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Modern version of a 1938 design providing 96 db. and 10 watts.

Front panel view of the home-built, general purpose amplifier unit.

A Flexible General Purpose AMPLIFIER

THE trend in some manufactured amplifiers has been toward lowered costs at a noticeable sacrifice of performance and flexibility. It is getting rather difficult to find a high quality 10 watt amplifier with enough gain to allow good variable equalization, working from a source like a variable reluctance pickup. If low cost is a requirement the problem of finding a satisfactory amplifier package is multiplied. One answer to this problem is to build a Chinese copy of an outstandingly successful amplifier which has been thoroughly "exorcised."

The general purpose amplifier shown in the accompanying diagrams represents a series of progressive improvements over its original ancestor, which was an amplifier designed by George Downs in 1938 to test and demonstrate the early *Miller* lightweight pickup and the early *Lansing* two-way theater horn systems. Cary, Howard, Gilbert, Kelly, Hisserich, Bretell, and others have all contributed ideas to its development over the years and particular credit must be given to M. O. Kappler for the particular phase inverter used in the present version. Countless other commercial and amateur amplifiers have stemmed from the original Downs ancestor but many of them got lost because of trouble with the three-stage negative feedback. Those of us who have achieved success with this basic design agree that the only source of possible trouble is in the use of an unbalanced phase inverter and/or the use of a low grade output transformer. Many manufacturers of p.a. and b.c. studio equipment have built and sold various versions of this basic unit only to withdraw it from the market after six months or so. The explanation, in most cases, was that the early serial numbers worked fine but the later production runs were touchy and might oscillate, or sing, if the load was removed or tubes aged. In every case the cause could be traced to substitution of a lower priced output transformer or circuit simplification in the phase inverter, as compared with the original model. A lot of "ragged edge" feedback amplifiers will work pretty well as long as the load resistance is connected and as long as the tubes maintain their rated G_m. That is one of the beauties of feedback. However, it takes good design and a well built output transformer to operate well at non-standard line voltages, flat tubes, unbalanced tubes, and a highly reactive load like a speaker whose field has deteriorated.

One test of good phase-inverter and output transformer performance is to measure the maximum allowable feedback, before singing occurs, with a resistance termination on the output. In this amplifier singing occurs at about 30 db. of feedback (1000 cycles) terminated, with about 26 db. as the maximum for the unterminated condition. Ordinarily, good design suggests that the feedback be set at least 6 db. under the singing point terminated, which implies that no value of reactive load impedance can then cause singing. Actually, one can have too much feedback because only a very few measurement amplifiers need more stability than can be obtained with about 16 db. of feedback. With the constants shown, this amplifier has 17.6 db. of feedback, when working into a resistance termination. Working into an average 16 ohm speaker voice coil the feedback differed from the resistance termination figure by only a few tenths of a db. The feedback could be increased to 24 db. if desired, but no measurable improvement in frequency response nor intermodulation distortion resulted so there was no point in throwing away the 6 db. of net gain involved just to be able to say that the unit had 24 db. of feedback.

Circuit Details

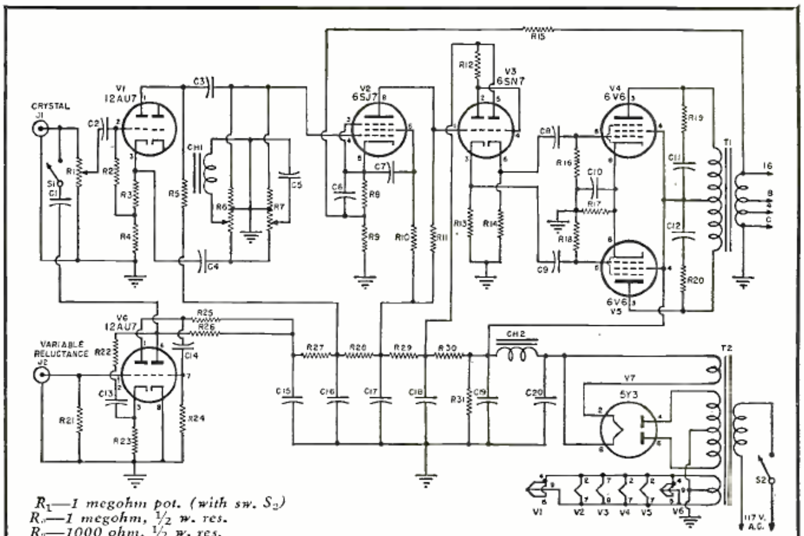
The amplifier has two input circuits so that sound sources of about 30 db. difference in 1000 cycle output can be handled without having to locate a gain control in a low level grid circuit. Actually, the high gain input was designed and equalized for a variable reluctance pickup, with the lower gain input designed for a crystal pickup. This feature is growing in popularity as critical record enthusiasts are indicating a preference for the variable reluctance pickup for 78 and 33 r.p.m. discs, with a good crystal the choice for the 45 r.p.m. discs. This fits in rather nicely with the belief that while there are several good combination 78 and 33 r.p.m. record changing mechanisms plus several good single speed 45 r.p.m. changers there does not seem to be a good three speed changer mechanism available that is completely happy at all three speeds and under all conditions of disc loading. Thus the high gain input gives a net corrected gain of 96 db. to the output terminals, while the low gain input shows a net gain of 70 db. Some thought was given to a d.c. filament supply but it will be found that turntable rumble will usually be more bothersome than the heater hum with the 60 db. volume range obtainable from this amplifier.

The preamplifier circuit is rather conventional except for the two-stage feedback whose purpose is fixed equalization and noise reduction. The feedback also acts to reduce the source impedance of the plate circuit of the second preamp stage and to keep it constant and independent of the tube aging, which would adversely affect the stability of the variable equalizer which follows the two-stage preamplifier. This particular equalizer is simple and effective. It allows separate adjustment of the low and high ends with 600 cycles kept constant. The 60 cycles can be raised 12 and cut 22 db., while 6000 cycles can be raised 12 db. and cut 18 db.

Any discussion of the theory of equalization will automatically produce a storm of mail for any technical writer so this one will merely say that after 20 odd years of building them, bearing with them, and burying them, I like the axis to bend up and down at 600 cycles, the geometric mean of the high fidelity speech band. I also like 60 and 6000 cycles as the design points for a combination equalizer and band limiting filter for music played at normal home volume. So you don't agree with me?—OK, so keep the iron hot and the *CR* box handy but the circuit and equalizer coil is a very good deal for a starter. This equalizer circuit has low insertion loss, being a feedback equalizer on the second preamp plate-cathode circuit, and has negligible transient and amplitude distortion. The A-74J has 70 db. of shielding, a very important item where the coil is followed by this much gain.

At the volume control the amplifier divides into what amounts to two parts. The first half is the three-stage preamp and equalizer followed by a high quality bridging amplifier with three-stage feedback giving exceptionally low noise and distortion. An extra input at the bridging amplifier input might be handy for program material that does not require variable equalization. (Is there any such program material?)

The first stage of the bridging amplifier is a rather conventional 6SJ7 stage with two points of interest. Note that the feedback from the voice coil winding (properly phased) is applied to the cathode tap and further note that there is no blocking condenser between the 6SJ7 plate and the first grid of the 6SN7 phase inverter. This d.c. coupling is very important in reducing the low frequency phase shift of the amplifier, which allows maximum feedback without low frequency motorboating. (High frequency phase shift is neutralized by the *RC* network across the primary of the output transformer.)



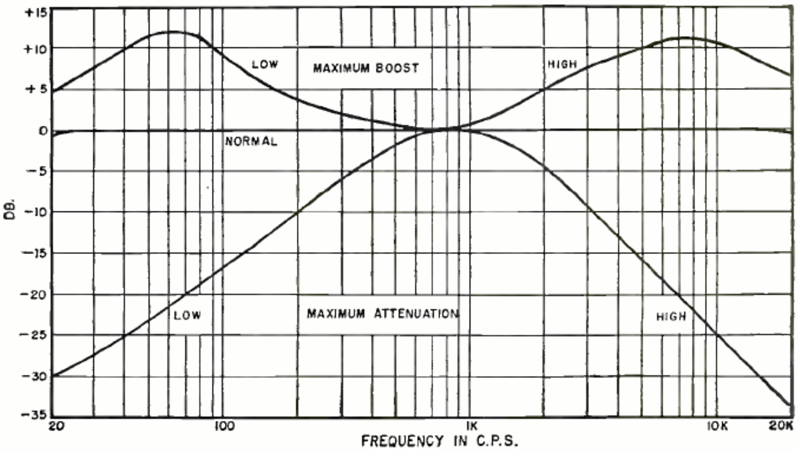
R_1—1 megohm pot. (with sw. S_2)
R_2—1 megohm, ½ w. res.
R_3—1000 ohm, ½ w. res.
R_4—22,000 ohm, ½ w. res.
R_5, R_{11}, R_{12}, R_{13}*—47.000 ohm, ½ w. res.*
R_6, R_7—1 megohm, center-tapped pot.
R_8—560 ohm, ½ w. res.
R_9—100 ohm, ½ w. res.
R_{10}—180,000 ohm, ½ w. res. (see text)
R_{14}, R_{21}, R_{22}, R_{25}, R_{26}—100,000 ohm, ½ w. res.*
R_{15}—750 ohm, ½ w. res.
R_{16}, R_{18}—470,000 ohm, ½ w. res.
R_{17}—270 ohm, 10 w. wirewound res.
R_{19}, R_{20}, R_{30}—2200 ohm, 1 w. res.
R_{23}—2200 ohm, ½ w. res.
R_{24}—10 megohm, ½ w. res.
R_{27}, R_{28}, R_{29}—22,000 ohm, 2 w. res.
R_{31}—10,000 ohm, 20 w. wirewound res.
C_1—.05 μfd., 400 v. cond.
C_2, C_7, C_8, C_9—.1 μfd., 400 v. cond.
C_3—.25 μfd., 400 v. cond.
C_4—.5 μfd., 400 v. cond.
C_5—.005 μfd., 400 v. cond.
C_6—25 μfd., 20 v. elec. cond.
C_{10}—40 μfd., 20 v. elec. cond.
C_{11}, C_{12}—.001 μfd., 400 v. cond.
C_{13}—.002 μfd., 400 v. cond.
C_{14}—.02 μfd., 400 v. cond.
C_{15}, C_{16}, C_{17}, C_{18}, C_{19}—20 μfd., 450 v. elec. cond.
C_{20}—10 μfd., 450 v. elec. cond.
J_1, J_2—Input jacks
S_1—S.p.s.t. toggle sw.
S_2—S.p.s.t. sw. (on R_1)
CH_1—Audio choke, 15 hy., zero dc., high "Q" (Triad A-74J)
CH_2—Filter choke, 9 hy. @ 125 ma., 250 ohms (Triad C-10X)
T_1—Output trans. 8000 ohms p.p. to 4, 8, 16 ohms, 15 watt (Triad S-31A)
T_2—Power trans. 350-0-350 v. @ 125 ma.; 5 v. @ 3 amps.; 6.3 v. @ 4.5 amps. c.t. (Triad R-14A)
V_1, V_6—12AU7 tube
V_2—6SJ7 tube
V_3—6SN7 tube
V_4, V_5—6V6 tube
V_7—5Y3 tube

** These resistors should be 5% units.*

Three feedback loops, d.c. coupling to and within a radical phase inverter, and wide-range variable equalization are featured in this new general-purpose amplifier design.

There is one semi-critical adjustment in the 6SJ7 stage and it is the only balance adjustment in the whole amplifier. The 180,000 ohm screen dropping resistor has to be trimmed to adjust the bias on the phase inverter. The bias on both halves of the 6SN7 is adjusted by means of the screen voltage of the 6SJ7. This adjustment does not have too much effect on the balance of the 6SN7 Kappler phase inverter but it sets the overload point and source resistance

Equalization curves showing available boost and cut in the new feedback equalizer which is characterized by wide range and low insertion loss.



of the two halves of the 6SN7 output circuit for the most graceful overload curve. This results in low, even-order harmonics even well into overload. This amplifier can be operated 3 to 5 db. higher than amplifiers of similar power rating because of the graceful way it slides into overload, thus taking the curse off the occasional high level peaks that sneak through.

The Kappler phase inverter is interesting because of its direct coupled input and interstage circuits. The elimination of coupling condensers is extremely important in stable feedback amplifiers. In fact, it is coupling reactances, such as blocking condensers and transformers, which limit feedback and not the number of vacuum tube stages within the feedback loop. In this three-stage bridging amplifier the two blocking condensers between the cathodes of the 6SN7 phase inverter and the grids of the 6V6 power amplifier are substantially in parallel as far as their contribution to phase shift and singing are concerned. Thus, this bridging section might be thought to include one blocking condenser and one transformer in the feedback loop, a feature which provides great stability against motorboating and high frequency oscillation.

By driving the 6V6 grids from low impedance cathodes of the preceding phase inverter stage the exciting voltage comes from a source of good voltage regulation so that the output grids can go slightly positive on level peaks without excessive peak clipping and consequent high order distortion.

The output circuit is conventional except that a phase correcting network is tied across the primary of the *Triad* S-31A output transformer. If any other output transformer is substituted a different phase shift network will be necessary. Many builders may infer that such phase shift networks are undesirable and may point out that their particular amplifiers need no phase correcting networks. My question to them would be, "Does *your* amplifier put 30 db. of feedback around three stages without oscillation?" This S-31A seems to have much better than average balance and lower leakage reactance than many output transformers selling for several times the price. The phase shift network might be eliminated by using the *Triad* HS-81 which has less high frequency phase shift, due to materially lower leakage reactance, and the extra octave of response is attractive to those with big horn systems.

The primary winding of the output transformer should be reversed if the amplifier sings, as one polarity of feedback is positive while the proper polarity acts to reduce the gross gain of the amplifier.

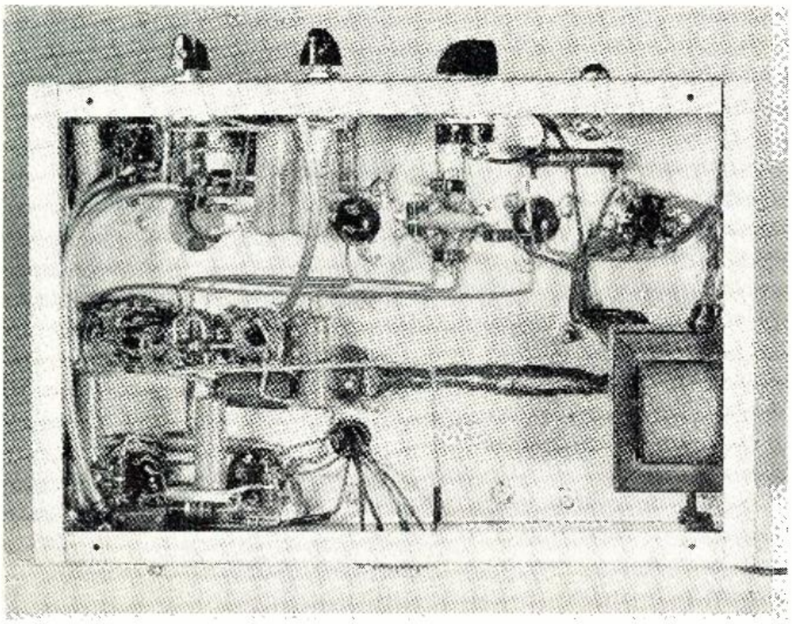
The screen voltage of the 6SJ7 stage should be set with a cathode-ray scope measuring the tone amplitude on each 6V6 grid in succession. The proper screen voltage setting is that which produces equal voltage just below the 6V6 grid current point.

The three phase inverter resistors of 47,000, 47,000, and 100,000 should be within 5% of the specified value. All the others can be the usual 10% to 20% tolerance. The plate supply voltage to the 6V6's is 275 volts and they operate as a relaxed class A, which is the most economical compromise for production tubes.

Conclusion

Under most home listening conditions the average audio power used is somewhere between one hundred and five hundred milliwatts.

Under chassis view of the general-purpose amplifier showing the simplicity of wiring.



On selections of great dynamic range, however, the peak passages may require several watts power. If the initial level is high, these peaks may well cause objectionable distortion due to overloading of the amplifier.

Many otherwise excellent amplifiers have a sharp rise in the distortion percentage when the rated output of the amplifier is exceeded.

As this amplifier has a very gradual increase in distortion, even above its rated output, it is capable of handling peak passages requiring great power without the distortion level becoming objectionable.

An often overlooked source of distortion is that caused by inferior speakers or speakers that are operated beyond their linear operating point.

Many of the low cost speakers will give excellent performance at low levels, but when their rated output is approached, the distortion becomes objectionable. Too often, this distortion is charged to the amplifier.

It would probably be well, before condemning an amplifier for poor performance, to make some further checks using speakers of known high quality. In this manner the defect may be easily localized.

This amplifier was designed to give about 10 watts without strain. The 0.3% amplitude distortion point is about 3 watts from 35 to 15,000 cycles. At 1% distortion the power output is 10 watts, from 35 to 15,000 cycles. At 5% distortion the power output is about 15 watts.

Much thought was given to the 6L6G *vs.* the 6V6GT for the output stage. The 6V6GT is made in vastly larger quantities than the 6L6G. It seems to suffer less from the annoying habit of periodically depositing active cathode material on the control grid, with consequent primary emission from the hot control grid which produces a very bothersome high order distortion.

Also it was felt that very few home horn systems are so inefficient that a good ten watt amplifier won't provide a good 10 db. of volume leeway in order to show the neighbors what you can do if you try. Actually, many music friends like to insert a 2 to 4 db. pad between the amplifier and the horn system so that the amplifier can pretend it is working into a gain set, and also so that the horn system can pretend it is being fed from Boulder Dam. A 2 db. pad in the output of this amplifier will have no noticeable effect on volume but may smooth out a dividing network so that it begins to operate as its designer hoped it might. This pad will also improve the volume range if you need another excuse to help justify its use.

When you have this amplifier working you can know that it is not a one man job dreamed up in a week to fit a particular chassis but represents 12 years of continuing development by top sound engineers working in a dozen different laboratories. —30—