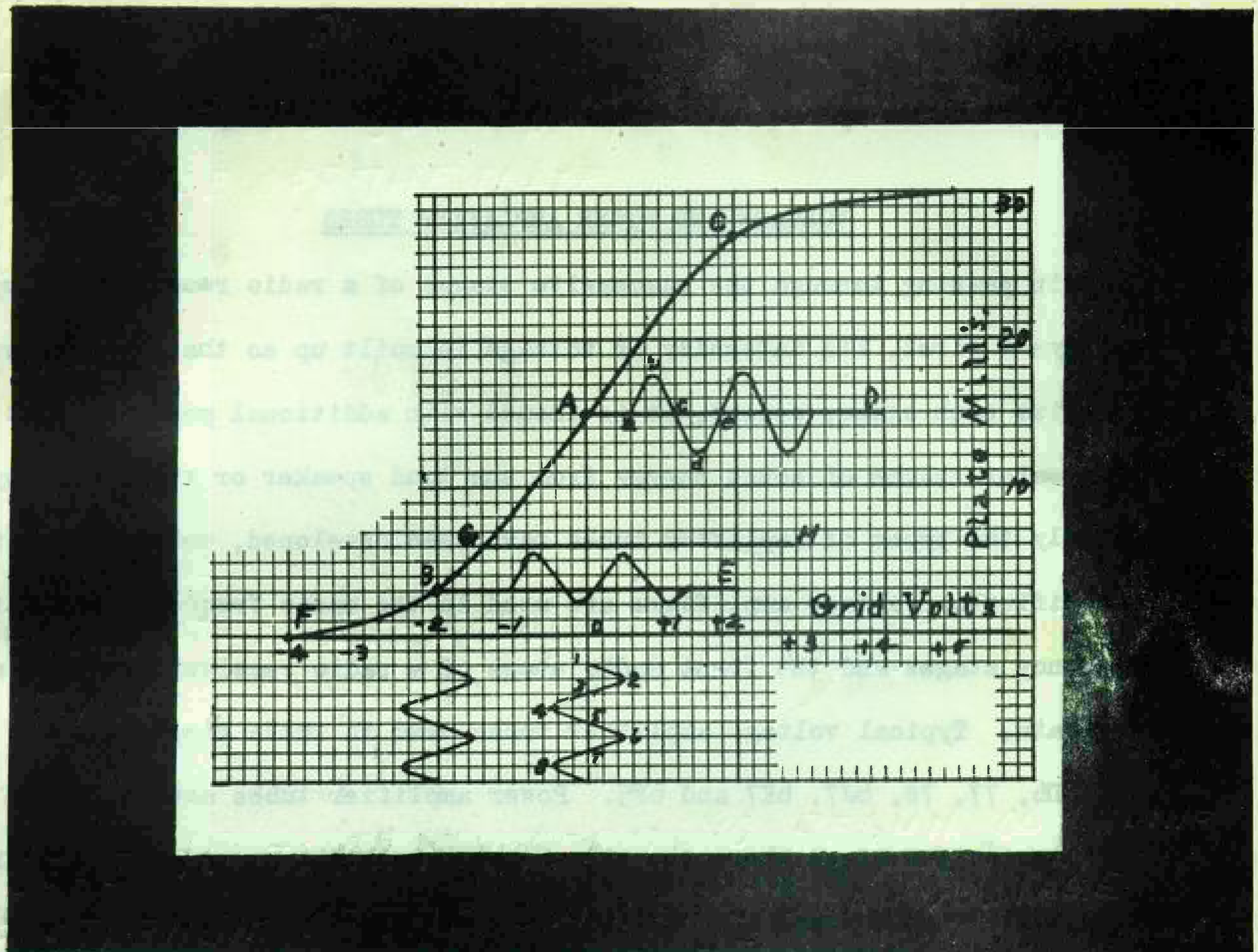

LESSON 20 R

VOLTAGE AND POWER AMPLIFIER TUBES

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A signal in passing through the successive stages of a radio receiver is amplified in twoways - first, its intensity or voltage is built up so that it can more actively energize each stage; second, it is imbued with additional power so that it can release greater volume of sound energy from the loud speaker or reproducer system.

Accordingly two types of amplifier tubes have been developed, voltage amplifiers and power amplifiers. Voltage amplifiers are used in the radio frequency and intermediate frequency stages and the first audio stage of a radio receiver and have a nigh voltage gain. Typical voltage amplifier tubes used in these stages are the 35, 57, 58, 6C6, 6D6, 77, 78, 6J7, 6K7 and 6F5. Power amplifier tubes are used only in the last audio or output stage where the signal has been built up to sufficient intensity to release large volumes of power in the plate circuit for operating the loud speaker or reproducer system. The voltage gain in these tubes, however, is relatively low. Typical power amplifier tubes in common use are the 41, 42, 45, 47, 2A3, 2A5, 59, 6A3, 6F6 and 6K6G. The characteristics and applications of these various amplifier tubes are all taken up in detail in the following lesson.

Tubes are also classified as to their operating points on their respective characteristic curves. The operating points are accomplished through biasing resistors. The classes of operation are Class "A", Class "B" and Class "AB" amplifiers which are used in radio receivers. Class "C" amplifier is used too, but only in a transmitting system. In a Class "A" amplifier the design of the tube is such or the grid bias is of such a value that the normal operating point is near the center of the straight portion of the characteristic curve, as at "A" in Fig. 1, and plate current flows for the full 360 degrees of each input cycle. As long as no signal voltage reaches the grid, a steady plate current flows; but a pulsating signal voltage impressed on the grid causes exactly similar fluctuations in plate current flow. As the grid potential swings from a positive maximum through zero to a negative maximum and back, the plate current also fluctuates from a maximum to a minimum value and back; that is, for every value of grid potential there is a value of plate current flow. In other words, plate current flows for the full 360 degrees of the input cycle.

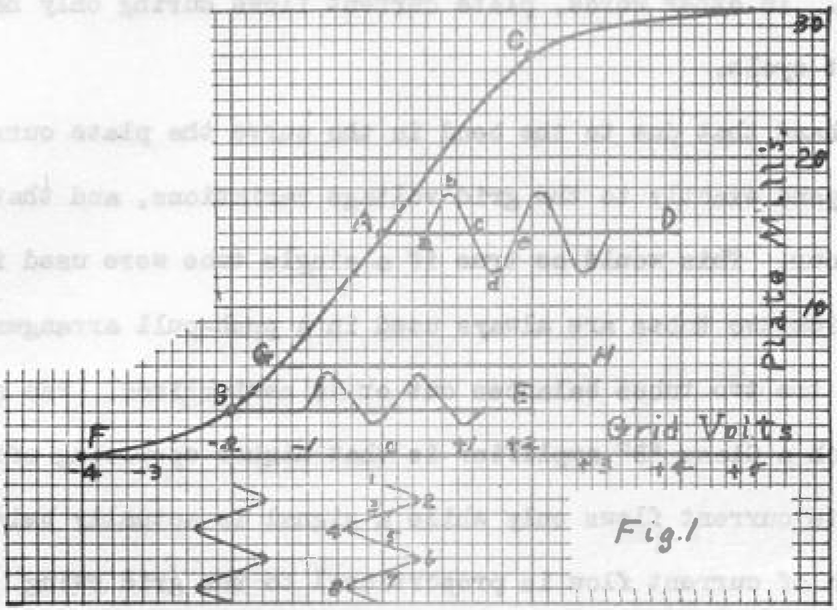

Fig.1

When a tube is operated as an amplifier, use is made of the fact that because the grid is closer to the cathode a small change in grid voltage causes a much larger change in plate current flow than would be produced by the same amount of change in plate voltage. Into the plate circuit of the tube some form of load impedance is connected (either a resistor, a choke coil, or the primary of a suitable coupling transformer), and the current pulsations in flowing through this load impedance build up across it a corresponding variable voltage drop. This voltage is similar in every detail to the signal voltage initially impressed on the grid but of greater intensity. In other words, the signal voltage has been amplified and is ready for further amplification in the next tube or to be converted into sound in a loud speaker or headphones.

In a Class "B" amplifier the tube design is such or the grid bias is of such a value that the normal operating point falls near the cut-off region on the curve, as at "F" in Fig. 1. As long as no signal voltage is impressed on the grid in this case, the plate current is zero or nearly so. However, as soon as signal voltage does reach the grid, during each positive half of the grid swing the plate current increases to a maximum and returns to zero, but during the negative half no effect is produced in the plate circuit. In other words, plate current flows during only half or 180 degrees of each input cycle.

It appears off hand that due to the bend in the curve the plate current fluctuations cannot correspond exactly to the grid voltage variations, and that distortion will consequently occur. This would be true if a single tube were used in such a system, but in practice two tubes are always used in a push-pull arrangement, and the distortion factor in the two tubes balances out or is neutralized. The advantage, however, of using such a Class "B" amplifier is that higher operating efficiency is obtained in that plate current flows only while a signal is actually being received, and then the strength of current flow is proportional to the grid swing. In other words, plate circuit energy is consumed only when signals are being received, and the amount consumed is directly proportional to the strength of the signal.

In a Class "AB" amplifier or Class "A" Prime as it is often called, the operating conditions are about midway between the Class "A" and the Class "B" amplifier. Class "A" amplifier tubes are used and overbiased somewhat so that their operating point slides pretty low down on the curve. During the periods when no signals are received the plate current is thus very much less than with a Class "A" amplifier. Also, when signals are received, the grid swing for a portion of the cycle drops below the cut-off point and the plate current is reduced to zero. This means that in a Class "AB" amplifier plate current does not flow the full 360 degrees of the input cycle but for more than 180 degrees. The Class "AB" or "A" Prime amplifier thus partakes of the nature of both the Class "A" and the Class "B" amplifiers. The system is used very extensively in modern radio receivers.

THE IMPORTANCE OF PROPER GRID BIAS

Another important point to observe in connection with the plate current characteristic illustrated in Fig. 1 is this: It is not the actual value of plate current flowing that determines the degree of amplification available from a tube but it is the variation or change in current flow for each input cycle.

To make this statement more clear - the current in the plate circuit of a tube consists of two components, a steady or constant flow as determined by the B-voltage and resistance of the circuit (corresponding to line "AD" in Fig. 1), and superimposed on this is a pulsating component created by the fluctuating signal voltage impressed on the grid (corresponding to the wave a-b-c-d-etc.). Further, a load impedance of some form is connected into the plate circuit, and the current in flowing through this load impedance creates a voltage drop across it. This voltage inherently also consists of two components, one is a constant drop caused by the normal current flow and the other is a pulsating potential caused by the current fluctuations. The constant potential is of no useful purpose; it merely dissipates part of the plate supply voltage, and the lower it can be kept, the greater will be the operating efficiency.

However, the pulsating potential built up across the load resistor is important, and the greater this can be made, the more amplification is secured from the tube. This involves two important considerations; the first is to maintain the steady plate current component at a low value so that as much as possible of the B-supply voltage is available for circuit operation, and the second is to make the grid very sensitive so that it has maximum influence on the electron movement. Both of these features, of course, are a matter of tube design and therefore a problem of the design engineer.

Keeping the steady plate current down, however, is to a great extent also a matter of operating the grid at the proper bias. The object is always to bring the normal operating point as low down on the curve as possible without drifting into the lower bend. For example, in Fig. 1 with the operating point at "A" (corresponding to zero grid potential) the steady value of plate current is represented by "AD" and has a value of 15 milliamperes. The current fluctuations due to the signal voltage on the grid vary about 3 milliamperes above and below this value. In other words, the total current fluctuation is 6 milliamperes.

If the operating point were shifted to "G" on the curve, corresponding to a negative grid bias of 1.4 volts, the steady plate current flow would be represented by "GH" with a value of only 6 milliamperes and with the same signal voltage on the grid the plate current could still fluctuate 3 milliamperes up and down without getting into the lower bend of the curve. Therefore, it certainly would be more economical to operate at point "G" than point "A", for there would be a saving of 9 milliamperes steady current flow without affecting the signal amplification.

However, there is one precaution that must be taken at this point, for if the signal voltages reaching the grid are strong enough to swing operation into the bend of the curve, the plate current fluctuations will not be uniform and symmetrical, and signal distortion will result. This means that the strength of signal voltage that can be applied to the grid is limited by the operating bias. In the operating data supplied by tube manufacturers for their different tubes, the indicated grid bias is generally of such a value that the normal operating point is located near the middle of the straight portion of the curve. The maximum signal that can then be applied to the grid without overloading the tube is limited to the bias voltage.

SPECIAL PURPOSE MULTI-ELEMENT TUBES

A number of special purpose tubes have been developed to meet the requirements of particular circuit applications. Among these is the type 46, which is a double grid filament type power amplifier tube that can be used in either a Class "A" or Class "B" amplifier system. Each grid is brought out to a separate terminal base pin.

For Class "B" service the two grids are connected together at the socket, and under these conditions the tube has a very high amplification and requires no grid bias. For Class "A" service the outer grid is connected to the plate and the tube functions as a triode and with far less output. The circuit applications of this tube are taken up in a subsequent lesson.

The type 49 is a similar double grid power amplifier tube but designed for battery operated receivers in which plate current economy is of vital importance. The tube can be operated as a Class "B" amplifier by connecting the two grids together at the socket, and two such tubes in a push-pull system have a power output of 3.5 watts. The tube can also be operated as a Class "A" amplifier by connecting the outer grid to the plate, but the output per tube is only 170 milliwatts. Further data on this tube and its circuit applications are also given in a later lesson on Class "B" amplifier systems.

Another special purpose tube is the No. 59 which is often called a universal output tube because it can be used as a Class "A", Class "B", or pentode amplifier. The No. 89 tube is its equivalent in the 6.3-volt filament series. It is a 5-element tube containing a filament, cathode, three grids and a plate, all of which are brought out to separate base pins and the tube requires a 7-pin base.

The mode of connecting these grids into the circuit determines the operating qualities of the tube. If the tube is to be used as a Class "A" power amplifier, grids No. 2 and 3 are connected together to the plate, the three elements thus acting as a single electrode. Then with an applied plate pressure of 250 volts and a control grid bias of -28 volts, an amplification factor of approximately 6 will be had, and a power output of 1.25 watts at a maximum grid swing of 28 volts. This compares with 1.6 watts for the '45 tube at a grid swing of 50 volts and an amplification factor of 3.5.

If the tube is to be operated as a pentode, No. 1 grid is used as the control grid, No. 2 as a screen grid, and No. 3 is externally connected to the cathode as a suppressor grid. With a plate pressure of 250 volts and a control grid bias of -18 volts, the amplification factor is approximately 110 and the power output 6 watts. This compares with 2.5 watts for the '47 pentode at a grid swing of 16.5 volts. When the tube is used as a Class "B" power amplifier in a push-pull stage, the No. 1 and No. 2 grids are connected together and serve as the control grid, while No. 3 grid is connected to the plate. Then at a plate pressure of 400 volts and zero grid bias an output of 20 watts is obtained for a pair of the tubes.

DOUBLE TRIODE CLASS "B" AMPLIFIERS

Another group of special purpose tubes includes a series of double triodes, which, as the name suggests, consist of two triodes (with a common cathode) built into a composite structure and housed in a single bulb. The type 6A6 tube is one of this group, and its equivalent in the 2.5-volt filament series is the type 53. These tubes are used primarily as Class "B" amplifiers in A.C. operated receivers. Typical applications in commercial receivers are given in a later lesson. The equivalent tube in the all-metal group is the 6N7, and in the octal base glass series the 6N7G.

These tubes can also be used as cascade amplifiers in a resistance coupled audio amplifier, in which case each section of the tube operates as a separate triode, as though two individual tubes were used. Each triode has a high amplification factor, so that an overall voltage gain of about 700 is obtained in such a cascade arrangement. A 3-volt grid bias is recommended and 250,000-ohm plate resistors for a 250-volt B-supply.

The tubes can also be used in an audio amplifier as a combination voltage amplifier and phase inverter - a system for obtaining push-pull resistance coupling to a pair of power output tubes that provides a gain which compares well with a transformer coupled triode combination. Such systems are now used extensively in modern receivers on account of the saving in chassis space that is effected, and the lower cost of the resistance coupling units compared to the cost of a good push-pull input transformer.

The type 79 tube and its octal base equivalent, the 6Y7G, are similar double triode amplifier tubes that can be operated either as Class "B" amplifiers or in a cascade system. On account of the lower no-signal plate current and the fact that they can be operated at 180 volts plate pressure, these tubes are better adapted to automobile radio receivers where this economy in current consumption is an important factor. Also, these two tubes are mounted in smaller size glass bulbs, and they occupy less chassis space. The type 6Z7G is a similar tube but designed primarily for use in battery operated receivers.

THE 6C8G DOUBLE TRIODE

The type 6C8G is a new double-triode tube that is designed especially as a voltage amplifier in a cascade system or as a voltage amplifier and phase inverter in a resistance coupled push-pull amplifier. The plate, grid and cathode of each triode section are brought out to separate terminal base pins and the tube is very flexible in its circuit applications. It is of the octal base glass type. Essentially it consists of two triodes built into one glass bulb.

THE 6F7 AND 6P7G PENTODE TRIODE

The type 6F7 is another composite tube consisting of a triode and remote cut-off pentode in a single glass envelope. Its equivalent in the octal base glass series is the 6P7G. The triode and pentode sections are independent of each other except that they have a common cathode, and the tubes are adaptable to a variety of circuit arrangements.

For example, the pentode section can be used as a radio frequency amplifier and the triode as a grid bias detector. Or in a superheterodyne receiver the tube can be operated as a combined first detector and oscillator, the triode section functioning as the oscillator and the pentode section as the mixer.

ADDITIONAL CHARACTERISTICS ON THE TYPE 59 TUBE

The type 59 tube is a triple-grid power-amplifier of the heater-cathode type for use in the output stage of a-c operated receivers. The triple-grid construction of this tube, with external connections for each grid, makes possible its application as: (a) A Class "A" power amplifier triode, (b) A Class "A" power-output pentode, and (c) A Class "B" power output triode. The tube requires 2.5 volts either a-c or d-c for its heater supply at a current of 2 amperes. For the triode connection grids 2 and 3 are tied to the plate and grid 1 is the control grid. For the pentode connection, grid 3 is tied to grid 1 and grid 2 is the screen grid. This is for Class A operation.

CLASS A PRIME POWER AMPLIFIER

	Triode Connection	Pentode Connection	
Plate Voltage........................	250 max.	250 max.	Volts
Screen Voltage(Grid No. 2)...........	---	250 max.	Volts
Grid Voltage(Grid No. 1).............	-28	-18	Volts
Cathode Resistor.....................	1080	410	Ohms
Plate Current........................	26	35	Milliamperes
Screen Current.......................	---	9	Milliamperes
Amplification Factor.................	6	--	
Plate Resistance.....................	2300	40000	Ohms
Transconductance.....................	2600	2500	Micromhos
Load Resistance......................	5000	6000	Ohms
Power Output.........................	1.25	3	Watts

CLASS B POWER AMPLIFIER--TRIODE CONNECTION

Grids No. 1 and No. 2 tied together; grid No. 3 tied to plate

Plate Voltage........................	300	400	Volts
Grid Voltage.........................	0	0	Volts
Zero-Signal Plate Current............	20	26	Milliamperes
Effective Load Resistance(Plate-to-plate)	4600	6000	Ohms
Power Output (Approx.)...............	15	20	Watts