The New *Multi-Mu* Tube

What It Is and What It Does

This new type tube marks a distinct step forward in radio progress, as demonstrated by experiments conducted by the author and described in this article

By Everett S. Wright, M.E.

WHEN the screen-grid tube was introduced it was hailed by experimenters and receiver manufacturers as a boon to the radio industry. It not only provided for tremendously increased radio-frequency amplification, but also permitted better methods of volume control. Moreover, it provided the incentive for improved circuit design and more careful attention to shielding. The total result has been that the present-day receiver is far more sensitive and more stable in operation than receivers of three or four years ago.

But receiver development has disclosed certain inherent faults in the -24. The most important of these have been the cross talk and modulation distortion on powerful signals, resulting from the high amplification provided by these tubes. Tube manufacturers have been working for some time on the development of a new type of screen-grid tube which would provide all of the advantages of the -24 type without these disadvantages. This research work has borne fruit in the form of the new multi-mu tube which has been placed on the market by a number of tube manufacturers.

At the time of this writing the preliminary information sheets issued by the various manufacturers show that their tubes are alike in their fundamental characteristics although differing slightly in some details. By the time this article appears in print, however, it is highly probable that further developments will have resulted in more complete standardization so far as the electrical characteristics of the tubes are concerned. For the information of readers a tabulation given below represents the standard adopted by some manufacturers. The outstanding exception is found in the Arcturus type 551 and the De Forest type 451 multi-mu tubes, which call for a plate voltage of 180 volts with a resulting plate current of 5.5 mils. Characteristics on these and others are shown in "What's New at the Trade Show."

Rating	
Heater voltage	2.5 volts
Heater current	1.75 amps.
Plate voltage	250 volts
Screen-grid voltage (maximum)	90 volts
Control grid voltage	— 3 volts

Preliminary Characteristics	
Plate voltage	250 volts
Screen-grid voltage	90 volts
Control-grid voltage	— 3 to — 50 volts
Amplification factor	370
Plate resistance	350,000 ohms
Mutual conductance (E_{cg} = — 3)	1050 micromhos
Plate current	6.5 ma.
Screen-grid current	Not over 1/3 of plate current

The type number generally adopted for this new tube is -35. Some of the individual manufacturers have their own type numbers, such, for instance, as Arcturus, who have designated this tube as their type 551.

The fundamental characteristics of the multi-mu or variable-mu tube is the variation of the transconductance with the grid bias. That is, the tube's amplification is controlled not by varying the screen-grid voltage between 0 and 90 volts, but by varying the control-grid bias ("C" bias) between — 3 and — 50 volts or thereabouts. Maximum volume is attained when the "C" bias is — 3 volts and minimum at — 50 volts.

Figure 1 shows this and indicates that the amplification of the -24 tube fell off sharply when grid bias was increased and became 0 at — 13 volts, while the amplification of the -35 tube diminishes much more gradually and more nearly in proportion to the "C" bias. In receivers employing automatic volume control the range of automatic control is extended by a factor of 20.

Modulation Distortion

Modulation (*Cont'd on page 76*)

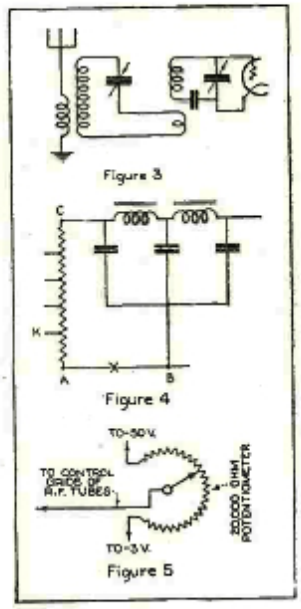

Figure 3. The single pre-selector circuit shown here, used with the new tubes, has been found by the author to provide adequate selectivity. Figure 4. The resistance network of a standard power pack. Additional "C" biasing resistor is connected at X. Figure 5. Method of controlling volume in an amplifier which employs the new multi-mu tubes

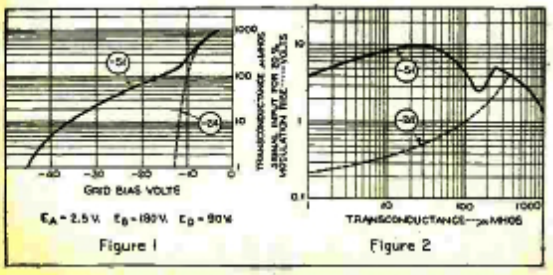

Figure 1. Transconductance of the Arcturus multi-mu tube, plotted against control grid-bias voltage. Figure 2 (right). Shows the modulation distortion limits for the -51 tubes as compared with the type -24

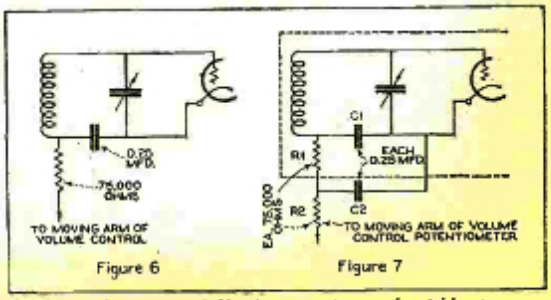

Figure 6. A normal filtering arrangement for grid return of -24 type tubes. Figure 7. The double filtering method recommended by the author for -35 tubes

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distortion is caused by non-linear transmission characteristics of r.f. tubes. The signal in passing through the tube becomes distorted because of an increase in modulation of the signal. This distortion is most evident when a powerful signal is tuned in and when as a consequence the volume control of the –24 tubes is set so as to cause only a small plate current in the tube. It is particularly evident in the –24 type due to its sharp plate current cut-off.

Figure 2 shows the maximum input voltage at which the –24 and –35 tubes will operate and yet not allow the modulation to rise more than 20 per cent., which is a satisfactory condition. Figure 2 means just this: Using –24 tubes in a tuner and tuning in a powerful signal the maximum voltage which can be applied to the grid of the –24 tube without introducing distortion is .2 to .4 volt, whereas if –35 type tubes are used a larger voltage of from 4 to 10 volts may be applied without causing any greater distortion.

Thus the new tube can handle a signal without distortion at about 20 times the voltage permissible with the –24 tube. The significance of this in receiver design will be pointed out later in this article.

Cross-Talk

Cross-talk is commonly caused by the inter-modulation in the r.f. tubes between the signal to which the receiver is tuned and a strong interfering signal of different frequency.

The result is that both signals are heard at once. In order to diminish the unwanted signal it has been necessary to use one, two or three preselector circuits ahead of the first tube. These, however, provide very loose coupling between the antenna and the grid of the first r.f. tube and as a result the volume control governing the screen grid voltage on the –24 tubes must be advanced, resulting in a tube hiss.

The –35 tube, however, due to its inherent properties reduces cross-talk by a factor of several hundred times and this fact, together with its ability to handle powerful input signals without distortion makes possible better design in the tuner. Preselector circuits may be cut down to one as shown in Figure 3 without trouble from cross-talk, and the resultant better coupling makes it possible to get the same volume at a lower volume control setting than if two or more preselector circuits were used. Consequently less tube-hiss results.

This is no mere theoretical advantage. It is plainly evident in a receiver. The writer has a four stage r.f. tuner. Listening to out-of-town stations a tube-hiss was painfully apparent using –24 tubes. Changing the tuner over to –35 tubes with one preselector circuit the hiss was entirely gone and the selectivity unimpaired so far as cross-modulation was concerned. The four stage r.f. job has no more internal noise when tuned into a signal than a battery set would have. The explanation is that –35 tubes enable you to take the "load" off the tubes and throw it on the antenna where it belongs. The –35 tubes will hiss much the same as a –24 tube when turned up to full power. But by utilizing their properties and using fewer preselector circuits, the requisite volume is attained at a low tube amplification and without distortion.

Pursuing this line of thought, do not use a tiny antenna even though your set is powerful. Use as long a one as the normal selectivity of the receiver will stand. A small antenna nullifies the advantage of eliminating preselector circuits. The thing to keep in mind is that the stronger the signal that can be impressed on the grid of the first tube the less amplifying the tubes must do and so less tube-hiss results.

Adapting the Multi-mu Tube to Present Receivers

The multi-mu tube may be placed in almost any receiver using –24 tubes. As a matter of fact it may simply be placed in the –24 tube socket without a single change being made and in some cases it will work as well, and perhaps better, because less liable to cross-talk. The volume may be controlled by varying the screen grid voltage or by any of the other methods commonly used in receivers employing –24 tubes. However, these methods do not yield the full advantage of the tube for the tube-hiss will not be diminished.

The volume should be controlled by varying the C bias or control grid bias on the r.f. tubes between –3 and –40 to –50 volts. This means some work on the power pack or voltage supply device. In a power pack of conventional good design, as for example the Amertran, used by the writer, this means that the 2000 ohm C bias resistor which supplies C biases to the detector, r.f., and first audio tubes must be supplemented by a 3500 ohm (approximately) fixed resistor in series with it.

The basic idea is this: Where the voltage divider in a power pack is arranged as in Figure 4, with K or cathode at a point say 18 volts above the most negative point A, it must be changed to about 50 volts above point A. In theory you would move K up on the voltage divider. In practice you leave K where it is and insert at X a fixed resistor with a value of around 3500 ohms, thereby creating a potential difference of approximately 50 volts between K and B. Portion K B of the voltage divider becomes that part used to tap off C biases for the r.f detector and first audio and portion K C provides the plate and screen grid voltages for the tuner.

The volume control for a tuner may be a 20,000 ohm wire wound potentiometer of the straight line curve type (no taper) connected as shown in Figure 5.

Of course the extra 30 volts or so abstracted for use as a C bias means 30 volts taken away from the maximum voltage of the power pack but the effect is very small.

Referring back to the tuner for another point. When the r.f. tubes get their C

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Talking Movies for Schools

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In the early days of sound systems, various input and output impedances were used by different manufacturers and the result was a great deal of poor quality caused by attempting to work a 4000-ohm pick-up into 500-ohm input transformers and similar mismatching. Nowadays manufacturers are standardizing more or less on certain impedances and are prepared to furnish units with whatever terminal impedance is required.

Suitable matching transformers are available from a number of transformer manufacturers, so there should be no problem of matching impedance values. For example, in the above equipment the output impedance of the universal head amplifier is regularly 4000 ohms. The Ward Leonard attenuator and the input of the Amertran 25A amplifiers each have a terminal impedance of 500 ohms. Accordingly it is necessary to replace the output transformer, T2, in Figure 2, with one having a secondary impedance of 500 ohms. A good unit to use for this substitution is to parallel feed the Amertran 993 transformer with the Amertran 3842 choke. The impedance of the pick-up should, of course, be 500 ohms, since it works into the same fader by means of a throw-over switch. If the one supplied with the turntable is of the high-impedance type it should be replaced with a theatre pick-up of 500 ohms of a type similar to the Presto Projectionist.

The same rules of matching apply in the output circuit. The output transformers of many amplifiers designed for sound pictures, such as the one specified, are fitted with a 500-ohm winding for the auditorium speakers and a 15-ohm winding for the booth monitor. In this case a matching transformer must be used to couple into the speakers behind the screen. This must have a secondary of 30 ohms for two dynamic reproducers in series or about 7 ohms if they are connected in parallel. The Amertran type 3377 is suitable for this unit, since it provides taps so that an adjustment can be made for the exact impedance of the speakers.

Some engineers attempt to correct for deficiencies in the frequency response of the system by deliberate mismatching. It is better practice to do this correcting by means of a variable tone control as shown in Figure 1. Some sort of tone control is very desirable if not essential in a sound motion picture system because of the variation in the recording on the film. This is particularly true of reproduction of speech, since it doesn't take much distortion to render it unintelligible. The amount of adjustment necessary will vary with the room and with the size of the audience.

For the smaller lecture halls one loud speaker is sufficient for the volume required. When only one is used, it is probably better to select a horn type, because of its projection qualities. There is some advantage in having two or even more speakers so that the angle of each may be adjusted to distribute an equal volume of sound to all parts of the room. The horns or cones should be placed directly back of a good sound screen so as to give the illusion that the sound is coming from the picture. The frequency-transmission characteristic of the screen is as important as any other link in the system. Much of the unintelligible speech heard on some systems is the result of an attempt to project sound through a heavy, closely woven screen which is not transvocent.

There are various miscellaneous points on the installation which contribute to the final result. All input and output lines should be twisted and shielded. They should be kept far enough apart to prevent oscillation due to feedback. The tubes selected for use in the head amplifier should be as non-microphonic as pos-

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bias through a common resistor as they do here, there is sometimes a pronounced tendency for oscillation to occur, even though the grid circuits of the r.f. and detector tubes are apparently well filtered as in Figure 6.

Using this method, a high gain 3 stage r.f. tuner was found to be quite unstable. The author then arranged a double filter circuit which entirely eliminated the trouble when applied to the grid circuits. Figure 7 illustrates this. C1 and R1 are inside the shielding and C2 and R2 are outside and the wire joining R1 and R2 is as short as possible, under 2 inches. This is simply doubly filtering each lead.

It was found essential to treat the grid circuit leads thus and it is desirable in a fine job to do the same to the screen grid and the plate leads. Space is generally at a premium so the 1094 series of Aerovox resistors and the small Aerovox condensers were found very convenient for this use. Values of R1 and R2 are 75,000 ohms for grid leads, as shown, and 10,000 ohms for screen-grid leads and for plate leads.

When using –35 tubes bear in mind that the plate current drain is higher than with the –24 type and that when volume is controlled by varying the control grid bias the plate current will vary considerably. This results in variation of the supply voltage, the amount of this variation depending upon the regulation characteristics of the power pack. In adjusting the plate voltage, therefore, a good plan is to measure this voltage with the volume control all the way up, and again with it all the way down, then adjust the voltage, strike a good working average, which will not permit excessive voltage with the volume control down or too little with the volume control turned up full.

The writer has designed a four stage r.f. tuner which seems to be all that can be desired—sensitive, selective and dead quiet. If you do not get results right away, just keep at it because the fault will be in you and not in the tube.