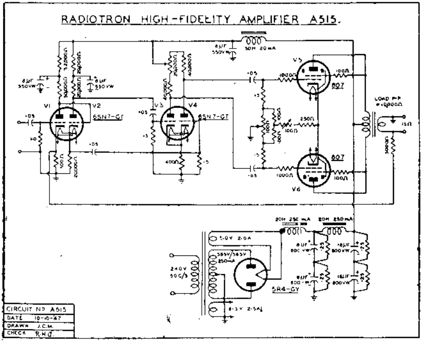
A NEW FIDELITY AMPLIFIER DESIGN



The latest issue of "Radiotronics" contains details of a most interesting amplifier. The Valve Company report on the circuit says: This amplifier is by far the best we have ever tested. It not only gives extraordinary linearity and lack of harmonic or intermodulation distortion, but is comparatively simple and involves no special problems except the choice of output transformer.

IF it is desired to reduce distortion to the absolute minimum, there appear to be two possible approaehes. The first is the application of push-pull pentodes (or beam power valves) with a high degree of negative feedback. Although capable of providing extremely good results, the design is complicated by the high degree of feedback and the precautions which require to be taken to avoid instability.

The second approach is through the application of push-pull triodes with negative feedback. In this case the initial distortion is considerably less, and the degree of feedback necessary to provide the required fidelity is not so great as to require abnormal precautions in the feedback loop.

ORIGINAL DESIGN

We were interested to read an article by D. T. N. Williamson, "Design of a High Quality Amplifier" in the "Wireless World," April and May, 1947, using push-pull triodes with negative feedback. We therefore adapted it to suit own own valve types and then caried out tests to see whether the claimed low distortion limit of less than 0.1 per cent. total could be reproduced.

The original amplifier used one triode valve as a resistance coupled amplifier with its plate directly coupled to the grid of a second triode operated as a phase splitter and cathode loads. The plate and cathode of the second valve were capacitance coupled to the grids of the push-pull triodes, which in turn were capacitance coupled to the grids of the power valves.

TRIODE CONNECTED 807's

The latter were the English type KT66 which is somewhat close in characteristics to types 6L6 and 807. The KT66's were operated with plate to cathode voltages of about 400 volts which were in excess of the maximum triode ratings for either type 6L6 or 807.

In order to attempt to duplicate the results obtained in the English amplifier, tests were carried out on type 807 to see whether it could be used with the higher screen voltage in triode operation. During these tests we had no valve failures and subsequently arranged for a number of 807 valves to be placed on life test with triode connection and a combined plate and screen voltage of 400 volts to cathode.

The results of these tests will not be known for some months, but in the meantime there does not seem to be any reason why the valves should not be used under these conditions for individual amplifiers at the risk of the user, since the risk appears to be quite small.

The screen dissipation is considerably below its maximum value and the only possible breakdown is through the increased screen voltage causing electrolysis or breakdown in the stem-press between adjacent leads. It would, of course, be possible for the output valves to be used within their maximum ratings by reducing the voltage from 400 to 300 but the power output would then be considerably smaller.

The valves used in the original voltage amplifier stages were type L63, which has characteristics resembling those of type 6J5-GT or one half of type 6SN7-GT. It was therefore decided to use two 6SN7-GT valves, one in place of each pair of L63 valves. This gave a valve complement of two type 6SN7-GT, two-type 807 and one type 5R4-GY rectifier.

PHASE SHIFT

Special attention was given in the original design to the avoidance of phase shift. The direct eoupling from the plate of the first valve to the grid of the second valve eliminated one possible cause of phase shift at low frequencies, while the cathode return eircut was purely resistive. All the cathode resistors are unbypassed so as to avoid any phase shift at low frequencies, leaving only the coupling condensers to the third and fourth stages, and the output transformer.

The latter was required to have a primary induetance of at least 100 henrys, measured at 50cs. with five volts rms on the primary, leakage inductaoce of not more than 30mH measured at 1000cs. and a primary resistance of the order of 250 ohms. In order to avoid the delay in having a special transformer made for the job, we substituted various transformers which were on hand. It was found that the transformer supplied with the Goodmans 12in. loud speaker would give quite satisfactory results, and this was therefore adopted for the initial tests. An order has been placed for a transformer specially designed for this amplifier, which should be available at a later date.

STATIC FIGURES

The amplifier was then wired up in accordance with the circuit diagram given herewith (A515).

The static plate currents in the final stage were balanced, and the drive to each valve was adjusted to give equal outputs at the plates when the valves were supplied with d-c. through separate chokes with individual loads of 5000 ohms each. The cathode bias resistors on the final stage were adjusted to keep the total plate dissipation less than 25 watts per valve. Without feedback, the amplifier was perfectly linear up on an output of 7.3 watts on a resistive load. With feedback, the amplifier was perfectly linear up to an output of 11.12 watts and it gave a smooth overload so that an output of 15 or 16 watts could be achieved without serious distortion.

The harmonic distortion for a power output of 11 watts was 0.01 per cent. 2nd harmonic, 0.04 per cent. 3rd harmonic, 0.01 per cent. 4th harmonic and 0.015 per cent. 5th harmonic. Even with an output of 17 watts as for an overload condition the distortion only reached the values of 0.46 per cent. 2nd harmonic, 0.31 per cent. 3rd harmonic, 0.53 per cent. 4th harmonic and 1.25 per cent. 5th harmonic.

SPEAKER LOAD

When tested on a speaker load it was found that for fairly large outputs at low frequencies a high frequency oscillation (about 60kcs.) would commence and be accompanied by a pulsed output of some

STATIC MEASUREMENTS
(with Avo model 7)

	No output	15W. output
Ground to cathode of V5 and V6 ..	39.0V	28.8V
Cathode to plates of V5 and V6 ..	400.0V	425.0V
Screen dissipation of V5 and V6 ..	2.16W	1.8W
Plate dissipation of V5 and V6 ..	47.4W	36.4W
Total B+ voltage	440.0V	452.0V
Total B+ current	142.0mA	112.0mA
Ground to filament of 5R4-GY	465.0V	565.0V
Input voltage to V1 (rms)		1.55V
Input voltage (rms) to V1 with no feedback		.144V
Input voltage (rms) to V5 and V6 (grid-to-grid) ..		85.0V
Output resistance .		0.3
Damping factor (RL/Ro)		50
Hum output (across 15 ohms)	0.34mV at 50cs. 0.06mV at 100cs.	

other frequency. Both these incipient oscillations were cured by the addition of a 0.0005uF capacitor from earth to the screen of the 807 valve which tends to provide positive feedback to the cathode of the input stage. It was found that the by-pass was slightly more effective when connected to the screen than to the plate.

The following tests were carried out with this addition. It was found practicable to apply sufficient feedback from the voice coil to the cathode of the input stage to provide 20db reduction in output with complete stability under all conditions. The phase shift between the input and output was quite small over a frequency range of 20cs. to 13kcs.

The frequency response on a resistive load was constant from 20 to 10,000cs. and rose only 0.42db

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to right, then flicks it quickly back to the starting point to begin a new excursion. The output from the oscillator must be consistent at all settings but variable in frequency from a few cycles to a frequency comparable with the highest signal frequency likely to be examined.

The conventional time base circuit has used a gaseous triode valve, which operates very well over the whole audio spectrum and usefully into the supersonic range. Thereafter, the waveform departs noticeably from the required saw-tooth effect and other circuit arrangements become necessary.

Various hard valve time bases have been featured in technical publications, some with excellent performance, but nearly all more complicated than the simple gas triode circuit—hence the popularity of the latter.

OSCILLATOR CIRCUIT

Quite recently, a comparatively simple circuit has been evolved using a single high-slope RF pentode and the negative transconductance property between screen and suppressor grids.

Although somewhat more complicated than the gas triode arrangement, the circuit is distinctly interesting and will probably be discussed at length later in this series of articles.

The time base circuit involves a number of panel controls which are fairly standardised in their function. It is usual to have a "coarse" and a "fine" frequency control, and another which allows the operation of the oscillator to be synchronised to the frequency of the observed signal, or to some multiple of it. In practice, the time base frequency is brought as near correct as possible with the direct frequency controls, then locked by advancing the "Sync." control.

It is usual also to arrange a switching or terminal system to allow the sweep oscillator to be locked in with an external signal or, yet again, to transfer the horizontal amplifier grid from the time base output to an external signal source.

OUR CIRCUIT

A practical illustration of all these points is given in the photographs and circuit of a 3" oscillograph, which has been in use in our own laboratory for many years. Though designed expressly for the American 906 type tube, the general circuit is applicable to all tubes with from 2" to 3" screens. In fact, the high tension voltage is nearer the mark for 2" tubes than for the latest 3" types.

In the light of the foregoing discussion, the purpose of the panel controls will not be difficult to follow.

The potentiometer in the upper left hand corner, looking on the front panel, is for vertical spot shift, allowing the initial position of the spot to be moved up or down as necessary. Beneath that is the intensity control and below that again the gain control for the vertical amplifier.

There are five terminals in line in the lower left corner. The top terminal is simply connected to a filament winding and provides a ready source of 50 cycle a-c. This can be fed to the vertical amplifier for checking purposes or to the sweep oscillator for 50 cycle synchronisation.

The second terminal connects directly to one vertical deflector plate, so that either high voltage a-c or d-c can be fed to it for observation or measurement purposes. Then comes the vertical amplifier output terminal, the vertical amplifier input, and earth at the bottom. In the normal way, the vertical amplifier output terminal is bridged across to the vertical deflector plate by a shorting link. Removing the link makes available the amplifier stage for separate use.

Down the right hand side of the panel is the horizontal spot shift, the focus control and the horizontal gain control. The topmost terminal is for the insertion of an external voltage for sweep oscillator synchronisation. The other terminals correspond to those on the left of the panel, except that they relate to the horizontal amplifier and deflector plate.

SYNCHRONISING

The potentiometer immediately below the tube face is the synchronisation control, under that the fine sweep frequency potentiometer, with the coarse frequency switch below it.

The toggle switch on the left, switches the sweep oscillator from internal to external sweep, while the one on the right switches the horizontal amplifier grid from the sweep circuit to the amplifier input terminal.

This general arrangement of the controls has proved very satisfactory for laboratory work and there appears to be little point in departing from it for any comparable instrument.

The remainder of the circuit and layout should be clear enough for enthusiasts likely to build this type of instrument. The whole job is built into a case measuring 12" x 8" x 16½", of crackle finished mild steel sheet. The chassis itself, is 16" long, 7½" wide and 3" deep, while the panel is just over 12" x 8", with a lip which turns back and fits over the outside of the case.

The vertical amplifier is on the right hand side of the chassis, with the gas triode behind it and the low voltage rectifier. The horizontal amplifier is at the other side, with the high voltage rectifier in the rear socket.

FILTERING

Two small chokes are included in the low voltage supply, but a single choke with higher inductance would do just as well. It is wise to use 600 volt electrolytics in both filters to give a margin of safety.

Shielding against magnetic fields is provided by a sheet metal bracket and tube, which hides a length of heavy water pipe, fitting around the neck of the CR tube. With this arrangement, spot definition is as good as can be expected from the particular type of tube and the limited supply voltage. Something nearer the maximum ratings for a 3" tube would be preferable, but the ratings and the supply position has undergone much change since the original instrument was built.

However, it does a very good job and will doubtless continue to do so for many years to come.

Next month we hope to present complete design details for another oscillograph, this time using a 5" tube and a hard valve time base.

A HIGH FIDELITY AMPLIFIER

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at 13,000cs. On a speaker load the output was practically constant from 20 to 13,000cs., using a Goodmans 12in. speaker, although the speaker was showing signs of frequency doubling with an input of 20cs., as would be expected. As a matter of interest the resonant frequency of the speaker, when used in a vented baffle, was 45cs.

It was found that harmonic distortion on the speaker load was very similar to that on a resistive load except at low frequencies. The distortion is extremely low, however, down to a frequency of 40cs.

At the time when these tests were carried out it was not possible to perform intermodulation distortion tests, but these will be carried out and published at the earliest opportunity. It is obvious that the total intermodulation distortion will be very low, and the tests are only intended to form a basis of comparison with other amplifiers.

This amplifier is by far the best which we have ever tested and we wish to give full credit to the original designer. It not only gives extraordinary linearity and lack of harmonic or intermodulation distortion but is comparatively simple and involves no special problems except the choice of output transformer. Unless the latter is specially designed for this circuit, or is one having extraordinarily low leakage inductance and exceptionally high primary inductance (such as the Goodmans transformers referred to in the article), the best results cannot be achieved.