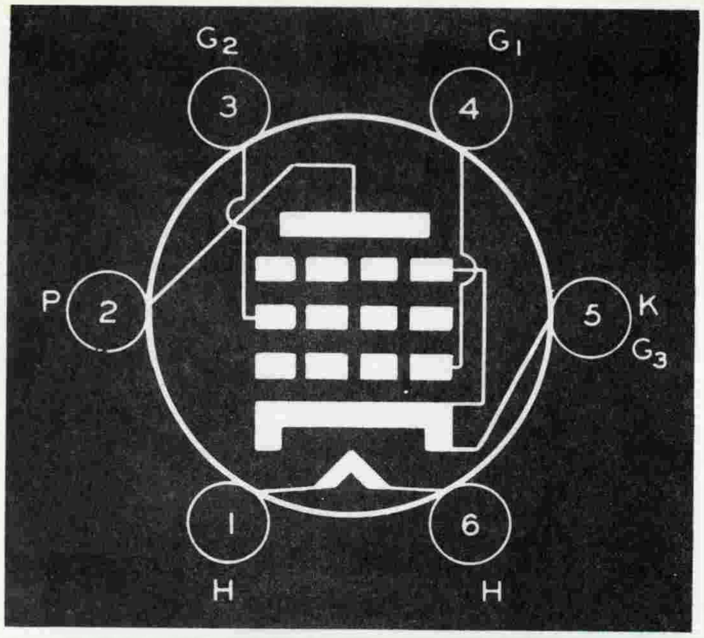

LESSON
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PENTODE CIRCUIT FEATURES

RADIO-TELEVISION TRAINING SCHOOL, INC.
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RADIO-TELEVISION TRAINING SCHOOL, INC.
5100 SOUTH VERMONT AVENUE • LOS ANGELES 37, CALIFORNIA, U. S. A.

PENTODE CIRCUIT FEATURES TO BE OBSERVED

There are a number of important features that must be observed in the design and arrangement of the associated circuits in the case of the pentode tube. In the first place, the output circuit requires special attention. Quite different from the ordinary triode power tubes, the pentode can deliver a distortionless output over only a relatively small range of load resistance. Also, distortion due to the presence of harmonics sets in and increases rapidly for load resistances above or below these values which give minimum distortion. With the former power tubes it was common practice to design the load impedance to be about twice the internal plate impedance of the tube. With the pentode, however, maximum undistorted output is obtained with a load circuit resistance equal to approximately one-eighth of the plate impedance of the tube. Consequently with a single pentode an output transformer with a primary impedance of about 7,500 ohms is generally used, this being nearly one-eighth of 60,000 the plate impedance of the tube. For push-pull operation a load resistance of 15,000 ohms would then have to be used.

Another condition that requires attention is the coupling effect the grid bias resistor has on the input and output circuits. If the bias resistor is connected as is customary between a center tap on the filament and ground, it is common to both circuits and causes a feed-back that tends to reduce the overall amplification. This influence is more prominent with the pentode than with other power tubes because the pentode is more sensitive and the bias resistor has a rather low value. The coupling effect, however, can be greatly minimized by shunting the bias resistor with a large capacity low-voltage condenser, which greatly reduces the A.C. voltage drop across the resistor and thus reduces the feed-back.

Another method that is used much in commercial sets to eliminate this feed-back effect of the bias resistor, is to obtain the bias voltage from some part of the power supply system. A resistor can be placed somewhere in the power supply, or part of the voltage drop across the speaker field winding (used as a filter choke in the negative return line) can be utilized. In either case, it is an easy matter to decouple the biasing circuit from the rest of the system.

The voltage drop across the speaker field winding as a bias for the pentode tube is a much used scheme. If only part of this drop is needed, the field winding is shunted by a tapped resistor and the grid return lead is brought to this tap. An advantage of this system is that no separate 2½-volt filament winding is needed for the pentode as would be the case if the bias resistor were connected into the filament circuit. Also, it happens that the hum in the grid circuit is opposite in phase to that applied to the plate of the previous tube, so that obtaining the bias from the negative side of the filter circuit at the same time aids in hum suppression. When two pentodes are used in push-pull, it is very common practice to obtain the grid bias for both tubes from a resistor connected into the negative return line of the power system. All these points are nicely illustrated in the various commercial circuits taken up in the following paragraphs.

REPLACING OUTPUT TUBES WITH PENTODES

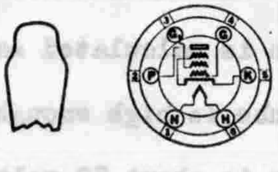
The advantage of the pentode power tube, it was pointed out, is its greater power output capacity at a relatively lower grid swing. In other words, it is a power output tube with a higher amplification factor, and is more economical in cost of operation. When employed in circuits designed for its use, the pentode gives quite satisfactory results; but if it is attempted to substitute it in circuits employing other power tubes, such as the 45 tube for example, a different situation presents itself.

In any well designed circuit, either of the tuned radio frequency or the superheterodyne type, the amplification gain is calculated so that the signal voltage at the time it reaches the output tube is high enough to produce full grid swing, which in the case of the 45 tube is about 50 volts. It is at once evident that if a pentode were substituted directly for a 45 tube, it would be overloaded by over 200 per cent, for the maximum grid swing for distortionless output with the pentode is only 16 volts. A reduction in signal strength is necessary. This could be done by reducing the sensitivity of the R.F. amplifier, but this would decrease the pick-up ability of the receiver for weak signals, and if carried too far would introduce serious distortion. The method is accordingly not to be recommended. Another scheme would be to eliminate the first audio stage and employ resistance coupling between the detector and the pentode. This might work out fairly satisfactory, but if the cost of making this change is considered as well as the other necessary alterations, no saving would be gained. Another point that needs consideration if such a replacement is contemplated, is the plate impedance of each tube and the recommended load resistance. Since these values differ widely in the 45 and 47 tubes, a change in output transformers would also be necessary if the tubes were changed. The bias resistor would likewise have to be changed, for while the 45 tube requires a grid bias of 50 volts at a plate pressure of 250 volts, the 47 pentode needs only 16.5 volts under the same conditions.

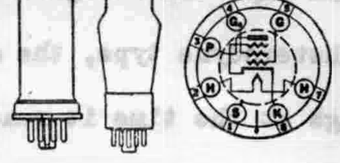
After all is considered, that is the circuit conditions that would require change or adjustment and the parts that would need replacement, very little, if anything, would really be gained by replacing a 45 tube with a 47 pentode, especially if there is ample R.F. amplification and a sufficiency of power output from the power tube in use.

THE TYPE 42, 2A5, 6F6 AND 6F6G POWER PENTODES

TYPE 42
POWER AMPLIFIER
TYPE 2A5



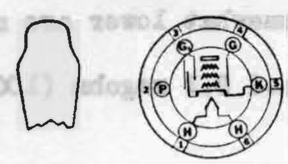
TYPE 6F6
TYPE 6F6G
POWER
AMPLIFIERS

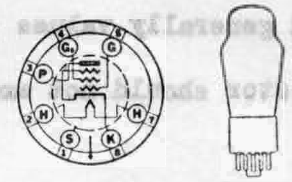


The No. 42 is a cathode type power output pentode with a 6.3-volt heater, while the 2A5 is its equivalent in the 2.5-volt filament series. The 6F6 is an all-metal tube with practically identical operating characteristics, and the 6F6G is the equivalent in the octal-base G-type glass tube. The terminal base pin arrangements of these tubes are illustrated in the accompanying diagrams. Although these tubes are somewhat similar to the type 47 pentode, they cannot be used as replacements. All four tubes, however, are widely used in the output stage of radio receivers, both singly and in push-pull.

Since these tubes are of the indirectly heated cathode type, they are practically free from A.C. hum. When operated into an optimum load resistance with 250 volts on the plate and screen and 16.5 volts grid bias, and supplied with a peak signal equal to the grid bias, these tubes are capable of delivering better than three watts output with minimum second harmonic distortion. Two tubes in push-pull can deliver between five and six watts. If resistance coupling is used, the grid resistor should not exceed 500,000 ohms with self-bias. If complete or partial fixed bias is used, the resistor must not exceed 250,000 ohms. A 7000-ohm load resistance is recommended for individual pentode operation, and 10,000 ohms for push-pull pentode operation, and these values should be adhered to as closely as possible in order to maintain harmonic distortion at a minimum.

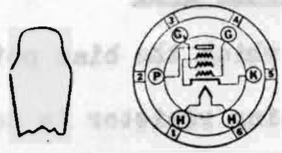
TYPE 41
INTERMEDIATE
POWER PENTODE



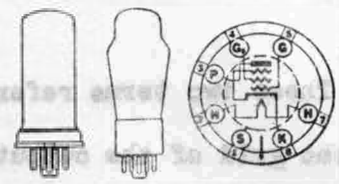


TYPE 6K6G
INTERMEDIATE
POWER PENTODE

TYPE 43
POWER AMPLIFIER
PENTODE



TYPE 25A6
TYPE 25A6G
POWER AMPLIFIER
PENTODES



The type 41 tube is an intermediate power pentode, also with an indirectly heated cathode, designed for operation from a 6.3-volt A.C. power supply or from a 6-volt storage battery. The 6K6G is its equivalent in the octal base G-type glass series. Although these tubes were designed primarily for use in the output stage of automobile receivers, they are also used to a very great extent in the output stage of A.C. operated home receivers.

When operated into the proper load resistance, and with 250-volts applied to the plate and screen, it can deliver an output of 3.4 watts with an input signal of only 18 volts. The plate current consumption under these conditions is also only 32 milliamperes. It is thus evident that the gain and operating efficiency are high compared to the characteristics of some other commonly used power output tubes.

These tubes can be used either singly or in push-pull. If a single tube is employed and self-bias is used, the biasing resistor should be shunted by a condenser of suitable capacity. At 250-volts plate and screen pressure, the biasing resistor should have a value of 500 ohms, and for two tubes in push-pull the resistor value should be 250 ohms. No bypass condenser is needed in a push-pull stage. Either transformer or resistance input coupling can be used, although resistance coupling is the more common. With self-bias the grid resistor should not exceed 1 megohm, and generally values somewhat lower are more desirable. With fixed bias the grid resistor should not exceed 0.1 megohm (100,000 ohms).

SELF-BIAS AND FIXED BIAS

These two terms refer to the manner in which the bias potential is obtained for the grid of the output stage. If a biasing resistor is connected into the cathode return line, for example, the combined plate and screen return current sets up a potential drop across the resistor and the cathode is biased above ground or chassis by an amount equal to this drop; and since the grid return is brought directly to ground, this is equivalent to biasing the grid negatively by an equal amount. The biasing potential is thus created by the cathode current within the amplifier stage itself, and the system is referred to as self-biasing.

In the fixed bias arrangement the cathode of the power output tube is grounded directly to chassis, while the grid return line is brought to a tap on a voltage dropping resistor connected between the chassis and the center tap on the high-voltage secondary winding of the power transformer. The entire plate and screen current of all the tubes then returns through this resistor and establishes a potential drop across it. Since the cathode of the power output tube is connected to the grounded end, and the grid return is brought to the opposite end of the resistor, the grid is lower in potential than the cathode (is biased) by an amount equal to the drop across this resistor. In other words, a fixed portion of the circuit voltage is also used as a biasing potential; and since this does not change appreciably unless some circuit component breaks down, the bias also remains nearly fixed. Both of these methods are used in commercial receiver circuits.

A SERVICE PROBLEM FREQUENTLY-ENCOUNTERED WITH POWER PENTODES

In power amplifier pentode circuits the grid resistor across which the input signal is built up plays a very essential part, and its importance is oftsn neglected or overlooked. Frequently a set manufacturer in an attempt to secure an exceptionally high gain in the output stage will use a higher resistance value here than is healthy for the best performance of the tube, and sooner or later trouble sets in. The tube will act choked or clogged and often die out altogether, and at the same time it will show signs of severe overheating.

With power output pentodes it is common practice to feed the screen and plate from a common B-supply line, the screen connection generally being made directly to the input or B-terminal on the primary of the output transformer. Although good performance requires that the screen and plate be operated at nearly the same voltage, due to the drop across the transformer primary the plate potential is less than that on the screen, and this is what starts the trouble.

With the screen being at a higher potential than the plate, all the electrons coming from the cathode do not reach the plate, but a large number of them fall on the screen, with the result that the screen current increases greatly. This overheats the screen and may even cause it to become red hot. The control grid, being very near to the screen, also becomes hot and begins to emit electrons, permitting current to flow through the grid circuit.

This grid current builds up a potential drop across this resistor of such a polarity that the grid end is positive and the cathode end negative. The polarity is thus opposite to the normal grid bias applied to the tube with the result that the net bias on the tube is proportionately reduced. With this decreased grid bias the plate and screen current increase, the tube overheats further, more grid current flows, the bias becomes less and less, and gradually all operation ceases. Of course, if the power is turned off for a while and the tube allowed to cool, normal operation will resume for a while until the overheating action again sets in.

To correct such a condition, two changes are necessary. The first of these is to connect a resistor in series with the screen circuit, that is, between the screen terminal on the socket and the point where it contacts the B-supply line. A 1-watt resistor of 10,000 or 20,000 ohms is generally satisfactory for this purpose, although higher values may be necessary in some cases. The second change is to reduce the value of the input grid resistor to 250,000 ohms or less. With these two alterations made, the voltage distribution associated with the various tube elements will be greatly improved and more stable performance will be had. Of course, after the output tube has suffered in this manner for some time, it may have become weakened or even exhausted, and in such a case it should be replaced in order to restore performance to the receiver.

FEEDBACK IN AUDIO AMPLIFIERS

Feedback in audio amplifiers, sometimes also referred to as degeneration or negative feedback, is a method of obtaining improved performance from an amplifier by feeding back part of the output signal voltage to the input circuit. Here it is superimposed on the signal just entering the tube, and is sent through the amplifier a second time, with the result that a large portion of the distortion, noise and hum ordinarily developed in the amplifier, is neutralized and eliminated.

The feedback voltage is timed to be opposite in phase with the incoming signal, and consequently the actual input to the amplifier is the vector difference between the two - therefore the term degeneration or negative feedback. Although such negative feedback diminishes the actual output of the amplifier, the high amplification obtainable with the modern output pentodes permits this partial reduction without sacrificing any volume. It is only with high gain output tubes that audio feedback is at all practical.

Essentially a degenerative feedback amplifier is no different than an ordinary audio amplifier, except that provision is made for coupling part of the signal output voltage back onto the input circuit, and if this is done properly, greatly improved operating qualities are imparted to the amplifier. The operating stability is much improved and the distortion component greatly reduced. Although a speaker is designed to match the plate circuit of the output tube, the load impedance varies within wide limits as the frequency changes, and this normally results in a proportionate amount of distortion. However, introducing degeneration greatly cuts down this distortion element and brings up the quality of the output. Similarly, noise, hum, and other forms of distortion are also reduced in the output.

DEGENERATION IN COMMERCIAL RECEIVERS

Degeneration in commercial receivers is usually obtained by feeding part of the signal voltage from the secondary of the output transformer back to the input of the first audio or driver stage. Seldom is feedback effected from the output to the input circuit of the same tube, only where a small degenerative effect is needed to overcome some distortion difficulty, etc. Two-stage feedback has the advantage that more gain is available between the feedback points, for this permits the use of a larger feedback factor and makes it possible to realize to a greater extent the benefits of degeneration.

Also, with 2-stage feedback amplitude and frequency distortion are reduced in both the driver stage as well as in the power stage. The driver can then be designed to deliver a higher gain and to operate the power tube with greater excitation. This greatly increases the power output, yet with a low degree of distortion due to the degenerative influence. In addition, with greater feedback the frequency response of the entire audio system is further greatly improved.

Feedback can be introduced either into the grid or cathode circuit, depending upon which is best adapted to the circuit system of the receiver. It is generally tapped off from one side of the output transformer secondary, the other side of the secondary being grounded. Sometimes the tap is taken from a voltage divider consisting of two low value resistors connected across the secondary, but more common practice is to connect directly from one side of the secondary to ground through two suitable resistors. The grid or cathode circuit where feedback is to be injected is then connected to the junction between the two resistors.

In some receivers the feedback circuit is also associated with a selective tone control system, so that base or treble response can be emphasized or diminished. For example, if the intermediate or high frequencies are fed back to a greater extent than the lower frequencies are, the middle and high frequencies are suppressed more due to degeneration, and the bass notes appear more prominent. If, on the other hand, there is a greater feedback of low frequencies, the bass response is subdued, and the middle and treble response is more prominent. Such a selective feedback system can be arranged with a simple network of resistors and condensers of suitable size, so that any desired type of response is obtained.