

# FOREIGN TECHNOLOGY DIVISION



PERMANENT STORAGE ON METALLIC CARDS

by

A. V. Petrov and V. I. Vinogradov



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# EDITED MACHINE TRANSLATION

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By: A. V. Petrov and V. I. Vinogradov

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<i>А а</i>	A, a	Р р	<i>Р р</i>	R, r
Б б	<i>Б б</i>	B, b	С с	<i>С с</i>	S, s
В в	<i>В в</i>	V, v	Т т	<i>Т т</i>	T, t
Г г	<i>Г г</i>	G, g	У у	<i>У у</i>	U, u
Д д	<i>Д д</i>	D, d	Ф ф	<i>Ф ф</i>	F, f
Е е	<i>Е е</i>	Ye, ye; E, e*	Х х	<i>Х х</i>	Kh, kh
Ж ж	<i>Ж ж</i>	Zh, zh	Ц ц	<i>Ц ц</i>	Ts, ts
З з	<i>З з</i>	Z, z	Ч ч	<i>Ч ч</i>	Ch, ch
И и	<i>И и</i>	I, i	Ш ш	<i>Ш ш</i>	Sh, sh
Й я	<i>Й я</i>	Y, y	Щ щ	<i>Щ щ</i>	Shch, shch
К к	<i>К к</i>	K, k	Ъ ъ	<i>Ъ ъ</i>	"
Л л	<i>Л л</i>	L, l	Ы ы	<i>Ы ы</i>	Y, y
М м	<i>М м</i>	M, m	Ь ь	<i>Ь ь</i>	'
Н н	<i>Н н</i>	N, n	Э э	<i>Э э</i>	E, e
О о	<i>О о</i>	O, o	Ю ю	<i>Ю ю</i>	Yu, yu
П п	<i>П п</i>	P, p	Я я	<i>Я я</i>	Ya, ya

\* ye initially, after vowels, and after ъ, ь; e elsewhere.  
 When written as ѣ in Russian, transliterate as yě or ě.  
 The use of diacritical marks is preferred, but such marks  
 may be omitted when expediency dictates.

**FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH  
DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS**

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	$\operatorname{sech}^{-1}$
arc csch	$\operatorname{csch}^{-1}$
—	
rot	curl
lg	log

## PERMANENT STORAGE ON METALLIC CARDS

A. V. Petrov and V. I. Vinogradov

Of considerable interest among the many developments of permanent storage [DZU] ( $\bar{D}3V$ ) are storage units on metallic cards.

For such devices the following peculiarities are characteristic: great high speed operation, high work reliability, long service life, simplicity of preparation, small dimensions and low cost.

The working principle of such a [ZU] ( $3V$ ) (memory unit) is based on the phenomenon of electromagnetic induction.

Let us assume that we have two concentric turns with radius  $r$  (Fig. 1). The distance between turns will be designated by  $d$ . Each turn possesses inductance (correspondingly,  $L_1$  and  $L_2$ ), which is determined by the form and dimensions of the circuits, permeability of wires and their surrounding medium and in the presence of alternating current, also by the character of current distribution along the section of conductors.

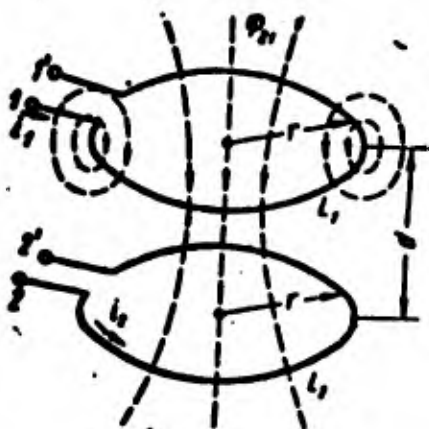


Fig. 1. Inductive coupling of two turns.

During flow along one of the turns of alternating current  $i_1$  there appears an alternating magnetic field. The magnetic flux  $\Phi_{21}$  causes an interconnection of the two turns and creates in the second turn the emf  $e_2$ . The magnitude which characterizes the interconnection of turns is called mutual induction  $M$ . It depends on the same factors as the value of inductance of turns, and also on their mutual location. For the case under study, mutual induction  $M_{21}$  can be approximately expressed by the relationship

$$M_{21} = \mu_0 r \left( \log \frac{8r}{d} - 2 \right),$$

where  $\mu_0$  is permeability of the medium;  $r$  is radius of the turns;  $d$  is distance between the turns.

The magnitude of emf  $e_2$  depends on the speed of change of mutual magnetic flux  $\Phi_{21}$  or, finally, on the magnitude of mutual induction  $M_{21}$  and the speed of change of current:

$$e_2 = \frac{d\Phi_{21}}{dt} v \text{ or } e_2 = M_{21} \frac{di_1}{dt} v.$$

By increasing or decreasing the coefficient of mutual induction  $M_{21}$  between circuits, we can obtain, accordingly, a larger or smaller emf of mutual induction in the secondary circuit, other things being equal. It is possible to change the mutual inductance, for example, by changing the distance between turns. The character of dependence  $M_{21}$  on distance  $d$  (Fig. 2) has a very important value when determining the value of the output signal.

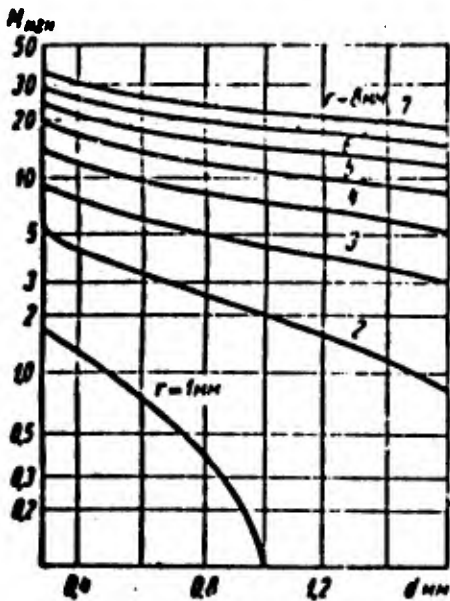


Fig. 2. Graph of the dependence of mutual inductance on the distance between turns.

To ensure discretion of signals which are read, between the turns a metallic screen with holes is introduced. Dimension of the holes should somewhat exceed the dimensions of the turns. In this case the magnitude of the emf induced in the secondary circuit decreases by approximately half, as compared to the case when the screen is absent. If, however, we place a solid screen, there, then the output signal should equal zero.

During the manufacture and assembly of memory plates of this device, of very great value is the mutual location of holes and turns in the screen, since this circumstance to a great degree determines the value of mutual induction. The very worst for a "1" which is being read is the case, when the digit which stores this information is surrounded by digits with the value "0." This is most clearly characterized by the dependence of the value of mutual induction  $M$  on the relative bias  $\lambda$  between the centers of the card hole and a turn on the exciting plate (Fig. 3).

As one of the criteria of noise immunity of the device we can give its resolving power, i.e., the signal-to-noise ratio. For determining the resolving power of devices we should take the worse variant of obtained values of "1" and "0." For "1," such a case is shown above. For the zero signal there corresponds such a combination of information location, when in the punched card around the digit which contains "0" there are digits which store "1."

Dependence of the value of mutual induction on bias of the card relative to the exciting plate is shown in Fig. 4.

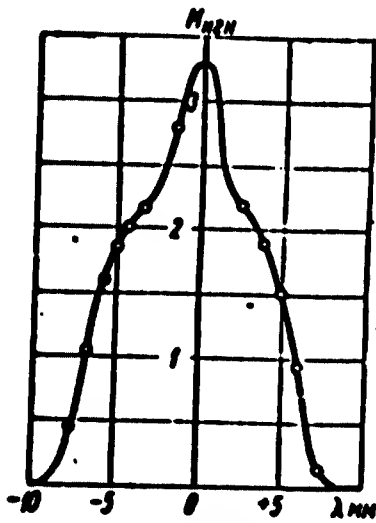


Fig. 3. Graph of the dependence of mutual inductance  $M$  on the bias of centers of holes  $\lambda$  during a readout of "1."

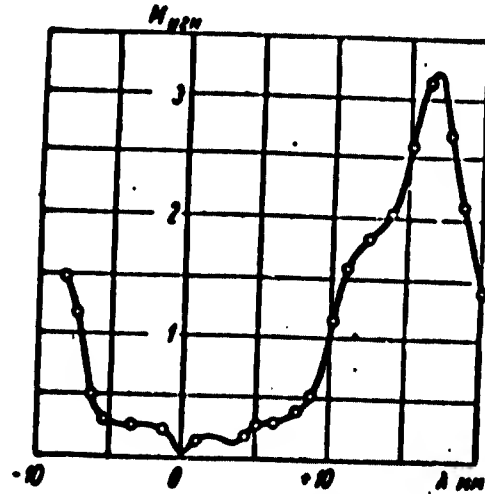


Fig. 4. Graph of the dependence of mutual inductance  $M$  on the bias of centers of holes  $\lambda$  during a readout of "0."

In the examined memory unit, instead of round turns and round holes in the screen it was more convenient to use rectangular openings and two pairs of parallel conductors, between which an inductive coupling is set. In Fig. 5 a cross section is shown of the assembled remembering cell, consisting two plates (excitation and readout), on which by the printed circuit method the turns are applied. Between plates there is the metallic punched card, isolated from them, storing the assigned information in the form of holes.

The principle of inductive coupling enables us to construct a constant permanent storage, i.e., a device without a rapid change

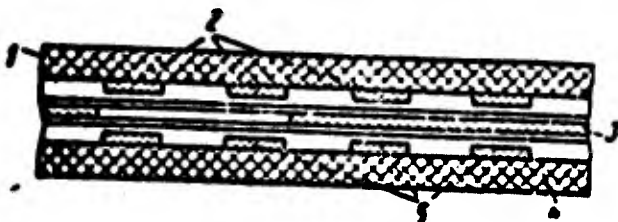


Fig. 5. Memory cell: 1 - exciting plate; 2 - exciting turns; 3 - punched card; 4 - reading plate; 5 - reading turns.

of information. In this case coded information is stored on the exciting plate. The presence of the exciting turn in a given digit corresponds to a stored "1," its absence corresponds to "0." In this case there is no need for metallic punched cards. Plate of excitation and readout are placed on one another, divided only by a layer of insulation.

As the material for the manufacture of punched cards there is thin metallic copper, duralumin, or brass foil. Dimensions of the card can be quite different, however, in order to be able to use standard equipment for automatic punching, sorting, and other operations, it is expedient to make the card like a standard paper

punched card. To satisfy the technological requirements during the manufacture of the printed plates a 45-column punched card was selected, the holes in which were punched with rectangular punches having dimensions of  $3.2 \times 6.35$  mm.

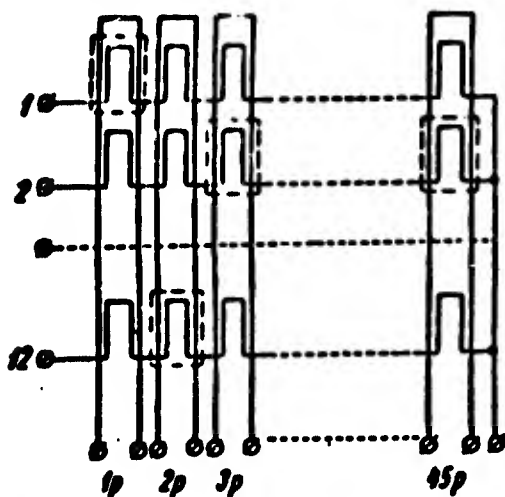


Fig. 6. Diagram of the location of excitation and readout turns.

A diagram of the location of excitation and readout turns is shown in Fig. 6.

In the examined permanent storage, all the digits of one work are read in parallel during the excitation of one certain line; therefore, the dimension of the exciting line is determined by the capacity of a word. This line is located perpendicularly to the sensing turns; however, to produce a maximum connection, the conductors on the window section must be parallel to each other. This is ensured by the corresponding form of the exciting line. The dimensions of the excitation

conductor are determined by the following considerations. Its width should be as small as possible, in order to reduce to a minimum the volume of connections, which is the original cause of "noise" interferences. Furthermore, the thinner the line, the greater the mutual induction between turns with a constant value of the connecting window. However, the technological difficulties of manufacturing the printed plate, the insufficient strength of printed lines and the distortion of the shape of the demand signal do not permit decreasing by much the width of the excitation are determined by following considerations. Therefore, the width is selected from compromise considerations.

Readout lines are located vertically and correspond to one of the digits, where by each line the contents of one digit of several words is read. Readout lines can be of two types: half-turn when the interaction occurs on one vertical section, and single-turn, when two vertical sections are used. Accordingly, in the second case the value of mutual induction is increased; however, storage capacity decreases by 2 times. The basic problem which requires serious solution during the designing of a readout system consists of the unification of readout turns and their linkage with the amplifying elements.

Let us consider the block diagram of a memory unit (Fig. 7). The permanent storage on inductances constitutes a permanent storage unit with capacity of 3072 binary 45-digit numbers. Information is placed on 256 punched cards containing 12 lines each. Access time is less than  $1 \mu s$ . This device anticipates the reliable storage of information and its rapid change during a replacement of the metallic punched cards.

The DZU selection circuits consist of two independent units; the card selection circuit and the number selection circuit with corresponding decoders.

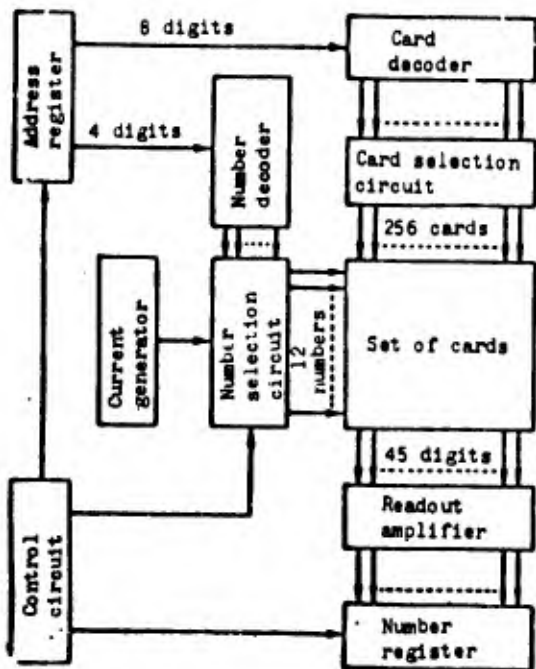


Fig. 7. Block diagram of a memory unit.

the output signal will be formed.

Let us examine the diagram of this unit (Fig. 9). Transistors  $T_1$  and  $T_2$  in the initial state are almost closed. At the emitter of transistor  $T_1$  the potential is close

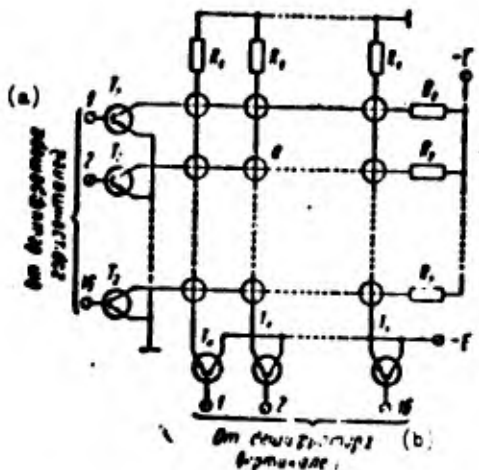


Fig. 8. Diagram of card selection

KEY: (a) From the decoder of horizontals; (b) From the decoder of verticals.

$\Delta_1$  was opened only in the presence of simultaneously open transistors  $T_1$  and  $T_2$ .

During the opening of diode  $\Delta_1$  its resistance drops sharply, and the current pulse is transformed in the secondary winding of

The card selection circuit (Fig. 8) has  $2 \times 16$  inputs and 256 outputs. To the input of the circuit proceed signals from the preliminary diode decoder. For selection of one of the 256 outputs, eight binary digits of the number address register are joined with the diode decoder, having four digits along the horizontal and four along the vertical. Sixteen outputs of the decoder of horizontals are united directly with the inputs of transistors  $T_2$ , while 16 outputs of the decoder of verticals are united with the inputs of transistors  $T_1$ .

Thus, with any combination of signals on the input of the decoder one of the horizontals and one of the verticals of the card selection circuit is excited. At their intersection (unit a, Fig. 8)

to zero. At the collector of transistor  $T_2$  voltage is close to  $E_1$ ; therefore, in the initial state, the diode  $\Delta_1$  is closed. In the primary transformer winding, current is practically absent. When at the base of transistor  $T_1$  a negative pulse arrives, the triode will be opened, and the potential of its emitter drops. Voltage  $E_1$  is selected at such a value so that during the opening of only transistor  $T_1$ , diode  $\Delta_1$  remained closed. If, however  $T_1$  is closed and  $T_2$  is opened, then the potential on collector  $T_2$  is increased, but it will remain negative. Consequently, diode  $\Delta_1$  will remain closed. The circuit is calculated in such a way so that diode

transformer  $T_p$ . Here the normally closed transistor  $T_3$  will be opened, passing the signal to one of 256 plates.

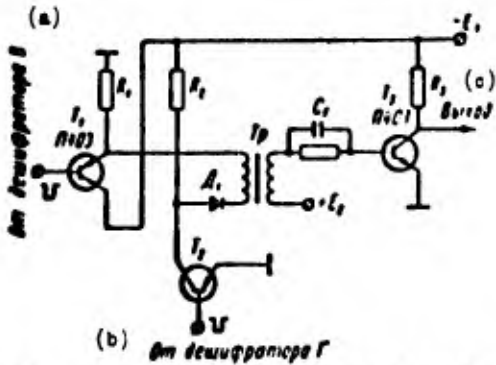


Fig. 9. Diagram of decoder coincidence (unit a).  
KEY: (a) from decoder C;  
(b) From decoder D; (c) Output.

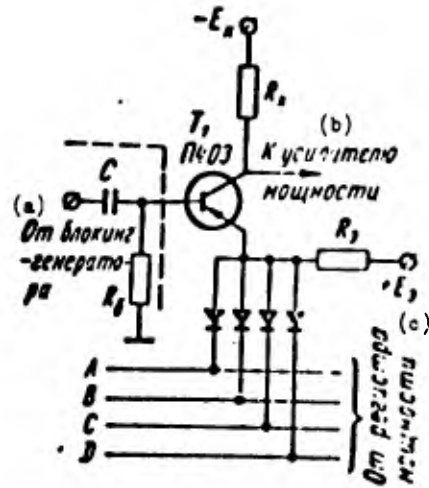


Fig. 10. Diagram of line selection.  
KEY: (a) From the blocking oscillator;  
(b) To the power amplifier; (c) From the power register.

Resistor  $R_4$  serves to prevent a breakdown of the transition base - emitter of transistor  $T_3$ . Capacitor  $C_1$  increases the high speed operation of the circuit. Source  $E_2$  serves for the reliable cutoff of transistor  $T_3$ . All transistors of the circuit are of the П403 type.

To select the necessary line of the card there is a decoder of number selection on the selection circuit (Fig. 10). The diode-type decoder has 4 inputs and 12 outputs per number of lines on the card. The signal from the diode decoder joins the emitter of transistor  $T_1$  and opens it. The transistor key is directly at the input of the power amplifier. If the initial state, transistor  $T_1$  is closed by negative voltage on one of the diodes. For circuit work 12 such keys are necessary, and, consequently, 12 power amplifiers.

From an analysis of the work of a permanent storage we see the basic requirement placed on the pulse generator and the power amplifier. The signal at the output of the permanent storage is proportional to the speed of change of the current in a turn, i.e.,

$$u_{out} = K \frac{di}{dt};$$

therefore, a current generator should ensure high speed of current growth.

Two types of current generators are possible for this circuit: a generator of sinusoidal current and a square-wave current generator.

A square-wave current generator consists of an exciter and a power amplifier. The exciter is a blocking oscillator, working in the self-oscillation mode (Fig. 11).

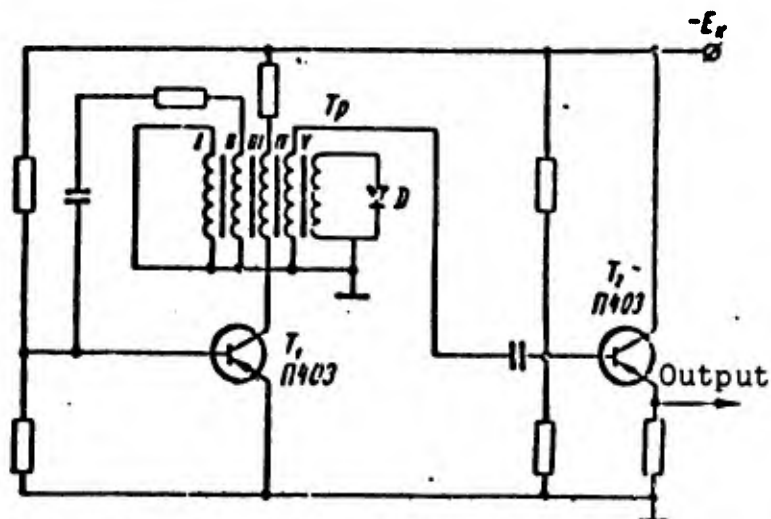


Fig. 11. Diagram of an exciter of current pulses.

This circuit works stably at frequencies of from 1-5 MHz, ensuring pulses the duration of which can be changed within wide limits; duration of the leading edge of a pulse is 0.05  $\mu$ s.

The value of direct diode resistance in winding V is quite dependent on the frequency of following of pulses. Short-circuited winding I is eliminated in the appearance in the circuit of sinusoidal oscillations.

Of special interest is the pulse power amplifier. At the output of the circuit it is necessary to obtain a powerful high-frequency current with amplitude of the order of 1 A.

For execution of these requirements devices are used which are based on the principle of current switches. This has permitted creating one of the most high speed circuits using transistors. However, circuits which are built on these elements contain a considerable number of transistors of the types П402 and П403, and they require the use of triodes which are sufficiently uniform in their parameters. Furthermore, when using support diodes in these circuits, especially stringent requirements are placed on the divergences of the magnitude of resistances and the stability of power supplies.

When developing devices which use high-frequency transistors П401-П403, considerable difficulties appear which are connected with the low value of dissipated power of the triodes.

First of all this appears in the comparatively low load capability of elements. The tendency is natural to use (for power amplification) triodes which have a great permissible value of dissipated power and, at the same time, high frequency properties.

So that their application did not cause a considerable drop of the high speed operation, special measures are necessary which allow accelerating the transient conditions. Several such methods exist.

One of the types of a pulse power amplifier, which is considerably free of the above-mentioned deficiencies, is the proposed circuit (Fig. 12).

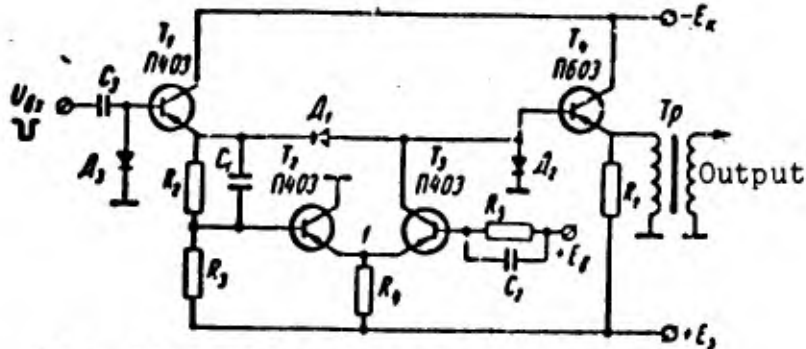


Fig. 12. Power amplifier

The pulse power amplifier consists of an emitter repeater on powerful triode  $T_4$  and a triode key on two high-frequency transistors  $T_2$  and  $T_3$  and an input stage on  $T_1$ . With the help of the key forcing is carried out of transient conditions in the powerful, but comparatively low-frequency, triode.

Let us assume that at the input of the emitter repeater  $T_4$  voltage  $U_{BX}$  acts. The voltage divider on resistors  $R_2$  and  $R_3$  is selected as such, so that triode  $T_2$  of the current key was open. The powerful emitter repeater on triode  $T_4$  repeats the voltage on the emitter of triode  $T_1$ .

For satisfactory circuit work mainly the transmission of a positive front through the emitter repeater with a load of capacitive character, it is necessary to have great natural emitter current. In connection with this, the power amplifier is made using a transistor of the П601 type. Great current and low power load of the transistors of type П601 make this system more reliable.

During the transmission of the positive front, switching occurs of the key current in triode  $T_3$ , and, consequently, a forced change of the state of the powerful triode. During transmission of a negative front, the key current is switched in triode  $T_2$ , and forcing is carried out by the emitter repeater on triode  $T_1$ . Divider  $R_2$ ,  $R_3$  displaces the output levels to the positive area, which is necessary for control of the current key. Capacitor  $C_2$  permits

obtaining the necessary forcing current of triode  $T_3$  only during the transient process.

Upon completion of the transient process, the collector current of triode  $T_3$  flows through diode  $\bar{D}_2$ , and voltage at the output of power amplifier  $U_{\text{ВНХ}}$  remains equal to zero. Diode  $\bar{D}_1$  serves to separate the circuit of triode  $T_1$  from the base of triode  $T_4$  and the circuit of the current key.

We must note that an increase of capacitance of capacitor  $C_2$  causes a growth of the collector (here forcing) current of triode  $T_3$ , and here it increases the switching time of the current key in the initial state, which leads to a drop of the resolving power of the circuit.

Selecting the voltage of power sources is very significant, since on its value depends the inverse voltage between the emitter and the collector of closed triode  $T_1$ . Value  $E_0$  is selected from the closing condition of triode  $T_3$  during the opening of triode  $T_2$ . Value  $E$  is selected from the closing of triode  $T_3$  during the opening of triode  $T_2$ .

Inverse voltage between the base and the emitter of triodes of the current key can attain values at which a breakdown of the transition base - emitter appears. We know that in the presence of considerable reverse breakdown currents the high speed operation of these circuits noticeably drops. For limiting the breakdown current in the circuit of the base of triode  $T_3$  resistor  $R_5$  is switched in.

The circuit of the power amplifier gives powerful high-frequency pulses in load. Delay in the circuit is near 30-40 Ns.

Great divergence is allowed of the parameters of transistors and diodes; therefore, the requirements on divergence of resistors and the stability of power supplies become more rigid. However, even they are technically comparatively easily feasible.

The generator of sinusoidal current consists of a highly-stable self-excited generator (Fig. 13) and a shaper-amplifier. The exciter circuit is calculated for work in a range of 1 MHz with inductive fine adjustment. Output power of the generator is sufficient only for feeding a buffer amplifier on transistors. In this circuit a diffusion transistor of type П403 is applied, which decreases the phase shifts.

Capacitance of the collector junction of this triode is about near 6 pF, and emitter - base capacitance is around 100 pF. One may assume that the instabilities connected with capacitances have a double dependence on them. Therefore, for the production of identical instability of frequency caused by these sources, it is necessary that the impedance of the collector load be considerably greater than the impedance at point a. This is easily achieved in a

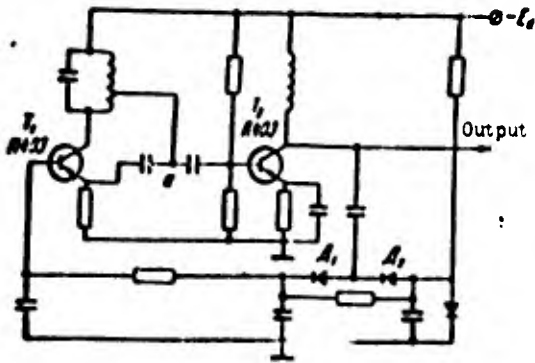


Fig. 13. Generator of sinusoidal voltage.

Instability of frequency, caused by deviations of supply voltages and the temperature dependence of the parameters of triodes, is eliminated by the addition of a circuit of automatic level adjustment, containing semiconductor amplifier  $T_2$  and a doubler of rectified voltage  $\bar{A}_1$  and  $\bar{A}_2$ .

The circuit of automatic amplification adjustment keeps the current of emitter  $T_1$  constant.

However, collector - base capacitance does not remain constant with a change of feed voltage: the found frequency shift, caused by collector capacitance, is shown in Fig. 14. When collector voltage drops, the increase of the transition time is the cause of a considerable decrease of frequency.

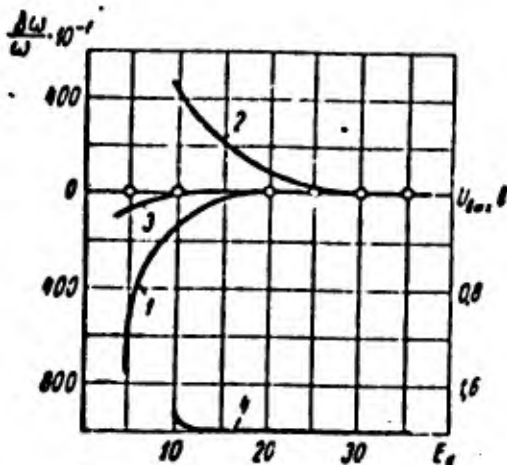


Fig. 14. Graphs of frequency shift and output voltage of the generator: 1 - measurement of frequency shift; 2 - measured frequency shift for amplifier without treatment of the coupling; 3 - calculated frequency shift, caused by a change of collector capacitance; 4 - output voltage.

three-point circuit by corresponding selection of a tap from the inductive coil to the emitter.

The operating point of transistors  $T_1$  and  $T_2$  is established with the help of the usual methods of direct current stabilization.

The resonance circuit of the generator has great equivalent resonance resistance and a high Q-factor. High resistance of the collector load ensures rapid and reliable starting.

The amplifier of powerful sinusoidal oscillations is made on the base of a pulse amplifier, the diagram of which is shown in Fig. 12. To transmit bipolar signals, the circuit consists of two symmetric pulse power amplifiers.

Construction of the circuit of the amplifier of exciting signals causes the same difficulties that appear during the construction of a pulse amplifier.

The circuit of a stable amplifier of readout signals (Fig. 15) is developed in accordance with the high requirements for a system which works with sufficiently great amplification at frequencies up to 10 MHz in a range of temperatures from  $-55$  to  $+65^\circ\text{C}$ .

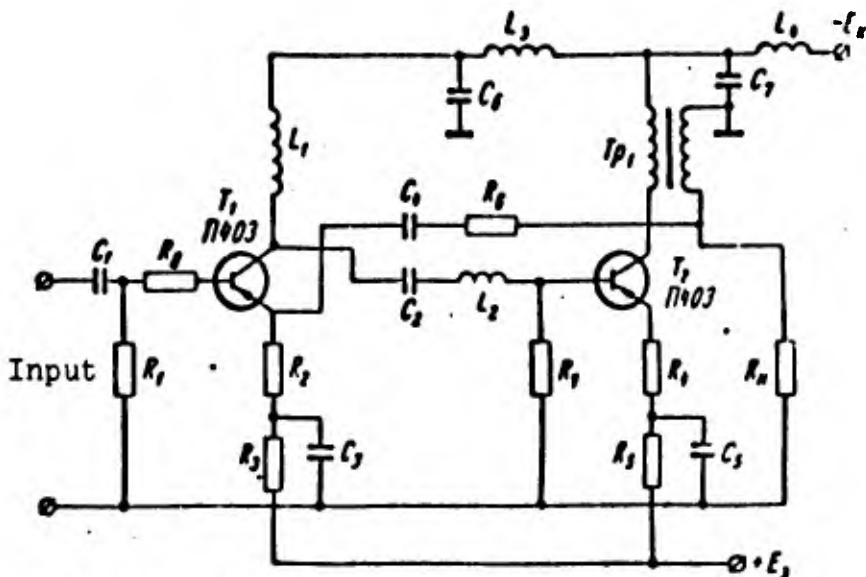


Fig. 15. Amplifier of readout signals.

Basic attention has been allotted so that drift or phase deviation of the amplifier did not exceed, correspondingly, 0.2 dB or  $1^\circ$ , and so that the input and output of the amplifier agreed with the coaxial cables by assigned characteristic impedance.

For the production of the greatest amplification with the lowest amount of transistors, in the circuit a transformer coupling is used. In the first stage circuit  $L_1 C_2$  is used, which, jointly with the input and output capacitance of transistors  $T_1$  and  $T_2$  in the presence of opened feedback is tuned to the needed frequency. Capacitance  $C_2$  is selected in such a manner that the input impedance of transistor  $T_2$  played the role of a great resistance, switched in parallel to the collector load of transistor  $T_1$ . This ensures good coordination of the transistors. Inductance  $L_2$  serves for correction of the frequency-response curve at high frequencies.

Resistors  $R_2$  and  $R_4$  serve to support as practically constant the input impedance of transistors  $T_1$  and  $T_2$ . Transformer  $T_p$  is wound on a torodial core of type  $\Phi 400$  (for feed of a 50- $\Omega$  load a ratio of turns of 40:8 is used).

Voltage feedback is carried out from the secondary winding of transformer  $T_p$  through resistors  $R_6$ ,  $R_2$  and capacitor  $C_4$ . Ratio  $R_2$  to  $R_2 + R_6$ , determining the feedback factor, is selected in such a way as to obtain the assigned amplification factor of the two stages enveloped by feedback. Resistor  $R_1$  will coordinate the input of the amplifier with the coaxial cable. Feedback to the emitter of transistor  $T_1$  increases its input impedance, which does not have to shunt resistor  $R_1$ . Capacitor  $C_3$  need not affect the

value of feedback, i.e., possess low resistance at high frequencies.

Inductance  $L_1$  is tuned in the presence of an open circuit to feedback at the required frequency, which is the average frequency of the selected range. Amplification factor of the amplifier without feedback at a frequency of 10 MHz is about 52 dB. Upon closing the feedback, the horizontal part of the frequency-response curve, within the limits of which amplification is changed not more than by  $\pm 1$  dB, has a bandwidth of about 30 MHz and amplification of 30 dB. This corresponds to the feedback factor of 22 dB at a frequency of 10 MHz.

Phase response of the amplifier can be expressed in the following way:

$$\alpha_{f_0} = \alpha_0 \frac{e^{-j m \frac{f}{f_0}}}{1 + j \frac{f}{f_0}}$$

where  $m$  is the coefficient, considering cleanliness of the base layer;  $f_0$  is the frequency at which the amplification factor decreases by 3 dB.

In the calculation it is considered that the phase shift of a transistor exceeds the shift, determined by the circuit with an approximation of the amplitude characteristic. Relative maximum changes of amplification and phase shift are, correspondingly, 0.12 dB and  $0.8^\circ$  in the presence of temperatures variations in the shown range.

If even greater stabilization is necessary, we increase the depth of feedback at the assigned frequency.

By changing the value of  $L_1$ , we can obtain satisfactory work of the amplifier at any frequencies. If the required frequency cannot be ensured by a change of inductance of  $L_1$ , it is necessary to replace it, to select corresponding value of capacitance  $C_1$ , and to be convinced that coordination is not disturbed. By tuning the amplifier with an open feedback circuit to a frequency smaller than 10 MHz we can obtain greater amplification than when tuning for frequencies higher than 10 MHz. Thus, feedback depth is changed depending upon the frequency of tuning of the amplifier without feedback.

With the help of this circuit it is possible to construct a broad-band amplifier with high amplification stability and phase shift with the desired average working frequency.

During cascading of such amplifiers, it is recommended that between resistor  $R_1$  and the base of transistor  $T_1$  to connect in series a 50  $\Omega$  resistor. This lowers the amplification factor

less than on 0.5 dB and ensures coordination of input of the second amplifier.

In the presence of resistance of the source of signals and load, equal to 50  $\Omega$ , the noise factor is about 12 dB.

The signal proceeding to amplifier input has an amplitude of about 5 mV, and the output signal should be not less than 5 V, i.e., the general amplification factor of the whole circuit should be 60 dB. Consequently, the full circuit of the reproduction amplifier should consist of two serially connected amplifiers. At the input of the system there is a matching transformer, made on a toroid of brand  $\Phi 400$ .

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