%	+36
V-3a, V-3b & V-4	None	0.40%	+36
V-2 and V-4	−6 db	1.50%*	+22

* 1.5% measured at +21 dbm.

the effect on the gain of the bus amplifier as well as its distortion, resulting from the failure of its various tubes. As is visible in Fig. 5, turret-type tube sockets are used throughout, allowing elimination of the sides of the chassis which results in better ventilation of the output stage. Two 0.5-mf bathtub coupling condensers between the driver and

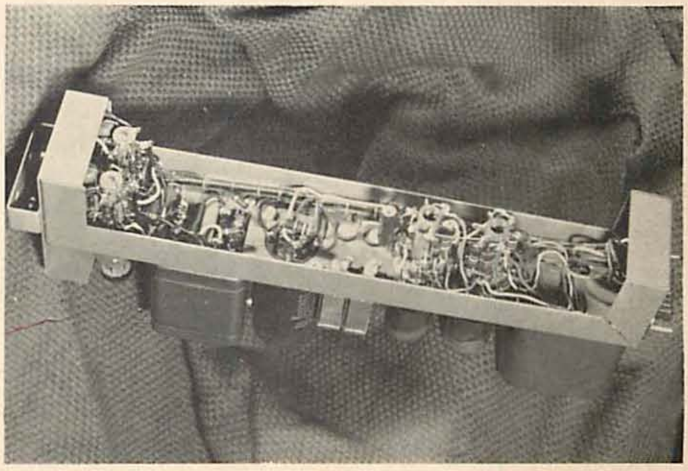

FIG. 5

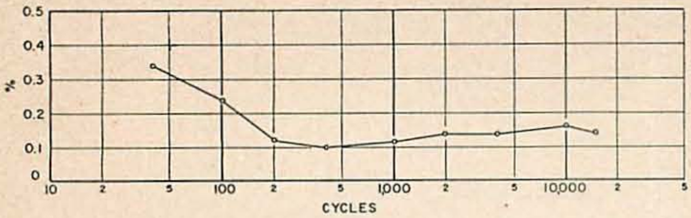

FIG. 6. Level of rms harmonic distortion at 10 db above program level. Measurements were made at +37 dbm (5 watts).

output stages are mounted on fiber washers to isolate them from chassis ground. This considerably reduces distortion at high frequencies produced by 600 $\mu\mu$f leakage capacitance between the condenser element and the condenser can, which is found in most units of this type. A 16-contact connector mates with a similar socket on the rack shelf. The power supply for this rack is located remotely in the power room and consists of a three-phase power transformer and bridge-type selenium rectifier which delivers approximately 4 amp at 330 volts dc. A ripple of 0.04% was found sufficiently low for an output noise level of −56 dbm (an equivalent signal-to-noise ratio of over 70 db). Filaments are AC heated, with 75 amps at 6.3 volt needed for the entire rack. Should our readers be skeptical about the seemingly

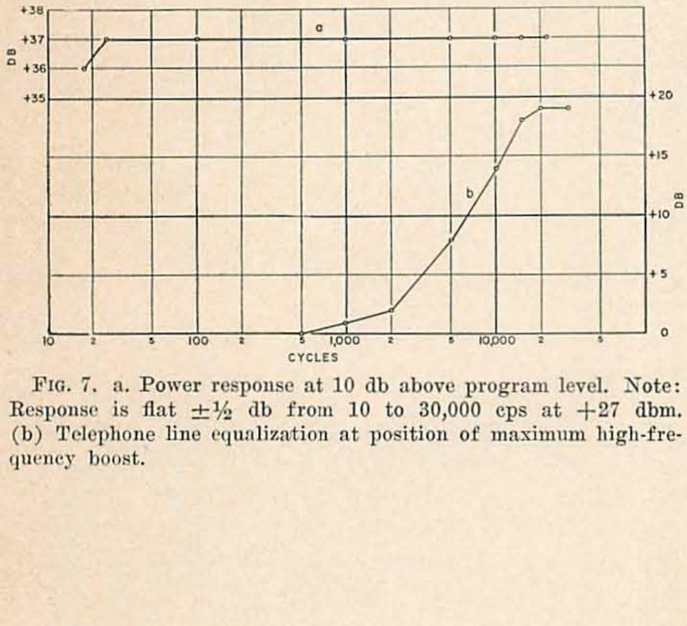

FIG. 7. a. Power response at 10 db above program level. Note: Response is flat ±½ db from 10 to 30,000 cps at +27 dbm. (b) Telephone line equalization at position of maximum high-frequency boost.

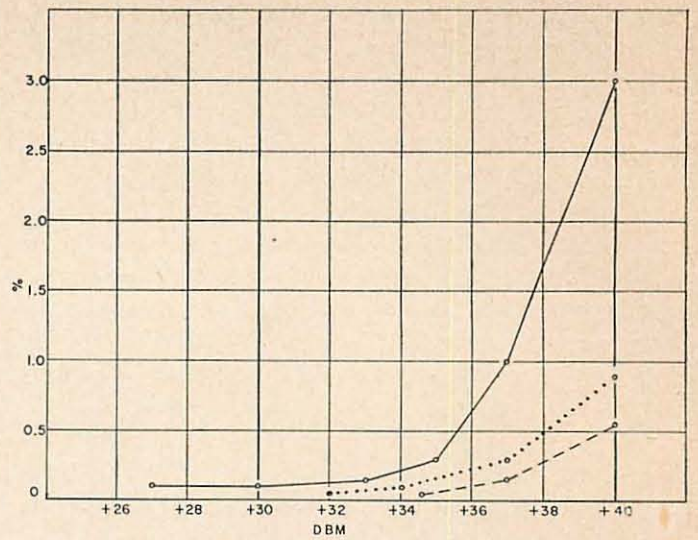

FIG. 8. Intermodulation distortion between a 60-cps and a 7000-cps signal having amplitudes in the ratio 4:1.
- - - - - - with two inputs across the bus
. . . . . . with ten inputs across the bus
———— with twenty inputs across the bus

high cost of such a supply, may we add that the total cost is about $3.00 per bus amplifier.

Figures 6, 7, and 8 illustrate several characteristic performance curves taken from a random production unit using a General Radio type 1932-A distortion and noise meter and type 1301-A low-distortion oscillator. In all cases the residual distortion of the test equipment has been deducted from the results shown.

We feel that the time has now come when power can be achieved without prohibitive size, making the high-level bus operation described possible, and more than that, advantageous. It permits, through the use of a single type of amplifier, the attainment of sufficient power, so that the total of all the loss devices that follow will return the signal to its required level. At no time is it necessary to dip back into the low-level regions in which hum, noise, microphonics, and crosstalk are a continuous hindrance to noise-free reproduction.