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CENTRAL INTELLIGENCE AGENCY

INFORMATION FROM

FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT [redacted]

CD NO.

COUNTRY	USSR	DATE OF INFORMATION	1950
SUBJECT	Scientific - Radio, tubes	DATE DIST.	6 Jul 1951
HOW PUBLISHED	Monthly periodical		
WHERE PUBLISHED	Moscow	NO. OF PAGES	6
DATE PUBLISHED	Dec 1950	SUPPLEMENT TO REPORT	[redacted]
LANGUAGE	Russian		

THIS IS UNEVALUATED INFORMATION

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SOURCE Radio, No 12, 1950, pp 47-49.

THE PENTODE 1A1P

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/Figures are appended./

Four types of miniature tubes designed for economical operation of battery superheterodyne receivers are produced at present. Three, the rf pentode 1K1P, the diode-pentode 1B1P, and the output pentode 2P1P, have been described previously (Radio, No 9, 1949, and No 2 and 4, 1950) [redacted] This article will describe the fourth of the series, the heptode converter 1A1P with variable conversion transconductance.

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Construction and Operating Principle

In external appearance, dimensions, and arrangement of pins, the 1A1P is the same as the other tubes of this series (see Figure 1). The cylindrical plate, within which the other electrodes are placed and secured between two mica plates, is placed vertically inside the glass bulb. The getter cup is also inside the bulb.

The directly heated cathode, of oxide-coated wolfram, is connected to pins 1 and 7. The suppressor grid is connected to pins 1 and 5. To prevent current flow in this grid, pin 1 should be connected to A- and pin 7 to A+.

The first grid G_1 (Figure 1) is used as the oscillator grid. The second grid G_2 (one screen grid) is maintained positive during operation. It accelerates the electrons during the first part of their flight and prevents capacitive coupling of the input and oscillator circuits. G_3 is the signal grid. Since the 1A1P has variable conversion transconductance, the pitch of part of the G_3 turns is increased.

A positive voltage is applied to G_4, connected inside the tube with G_2. G_4 is the screen grid. The fifth grid G_5 is the suppressor and counteracts secondary emission in the plate. The suppressor grid increases the ac plate resistance and decreases attenuation introduced into the i-f circuit. The final result is an increase in the amplification and sensitivity of the conversion stage.

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Thus, the 1A1P differs from the heptodes amateurs know, the SB-242 (or the SO-242 which has an oxide instead of a barium cathode), in the function and connection of the grids. In the SB-242, the second grid functions as the oscillator plate, but in the 1A1P, as well as in the 6A10 and 6SA7, this function is assumed by both the plate and the two screen grids. During operation these three electrodes are connected to the receiver chassis through capacitors which have negligible reactance at the oscillator frequency.

Besides economical power consumption, the 1A1P has operational advantages over the SB-242 arising from the above-mentioned method of using the grids. These advantages are the almost complete independence of oscillator frequency from signal strength and the ease of exciting oscillations at low plate voltage (45 v).

To explain the ideas underlying the 1A1P design, a cross section of its electrodes is shown in Figure 2. Their open spaces are indicated by small circles, the grid turns by dotted lines. As seen in the figure, the open spaces of G_3 are arranged not on the common line for other open spaces but perpendicular to it. Therefore, many electrons which do not pass through the signal grid G_3 are thrust slightly to one side by its open spaces and intercepted by the open spaces and turns of the screen grid G_2 on their return path. Thus, since only a very few electrons can return to the cathode, the influence of the signal grid potential on the space charge near the cathode is greatly reduced. In addition, the direct influence of the signal grid potential on the space charge in the cathode region is also negligible because of the screen grid G_2 between these electrodes.

The preceding statements amount to saying that a voltage variation in G_3 has very little effect on cathode current. Of course these variations change the plate current, but plate current variations are compensated by current variations in screen grids G_2 and G_4 which are almost equal in magnitude but opposite in sign. For this reason the variable rf signal voltage applied to G_3 modulates the plate and screen grid currents but does not produce variations in the cathode current at signal frequency. This means that if any resistance or reactance is connected between the cathode and the receiver chassis (As is the case in Hartley circuits), there will be no signal-voltage drop across it. Thus, it is possible with an ungrounded cathode to apply the signal voltage entirely between the signal grid G_3 and cathode and to prevent coupling between these circuits.

Another important advantage of the 1A1P over the SB-242 is the almost complete independence of oscillator plate current from signal grid voltage. As mentioned above, the plate and screen grids G_2 and G_4 of the 1A1P function as the oscillator plate. Their total current does not depend on the potential of G_3. This means that the transconductance of the oscillator will not charge with variations in the AVC voltage at G_3. Since the space charge at the cathode surface depends only slightly on the potential at G_3, the capacitance of the oscillator grid G_1 will not depend on the AVC voltage. As a result of both these factors, the oscillator frequency will remain practically constant, ensuring stable receiver tuning when AVC voltage variations occur following amplification of fading of the signal.

The transconductance of the oscillator section of the 1A1P is almost twice that of the SB-242 or SO-242, although it draws only half as much plate current. The reason is that the oscillator plate current is composed of the screen grid current and the plate current and is equal to the current taken by the tube from the B battery. Consequently, the transconductance of the oscillator section of the 1A1P is considerably greater than that of the SB-242, where the plate current of the oscillator (second grid G_2) is only about 35 percent of the B battery current. This high transconductance ensures reliable oscillator operation in the 1A1P when the supply voltage drops and when the equivalent circuit resistance is relatively low because the tuning capacitor is turned to the maximum capacitance position.

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Parameters and Characteristics

The maximum and minimum voltages for electrodes and maximum admissible cathode current for the 1A1P are given below. To avoid deterioration and short life these limits should not be exceeded even for short periods.

Maximum filament voltage	1.4 v
Minimum filament voltage (This was changed from 1.05 v to the present figure for all four miniature tube types at the end of 1950)	0.9 v
Maximum plate voltage	100 v
Maximum voltage on screen grids G_2 and G_4	75 v
Maximum bias voltage on the signal grid G_3	0 v
Maximum cathode current (sum of plate current and current drawn by all grids)	6.5 ma

Voltages at the tube electrodes are determined with respect to the negative side of the filament terminal (tube pin 1).

Interelectrode capacitances of the 1A1P without an outside shield are:

In	7 mmfd
Plate to grid	0.4 mmfd
Out	7 mmfd

The tube has the following parameters when used as a frequency converter:

Filament voltage	1.2 v
Filament current*	60 ma
Plate voltage	90 v
Screen grid voltage	45 v
Signal grid voltage	0 v
Effective value of ac voltage on oscillator grid	15 v
Bias resistance in oscillator grid circuit	0.1 megohm
Plate resistance	0.8 megohm
Conversion transconductance	0.25 ma/v
Plate current	0.64 ma
Screen grid current	1.7 ma
Cathode current	2.48 ma

The transconductance (oscillator plate current with respect to the voltage at the first grid) provided

$$U_a = 90 \text{ v},\ U_{g2+4} = 45 \text{ v},\ U_{g3} = 0 \text{ v, and } U_{g1} = 0 \text{ v}$$

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(the initial moment of oscillation) is approximately 1 ma/v, which is quite sufficient for reliable oscillation in most cases.

Figure 3 shows the family of curves for the 1A1P when connected as a triode (grids G_2, G_3, and G_4 connected to the plate). The figure characterizes the 1A1P as a tube for generating oscillations. For a plate current of 2.5 ma, the following parameters are obtained: transconductance S = 0.9 ma/v, amplification factor $\mu = 6$, and plate resistance $R_i = 6{,}700\ \Omega$.

The relation between the conversion transconductance and the grid-bias voltage is shown in Figure 4. The elongated characteristic is similar to that found for the rf pentode 1K1P. The curve is regular and shows the efficiency of the signal grid in controlling the plate current.

Basic Applications of the 1A1P

Since the 1A1P oscillator plate consists of three electrodes, the most natural circuit for generating oscillations is a Hartley circuit with the plate grounded.

Figure 5 is a schematic diagram of a converter stage using a 1A1P. The tap of the oscillator coil is connected to the first pin of the tube, while the end of the coil grounded at the chassis is connected to A-. The positive side of the filament (pin 7) is connected with A+ through the rf choke. In other particulars, the circuit diagram is very much like that for the 6A10 and 6SA7 heptodes which are widely used in line receivers. To avoid high losses in the circuit, the inductive reactance of the filament choke to rf currents must be five to six times higher than the resistance of the filament, i.e., at least 100 to 120 Ω. On the other hand, to avoid excess loss of the A battery voltage, the effective resistance of the choke must not exceed 1 Ω. The recommended resistance for R_{g1} is 0.1 megohm and the recommended capacitance for C_{g1} is 40 to 50 mmfd. The capacitor C_c is a padding capacitor.

The number of turns in the cathode section of the circuit coil is approximately 7 to 10 percent of the total number of turns and is so chosen that the effective voltage in this section will be 0.5 to 0.7 v at the low-frequency end of the band. A good index of correct converter operation is provided by the current of the oscillator grid, which can be measured by a micrometer connected between the grid resistor R_{g1} and the negative side of the filament. The oscillator grid current should be between 50 and 250 μa for a screen grid voltage of about 45 v, and between 70 and 350 μa for a screen grid voltage of 65 to 70 v. In both cases the minimum current for satisfactory operation of the tube is 20 μa.

The circuit of Figure 6 differs from that of Figure 5 in the use of a separate feedback coil. This circuit is entirely satisfactory for superheterodynes without short-wave bands because it is easier to obtain the ac voltage on the first grid for normal excitation with a feedback coil than from a Hartley circuit. The feedback circuit has this defect; the rf potential applied to the screen grids may induce an oscillation-frequency alternating voltage in the control grid. Because of the relatively small detuning of the input and oscillator circuits in short-wave reception, this may lead to transmission of the oscillation frequency to the receiving antenna.

Component values for the control grid circuit are the same as in the first circuit, i.e., 40 to 50 mmfd and 0.1 megohm. The coupling coil and feedback should be selected to give oscillator grid currents within the limits recommended above.

Production of the 1A1P heptode is an important step toward more economical power consumption by battery receivers. Power drain by the 1A1P filament is 72 mw, as compared with 360 mw for the SB-242 and SO-242. The conversion transconductance the 1A1P is noticeably inferior to the SO-242, but this deficiency is fully compensated by the appreciably higher plate resistance. Thus, the amplification factor of the 1A1P is as good as that of the SO-242 and its selectivity is considerably better.

It should be noted that 1A1P performance is excellent even at lower plate voltages. When 45 v is used instead of 90 v (the screen grid voltage in both cases is 45 v), the conversion transconductance drops by about 10 percent. The 1A1P filament, like the 1K1P and 1B1P filaments, can be connected either in parallel or in series with the filaments of other tubes. Problems concerning filament supply of miniature tubes were discussed in detail in Radio, No 4, 1950.

/Appended figures follow./

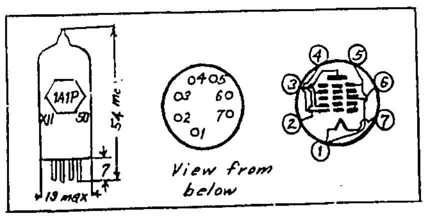

Figure 1

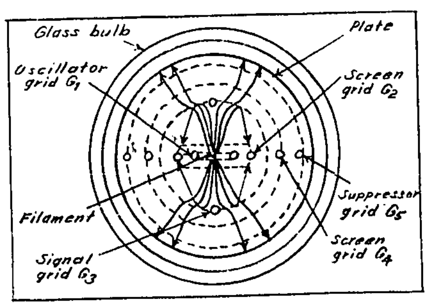

Figure 2

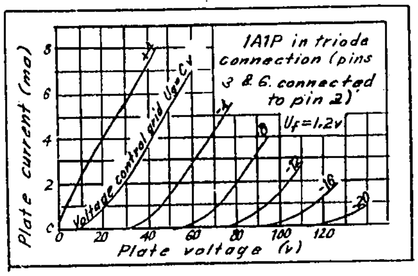

Figure 3

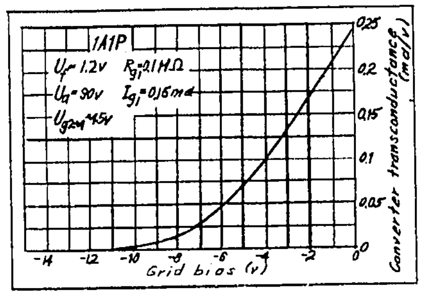

Figure 4

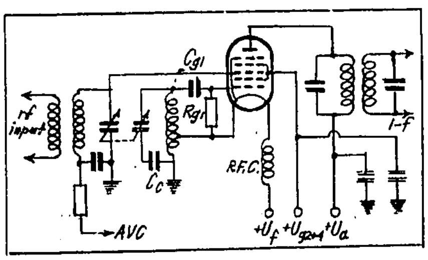

Figure 5

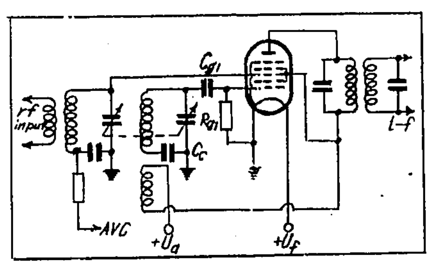

Figure 6

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