**INTRODUCTION**

The year's project in the discipline of ELECTRONIC DEVICES AND CIRCUITS aims to familiarize students with manufacturing methods, basic parameters and their lifting for bipolar and field effect transistors. At the same time, the students learn the methods of solving the problems related to the correct use of the active elements in the electronic circuits, the selection of the operating regime after direct current and the design of the amplification floors after voltage and power with bipolar transistors.

The task for the design of the year is handed to each student at the beginning of the semester and includes the following basic points:

* technology of manufacturingbipolar transistor;
* static characteristics of the bipolar transistor coupled in the common emitter scheme and common base;
* analysis of equivalent schemes of the bipolar transistor;
* H-parameters for the bipolar transistor,
* operation of the bipolar transistor in switching mode;
* raising the parameters of the bipolar transistor in static and dynamic regime;
* basic parameters for the bipolar transistor;
* the use of bipolar transistors in electronic circuits (the principle of operation for 3 principled cheme of electronic circuits containing bipolar transistors from the class nominated by the teacher with a minimum number of elements 15 is analyzed);
* the first three problems are solved with the typical use of transistors in various circuits according to the variant corresponding to the order number of the student in the bordiro of the academic group;
* according to the variant, a power amplification floor is designed in the base of the bipolar transistor without the use of the transformer;
* for thedesigned amplifier , the printed waferand the mounting plate of the elements used are developed.

**1. TYPICAL PROBLEMS WITH USE**

**TRANSISTORS**

**Issue 1**

According to the current-voltage (CCT) characteristics of the bipolar transistor (see the respective annexes) the following calculations should be made using the graphical method for the amplification floor:

* to draw the load line;
* to draw on the family of static characteristicsthe diagrams of the currents and voltages in time and to determine whether nonlinear distortions of the amplified signal may occur;
* for the linear amplification regime (distortions are excluded) to calculate the input and output resistance of the floor, the amplification coefficient after current, voltage and power. Determine the useful power cut at the load and the power scattered on the transistor collector. 

**Issue 2**

According to the CCT of the bipolar transistor (see the respective annexes) and its parameters at high frequency, the following calculations should be performed for the amplification floor:

* to calculate the values of the parameters and to build the equivalent circuit of the active device analyzed at low frequencies;
* to calculate the physical parameters of the equivalent circuit at high frequency.

**Issue 3**

According to the CCT of the bipolar transistor (see the respective annexes) to determine the parameters of the amplification floor in the power recoupling regime:

* to draw the load line;
* to determine the value of the rest voltage of the open key , the input current and the power required to open it.

**Issue 4**

According to the data in the guidance, to draw the static characteristics for the transistor with field effect and to perform the following calculations for the amplification floor with the use of the graphic method:

* to draw the load line;
* to draw on the family of static characteristicsthe diagrams of the currents and voltages in time and to determine whether nonlinear distortions of the amplified signal may occur;
* for the linear amplification regime (distortions are excluded) to calculate the input and output resistance of the floor, the amplification coefficient after current, voltage and power. Determine the useful power cut to the load and the power scattered on the transistor collector

**Issue 5**

According to the static characteristics of the field effect transistor and its parameters at high frequency (see guideline) to calculate:

* parameters of the equivalent circuit (with its simultaneous construction for low frequency);
* parameters of the equivalent circuit (with its simultaneous construction for high frequency);
* the active component of the input conductivity and the module of the slope of the active device analyzed at the frequency of .

**Issue 6**

According to the static characteristics of the transistor with field effect (after solving problem 4) to perform the calculation of the properties of the transistor at the operation in the variable resistor regime:

* to calculate and trace the characteristic ;
* calculate the power gain coefficient for the power regulator mounted on the basis of the field effect transistor.

**2.**  **METHODICAL GUIDELINES ON SOLVING**

**PROBLEMS**

The basic notions necessary to solve the problems proposed in the draft year can be selected in the specialized bibliography and the lectures in the ELECTRONIC DISPOTENTITIVE discipline. In order to ensure a deeper understanding of the material, we will explain some of the aspects that may arise when solving the proposed problems.

**2.1. Guidance on problem solving 1**

After tracing the families of the static characteristics of the bipolar transistor (see fig. A.1, fig. A.2, fig. A.3, fig. A.5 and fig. A.6) Pay attention to the fact that the input feature is presented as a single curve. This is explained by the fact that the output voltage influences very poorly on the input circuit of the transistor. As a result, the family of input characteristics is placed on a very small area. For these reasons, only one input feature is used (as indicated in the fig. A.1 and fig. A.5).

The load line corresponds to the equation

 (2.1)

which can be transcribed in the form of

 . (2.2)

On the family of output characteristics the order of this line to the values  corresponds to the point  . The abscissa corresponds to the point . If we now join these two points we will get the right task sought. The intersection of the load line with the curves corresponding to different values for the current of the base determines the operating point of the amplification floor that has as

load the resistor . The coordinates of the operating point determine the working regime of the output circuit and , and the coordinates also on the input characteristic – the working regime of the input circuit for the given transistor.

Then constructing the sinusoidal variation for the value of the base current (according to the load received from the teacher) with the amplitude we determine the diagrams of the variation of currents and voltages on the transistor terminals.

After we trace those diagrams over time, it is necessary to determine the probability of nonlinear distortions of the amplified signal.

According to the diagrams we can say, that under the action of alternating current input the operating point moves on the right of the load. If for some moment of time the operating point hits the region of saturation or blocking, then nonlinear distortions occur, which are called "limitation". In such a case it is necessary to reduce the amplitude of the alternating signal at the input of the active device to such a value that would ensure the variation of the operating point in the active working range for the selected transistor.

The following calculations are made only for the active operating regime of the transistor. Such operating mode is called linear mode (without distortion of the signal).

When we appeal to the values , , (on the families of the CCT) we draw attention to the fact that for the semi-positive and negative periods of the signal they may be different. For these reasons, for the signal with major amplitude, the nonlinear distortions may also occur in the active operation of the electronic device.

For the following calculations the amplitude values are

determined as an average value over a period:

 ; (2.3)

 ; (2.4)

 . (2.5)

The respective values of the operating parameters for the analyzed amplification floor can be determined according to the diagrams obtained as the ratio of the amplitudes of the respective currents and voltages:

; ; ; (2 .6)

; ; . (2.7)

**2.1.1. Example of problem solving 1**

It is known: the amplification floor is mounted in the base of the bipolar transistor type ГТ322A. Supply voltage , nominal resistance load , , .

The current voltage characteristics of the terminator transistorare shown in fig.2.1. Coordinates of the load line: and . According to these coordinates we draw the right of the load. Theoperating mode of the floor corresponds to the O point on the output and input feature. We construct the time charts for the collector current, the voltage applied to the base and collector of the transistor when applying the alternating (sinusoidal) signal with the amplitude.

We mention, that if the current of the base does not correspond to

U BE,mV

t

t

2IBm

UWhat = 5V

a)

0

50

100

150

200

I B,μA

2ube

-160

-320

UWhat =0V

t

2

I C,mA

U EC,V

t

2uCEm

Urest.

2ICm

b)

0

01

4

6

8

10

50

100

150

200

250

IBm

4

8

12

Fig.2.1. Static characteristics for the transistor

analyzed in issue 1

step of the family of current-voltage characteristics, then independently draw the intermediate curves (fig.2.5).

According to the static characteristics drawn we determine the amplitudes of the currents and voltages.

 ;

 ;

 .

The diagrams are constructed taking into account the fact, that the voltages applied to the base and the collector are in counterphase.

We now determine the respective values of the operating parameters for the analyzed amplification floor.

 ;

 ;

 ;

 ;

 ;

 .

**2.2. Guidance on solving the problem 2**

We draw the static characteristics of the analyzed transistor and then determine the hybrid parameters . The nominated parameters are determined according to the respective curves (except for the parameter ). The dimensions of the carac-terrestrial triangles must be reduced to a minimum. In reality, the required accuracy can be ensured if we choose the sides of the respective triangle approximately with the value of 20% of the respective values for the DC operating regime.

The parameter is determined according to the output characteristics. According to the independently selected value, several additional curves of the current-voltage characteristics are drawn (fig.2.5). In such a way we can write

 ; (2.8)

 ; (2.9)

 . (2.10)

The parameters  determine the basic properties of the transistor at low frequency (if we amplify signals with low amplitude). To illustrate this we refer to the drawing in fig.2.2.





















Fig.2.2. Equivalent circuit of the transistor

bipolar at low frequencies

The circuit shown in fig.2.2 can be described using the equations below.

 ; (2.11)

 . (2.12)

In connection with the reduced value of the reaction in the low frequency transfer we can assume for the value.

If the transistor works at high frequency, then all the parameters become complex numbers, that is, they can be represented by means of active and reactive elements.

In addition, the values of the active and reactive components vary with the frequency. For these reasons, the equivalent circuit of the bipolar transistor for high frequencies was also modernized. Fig.2.3 shows the equivalent circuit for the bipolar transistor at high frequencies (after Djacoletto).



























Fig.2.3. Cequivalent for the bipolar transistor at

high frequencies (after Djacoletto)

the elements , , , shape the regime of the transistor base and the capacity of the collector's junction. The elements and model the input circuit for the ideal transistor (without reaction). The elements also  shape the input circuit of the transistor at its coupling in the scheme with common emitter. We emphasize, that the equivalent current generator in the output circuit depends on the voltage . This allows us to consider that the slope does not depend on frequency.

With the help of the equivalent physical scheme we can determine any parameter of the transistor at the known value of the frequency. For example, the parameter can be determined if at the output of the scheme we have a short circuit after alternating current (see fig. 2.4).

















Fig.2.4. Equivalent circuit of the bipolar transistor

used to calculate the resistance value

high frequency input

The values of the elements of the equivalent circuit are determined in the following manner.

 , (2.13)

where: shows the resistance of the base of the bipolar transistor; - the time constant for the reaction circuit of the transistor, raised to a value known for the collector's current ; - the total capacity of the collector junction.

The other parameters for the nominated regime are determined in the following manner:

 ; (2.14)

 ; (2.15)

 ; (2.16)

 ; (2.17)

 ; (2.18)

 , (2.19)

where: is the slope of the transistor after the junction of the emitter; - the limit frequency of the transistor (); - the value of the collector's current at the operating point of the transistor; - the barrier capacity for the emitter junction.

It follows that we can calculate the input conductivity for the analyzed transistor () and the input capacity (). For this we use the following relationships:

 ; (2.20)

 , (2.21)

where

 . (2.22)

The last relationship is not calculated. Only the calculations for and  depending on the relationship for ten values (in the range of 0,1...1,0) are performed.

**2.2.1. Example of problem solving 2**

As mentioned above, the parameters are determined for an increase below the 20 % limit from the values obtained at the selected operating point. For values and (point O in fig.2.5) we have:

 ;

 .

Taking into account the fact, that the inclination of the curves at the point of operation is very small it is necessary to increase the value for . In such a case we will determine the value more precisely . For these reasons we select for the value .

The respective triangles corresponding to the data originally obtained are shown in fig.2.5 hashed. Now we can write the following:

U BE,mV

a)

0

50

100

150

200

I B,μA

δuBE

-160

-320

δiB

2

I C,mA

U EC,V

δuCEm

b)

0

01

4

6

8

10

50

100

150

200

250

4

8

12

0

δiC

δiC1

135

165

Fig.2.5. Graphical method for determining parameters 

 ;

 ;

 .

The equivalent circuit of the transistor analyzed for low frequencies is shown in fig.2.6.













Fig.2.6. The equivalent circuit of the transistor analyzed in

problem 2 at low frequency

We now determine the values of the physical elements of the equivalent circuit at the coupling of the bipolar transistor into the common emitting circuit:

 ;

 ;

 .

For the value we get:

 ;

 ;

 ;

 ;

 .

The value of the barrier capacity is very low and is not taken into account. The equivalent physical circuit in the analyzed regime is shown in fig.2.7.

























Fig.2.7. The equivalent physical circuit of the transistor

in the regime under review

**2.3. Guidance on solving the problem 3**

We draw the static characteristics of the transistor according to the respective variant and determine its properties as an electronic key.

The marking of the load line is carried out analogous to problem 1. However, in this case the operating point of the transistor will be placed in blocking mode (the transistor does not conduct current), or in saturation mode (the transistor leads to the maximum). The rest voltage is determined according to the output characteristics.

In order to obtain a reduced value for the coupling time of the transistor, it is recommended to apply input current several times higher than that which ensures the saturation regime, i.e.

 , (2.23)

where: shows the saturation coefficient. As a rule, the value of this coefficient is placed within the limits of 3 to 5.

The power used by the input circuit () when the key is engaged

 , (2.24)

where  the value is determined according to the input characteristic of the transistor for the value (saturation regime). The power scattered on the transistor collector in "coupled" mode

 . (2.25)

Resistance of the transistor in "coupled" mode

 . (2.26)

**2.3.1. Example of problem solving 3**

The operating mode of the transistor as an electronic key can be analyzed using the characteristics shown in fin.2.1. The placement of the point corresponds to the open transistor regime. Tenssion of that remainder, or

 .

The value of the base current, required for the secure coupling of the transistor, is higher than at values for 

 .

The engaged transistor is in saturation mode, that is, we can say that . The input voltage corresponding to the coupling current is determined according to the input characteristics for the values . In the example given the voltage . Respectively we get for  , and .

**2.4. Guidance on resolving the problem 4**

As a rule, the static characteristics of field-effect transistors are not indicated in the guidance. In their place the cunt presented some basic points for the respective characteristics that allow their construction using the graphic-analytical method.

For example, the transfer feature for the field effect transistor 

Can be described in the following way

 , (2.27)

where , shows the basic points of the static characteristic shown schematically in Fig.2.8.

****

****

****

****

****

****

****

****

Fig.2.8. Transfer feature

for the field effect transistor

For transistors with a field effect based on the p-n junction is considered . For MOS-type transistors , the value is not indicated in the guide, but it can be determined according to the grid voltage , which corresponds to the given current (for example ) or according to the current of the drain , which corresponds to the voltage on the grid  (the initial current). For this purpose the equation 2.27 is

solved relatively by . We emphasize, that for mos type transistors with induced channel the locking voltage is called the threshold voltage.

When constructing the static characteristic, we pay attention to the polarity of the voltages applied to the transistor terminals. For these reasons, there may be different combinations of current directions.

The family of output characteristics is traced in the coordinates .

In the active operating mode of the transistor, the drainage current practically does not depend on the value of the voltage applied on the drain. This allows us to trace the characteristics parallel to the axis of the voltage. In Fig.2.9 these curves are drawn dotted.

****

****

****

****

****

****

****

****

****

****

****

****

****

****

Fig.2.9. Output characteristic for the transistor

with field effect

The active operating regime of the transistor with field effect corresponds to itby marking these points , which correspond to different values of , we obtain on the drawing points 1,2,3,4. As a result we get the static characteristic of the field effect transistor. According to the operating point () and the load resistance value (or the supply voltage value) we can draw the load right. The procedure is analogous to solving problem 1 except that it is necessary to determine the value 

 . (2.28)

On the family of output and transfer characteristics we note the operating point of the transistor. The regency of the allowable values of voltages and currents is bounded from the left by the points 1,2,3,4, and from the right – with the values of the allowable power that can be scattered on the transistor drain. The scattered power characteristic shows a hyperbole that is described by means of the following equation:

 . (2.29)

When drawing the diagrams of the currents and voltages in time, it is possible to appear distortions of the amplified signal because the operating point is moving in forbidden regime. In such a case we will reduce the amplitude of the input signal up to the value that allows the operation of the electronic device in normal mode. It is for the value of this amplitude of the signal that we will determine the basic parameters and construct the current and voltage diagrams as a function of time.

To determine the amplification coefficient it is necessary to use the mean value for the current of the drain

 , (2.30)

where is the amplitude of the positive semiperiod of the signal, and - the amplitude of the signal for the negative half-period.

The average slope of the device

 . (2.31)

Voltage gain coefficient for the amplification floor

 . (2.32)

The value of the input current is determined by the resistor in the grid circuit , through which constant voltage is applied to the control grid . As a rule . At such condition the coefficient of amplification after current of the device

 . (2.33)

Amplifying the floor by power

 . (2.34)

If we determine the input resistance of the transistor according to the static characteristics we get that it is infinite. In reality .

**2.4.** **1. Example of problem solving 4**

Drawing the static characteristics of the transistor with field effect we will illustrate it for the transistor КП313A (channel type-n).

According to the guide the given transistor possesses the following basic parameters: ; (at values); ; .

According to the data exposed above we can determine the numerical value of the voltage that corresponds after the formal

 , (2.35)

or

 .

The equation of the desired feature has the form:

 .

We now complete Table 2.1.

Table 2.1.

Feature equation 

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 0,32 | 1,30 | 2,90 | 5,00 | 7,90 | 9,60 |
|  | -3,0 | -2,0 | -1,0 | 0 | 1,0 | 2,0 | 2,5 |

The given table corresponds to the dependencies shown in fig.2.10.

Although according to theoretical data, the current of electrons has a negative reaction, all the characteristics are drawn at the top of the coordinate axes, i.e. the current of the drain is placed on the **coordinate +y**.

Between the limit values and we draw the family of the output characteristics of the device. If now we draw lines parallel to the x axis with the interval (of

8

6

4

2

10

1

2

3

-1

-2

-3

0

I D,mA

UGS,V

ImD+

ImD-

t

Umgs=2V

Umgs=1V

Fig.2.10. Feature for transistor

analysed in issue 4

example ), we get the family of characteristics with different range values . We can also draw the characteristics with equal range of voltages , for example .

We now determine the coordinates of the points corresponding to the transistor locking regime:

point 1 is coordinated ;

point 2 has a coordinate ;

point 3 has a coordinate,  etc.

We now trace the rays from the origin of the coordinates at the points obtained 1,2,... 6 and we get the family of features sought after. If we now compare the results obtained with the families of real characteristics listed in the annex, we can see that they correspond satisfactorily in the first approximation.

The drawing of the load line and the diagrams for voltage and current over time is performed analogous to problem 1 (see fig.2.11). Either, for example, ; ; and . The operating point is in position 0. We emphasize, that the value is taken arbitrarily and in the variants of the problems it is not encountered. When constructing the diagrams in time, it is noticed that for the nonlinear distortions of the amplified signal occur because the operating point is placed in the ohmic region of the families of characteristics. For these reasons we reduce the amplitude of the voltage on the grid . In such a case the distortions disappear. We determine according to the curves of the characteristics the value . Now we can determine the mean value for the slope of the transistor with field effect

 .

8

6

4

2

10

2

4

6

0

I D,mA

UDS,V

UmGs=1V

t

8

10

12

14

0

UG=0V

-1v

6

5

4

3

2

1

-2V

+1V

+2V

+3V

UmGs=2V

UmDS1

UmDs2

UDs

t

Fig.2.11. Family of output features for

transistor analyzed in problem 4

Using the data obtained we can write the following:

* the coefficient of amplification after voltage for the device analyzed in the present problem is; 
* strength of entry ;
* the amplitude of the grid current ;
* the amplitude of the current of the drain ;
* the coefficient of amplification after current ;
* the coefficient of amplification by power ;

The scheme of the transistor coupling is shown in fig.2.12.













Fig.2.12. Diagram of transistor coupling according to

problem data 4

**2.5. Guidance on resolving the problem 5**

For transistors with a field effect at low frequencies, only two basic parameters are determined: the slope of the transfer feature

 (2.36)

and the output resistance

 . (2.37)

For such analysis the input resistance is considered equal to the nominal and equal to .

The parameters  and are determined by the angle of inclination of the transfer andoutput characteristics for the given operating point. As in the case of bipolar transistors the values and are taken 20 % from the nominal at the operating point. Taking into account that the output characteristics have a very low inclination we will often have to considerably increase the value .

The equivalent scheme of the field effect transistor shall take the form shown in Fig.2.13. We often neglect the value of the input resistance and then the transistor with field vefect can only be modeled by means of the output circuit.

The respective calculations of the parameters of the transistor with field effect at high frequencies are performed using the equivalent scheme shown in fig.2.14. All elements of this scheme do not depend on frequency. The grid circuit is shaped by the capacity and resistance of the conduction channel. The output circuit is shaped by the resistance of the alternating current channel, the output capacity and

the equivalent current generator .





















Fig.2.13. Equivalent scheme of the transistor with

low frequency field effect























Fig.2.14. Equivalent (physical) scheme of

field effect transistor

The reaction loop between the transistor input and output is determined by the capacity . The nominals of these capacities are indicated in the guidance, and can be accepted equal to . The values are given in Annex 5. We emphasize that often the numerical values for and are equal.

An important peculiarity of the presented scheme is the fact, that the equivalent generator depends on the voltage applied to the grid and does not depend on the input voltage. Namely this peculiarity and reflects the real frequency dependencies of the device parameters (and ) .

Using the equivalent scheme, we can perform some important calculations. For example, we can determine the active component for the input conductivity of the transistor at high frequency according to the relationship

 (2.38)

or the module of the transfer slope of the transistor

 , (2.39)

where  (- the operating frequency), and - the value of the transistor slope at low frequencies.

**2.5.1.Example of problem solving 5**

The first part of the problem is solved by means of the characteristics shown in Annex 4.

Either ; ; Assuming

 ; ,

we determine with the help of the transfer feature the value of the slope

 .

According to the family of output characteristics we determine the value

 .

The respective equivalent scheme is shown in Graph 2.15.



















Fig.2.15. Physical equivalent scheme)

that corresponds to problem 5

**2.6. Seas on solving the problem 6**

At low values of the drainage voltage, the field-effect transistor has a nominal linear resistor, which depends on the potential applied to the grid. On the output characteristics this region is called the ohmic or triod type.

The diagram of an alternating signal attenuator, which uses the indicated regime of the field-effect transistor, is shown in Fig.2.16.

















Fig.2.16. Schematic of a signal attenuator in

base of the field effect transistor

The properties of the regulator are described by the equation



where it shows the resistance of the ac current transistor in the chosen operating mode. The feature is traced by calculating the inclination of the initial portion of the output characteristics for different values of . The directing power at the output of the attenuator . The steering power at the regulator input is determined as . The continuous voltage and the value of the amplitude of the signal are practically identical (of the order ). It follows that the amplification coefficient by power (maximum) of the governor

 . (2.40)

**2.6.1.Example of problem solving 6**

According to the static characteristics of the device (fig.2.11, coordinates of points 1...6) we determine six values of the resistance ofthe transistor in ohmide modec:

 ;

 etc.

As a result, we obtain the dependence shown in fig.2.17. Maximum regulator amplification

 .



















Fig.2.17. Characteristic of the governor according to the data

presented in Issue 6

# 3. METHOD OF DESIGNING THE FLOOR OF

# AMPLIFICATION IN TENSION AND FLOOR

# AMPLIFICATION IN POWER

In fig.3.1 and fig.3.2 are shown two typical schemes of amplifiers with the use of the bipolar transistor as an active element.

**RЭ**

**RC**

# r1

**RG**

# r2

**Сd2**

**Сd1**

**RS**

**UG**

**Uget out.**

**Uflax.**

**IB**

**IE**

**IC**

**EC**

**Vt**

**СE**

Fig.3.1. The principled scheme of the amplification floor in

audio frequency of the amplifier with transistor

bipolar coupled with the common emitter

**RE**

# r1

**RG**

# r2

**Сd1**

**UG**

**Uflax.**

**IB**

**EC**

**Vt**

**СE**

**RS**

**T**

**Uget out.**

Fig.3.2. Principled scheme of the amplification floor

in power of the amplifier with transistor

bipolar coupled with the common emitter

In tab.3.1 and tab.3.2. the initial data necessary for the design of such amplification floors are presented.

Students use the data presented in these tables in the following way. The number of the variant that belongs to the student corresponds respectively with the serial number in the register of classes for the given group. The transistors are selected according to the initial data with the use of the guidelines indicated in the bibliography.

Table 3.1.

Initial data for the design of the floor

voltage amplification without transformer

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.**  **lime.** | **Uieş.мах..** | **Rs, Ohm** | **Fj,**  **Hz** | **Mj** | **EC,**  **V** |
| 1 | 1,8 | 320 | 140 | 1,20 | 6 |
| 2 | 3,6 | 480 | 200 | 1,15 | 9 |
| 3 | 3,5 | 560 | 230 | 1,10 | 12 |
| 4 | 3,2 | 580 | 240 | 1,10 | 9 |
| 5 | 3,1 | 550 | 100 | 1,25 | 9 |
| 6 | 3,0 | 540 | 180 | 1,25 | 9 |
| 7 | 2,8 | 520 | 170 | 1,20 | 9 |
| 8 | 2,7 | 500 | 160 | 1,15 | 9 |
| 9 | 2,5 | 480 | 150 | 1,30 | 9 |
| 10 | 2,3 | 450 | 140 | 1,20 | 6 |
| 11 | 2,1 | 400 | 120 | 1,15 | 6 |
| 12 | 2,0 | 350 | 90 | 1,30 | 6 |
| 13 | 1,7 | 250 | 70 | 1,15 | 6 |
| 14 | 3,4 | 600 | 150 | 1,15 | 12 |
| 15 | 4,0 | 590 | 170 | 1,20 | 12 |
| 16 | 3,4 | 550 | 140 | 1,20 | 12 |
| 17 | 6,0 | 350 | 150 | 1,25 | 15 |
| 18 | 4,0 | 250 | 120 | 1,30 | 9 |
| 19 | 3,0 | 600 | 100 | 1,25 | 9 |
| 20 | 2,0 | 400 | 90 | 1,30 | 6 |
| 21 | 10 | 450 | 200 | 1,15 | 24 |
| 22 | 2,4 | 600 | 180 | 1,10 | 6 |
| 23 | 1,6 | 280 | 160 | 1,10 | 6 |
| 24 | 2,2 | 440 | 110 | 1,15 | 6 |
| 25 | 2,5 | 200 | 60 | 1,20 | 6 |
| 26 | 3,8 | 300 | 80 | 1,20 | 9 |
| 27 | 1,5 | 200 | 70 | 1,10 | 12 |

Table 3.2.

Initial data for the design of the floor

power amplification with transformer

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.**  **lime.** | **Pieş.** **,**  **W** | **RS, Ohm** | **Fj,**  **Hz** | **Mj** | **EC,**  **V** |
| 1 | 4,0 | 3 | 110 | 1,20 | 9 |
| 2 | 1,5 | 15 | 110 | 1,15 | 24 |
| 3 | 1,5 | 19 | 110 | 1,12 | 24 |
| 4 | 1,5 | 18 | 200 | 1,20 | 24 |
| 5 | 1,5 | 17 | 200 | 1,25 | 24 |
| 6 | 2,0 | 16 | 200 | 1,20 | 12 |
| 7 | 2,0 | 15 | 160 | 1,25 | 12 |
| 8 | 2,0 | 14 | 160 | 1,20 | 12 |
| 9 | 2,0 | 13 | 160 | 1,12 | 20 |
| 10 | 2,5 | 12 | 100 | 1,15 | 18 |
| 11 | 2,5 | 11 | 100 | 1,20 | 18 |
| 12 | 2,5 | 10 | 100 | 1,14 | 12 |
| 13 | 4,0 | 13 | 200 | 1,12 | 24 |
| 14 | 1,5 | 8 | 120 | 1,20 | 12 |
| 15 | 1,0 | 15 | 160 | 1,20 | 6 |
| 16 | 0,5 | 12 | 140 | 1,14 | 12 |
| 17 | 2,5 | 4 | 120 | 1,12 | 9 |
| 18 | 0,9 | 10 | 60 | 1,20 | 6 |
| 19 | 2,0 | 6 | 110 | 1,15 | 12 |
| 20 | 3,0 | 5 | 100 | 1,12 | 24 |
| 21 | 1,0 | 3 | 90 | 1,14 | 6 |
| 22 | 1,8 | 9 | 70 | 1,20 | 18 |
| 23 | 2,0 | 4 | 90 | 1,14 | 12 |
| 24 | 1,8 | 6 | 100 | 1,12 | 24 |
| 25 | 1,5 | 55 | 130 | 1,18 | 9 |
| 26 | 1,0 | 5 | 180 | 1,20 | 12 |
| 27 | 1,5 | 10 | 110 | 1,13 | 9 |

**3.1. Method of designing the amplifier**

**tenssion based on the bipolar transistor**

Initial data: the coupling scheme of the common emitter transistor (EC); the voltage at the output of the amplification floor (on load) **Uexits.max.** **;** load resistance; lower limit frequency; permissible value of the coefficient of nonlinear distortion in the lower frequency range; voltage of the power supply **ЕC**. When performing the calculations it is assumed that the ambient temperature where the amplifier is placed is in the range + 15...+ 25 0С.

Determine:

* the type of transistor to be used in the circuit;
* the operating regime of the transistor;
* the nominal of the resistor in the circuit of **the emitter RE**;
* the nominal of the blockage capacitor **СE**;
* the nominal of the voltage divisor resistors in the circuit of the base **R1, R2**;
* the nominal of the dividing capacitor **Ср2**;
* the nominal of the resistor from the collector circuit **RC**;
* the amplification coefficient of the floor after voltage **КU**.

**3.1.1. Calculation of the voltage amplifier**

1. We choose the type of transistor leading us to the following:

а) **UCE.admitted.**  ** (1,1... 1,3)ЕC**, where **UCE.admitted.** – the maximum allowable value of the voltage between the collector and the emitter (according to the guidance for electronic devices);

б) **IC.admis.**  ** 2Is.max.**  **= 2Uieş.max.** **/Rs**, where **Is.max**. – the allowable value of the current amplitude of the load, and **IC.admitted.** - the allowable value of the collector's current (according to the guidance for electronic devices).

For such amplification floors, low power transistors are usually used. We emphasize that for the range of ambient temperatures, expected when calculating the amplification floor, any transistor can be used. For these reasons we exclude the influence of temperature on the parameters of the transistor used.

For the transistor selected from the guide, the families of the output characteristics and the input characteristic are drawn on millimetre paper at **the value UCE** = – 5 V. At the same time, the values of the current amplification coefficients for the EC и coupling scheme and the maximum allowable values for **the permissible UCE are noted.** **, IC.admis.** **, РC.admis.** .

In some guidance, the values of the amplification coefficients for the common base coupling scheme (BC) are present. In this case, the value of the current amplification coefficient for the EC coupling diagram is calculated using the relation.

2. The operating mode of the transistor shall be determined according to the load line (dynamic output characteristic), drawn on the family of output characteristics for the EC coupling scheme. The drawing of the load line is shown in fig.3.1,a. The load line is drawn after two points: the initial P and the point 1 which is determined by the value of the supply voltage **ЕC**. The coordinates of the P point are current **IC0** and voltage **UCE0** (i.e. the current and voltage corresponding to the U value **in.max.** = 0).

It defines I0C = (1,05... 1,20)Ieş. = (1,05... 1,20)Is.max. but not less than 1 mА and **UCE0 = Uiasi.max.**  **– Urest.max**. , where – **Urest.max**. shows the minimum allowable value for UCE.

At **UCE**  values  **< Urest.** quite large nonlinear distortions occur, being the fact that in the working range are placed the portions of the static characteristics with major nonlinearity. For low power transistors we can **Urest.** = 1 V. For class A operating mode the work point P must be placed in the middle of the dynamic feature (when the input signal is not). In this case, the variation of the input current (base current) correspond to proportional variations of the collector's current (output current).

When selecting the operating regime of the transistor it is necessary to meet the condition **IC.min.** ** ICs = IC0**.

After a few points to draw the curve of the allowable power that the transistor can spread

**РC.admis.**  **= ICUCE** = const.

and for temperature values **Тmed.norm.**  **= + 25 0С** it is indicated whether the chosen transistor possesses the parameters of the thermal regime.

1. We determine the nominal values for **RC** and **RE**. According to the output characteristics shown in fig.3.1, to find the total **R** value  **= RC + RE**. The total resistance in the emitter-collector circuit **total R= ЕC/I**, where iг **I** shows the current, determined in point 4, i.e. at the intersection of the load line with the current axis. If defined

**RE = (0,15... 0,25)RC** ,

Get

 ; .

4. According to the static input feature we determine the maximum values in amplitude for the input signal **Iintr.max.** and **Uin.max**. , necessary to ensure the necessary value **Uiasi.max**. . If we start from the value of the minimum coefficient of amplification after current of the transistor used, we obtain:

; .

Then

.

After the static characteristic of input in the EC schema, raised to **values UCE** = - 5 V (fig.3,b) and the values obtained for **IB.min.** and **IB.max.** determine the value **of 2Uin.m.** **.**

t

4

1

2

5

Р

3

IC

IC=PC.adm. /UWhat

Ib5

Ib4

Ib3

IB2

Ib1

UWhat

EC

t

UEC0

Urest.

UC.m..

UC.m..

I

IC.max.

IC.m..

IC.m..

IC.0.

IC.min.

IC.min.adm.

IB

UBE

11

21

P1

t

t

IB.max..

IB.min.

2IB.m.

2uintr.m.

UB.min.

UBE.max. .

UCE =-5V

a)

b)

Fig.3.1. Determination of the operating regime of the

transistor by families of characteristics

output

5. We determine the input resistance of the amplification floor after alternating current **Rintr.** (without taking into account the voltage divider **R1** and **R2**):

 .

6. We determine the nominals of the resistors of the voltage divider **R1** and **R2**. To decrease the shunting action of the divisor on the input circuit we assume

 ,

where

 .

In such a case

 ; .

7. We determine the coefficient of stability in the operation of the floor:

 ,

where it shows the maximum possible value of the current gain coefficient for the requested transistor. 

For the normal operation of the amplification floor, the value of the stability coefficient must not exceed the value of a few units.

8. We determine the capacity of the splitting capacitor **Сd2**:

 ; ,

where is the output resistance of the transistor, determined according to the output characteristics for the EC coupling scheme. In most cases. For these reasons we can write .

9. We determine the capacitor capacity **СE**:

 .

10. We determine the value of the coefficient of amplification of the floor by voltage:

 .

**3.2. Design of the amplification floor in**

**power with the use of bipolar transistor**

Initial data: the power at the output of the amplification floor **Рieş**. ; resistance of the load **RS**; the lower limit frequency **Fj**; the coefficient of the nonlinear distortion of the floor at low frequencies **Мj**; the voltage of the supply supply **ЕC**; ambient temperature + 15...+ 25 0С.

Determine:

* type of transistor;
* the operating regime of the transistor;
* the nominal of the resistor in the emitter circuit;
* capacitor capacity **СE;**
* the nominals of the resistors in the voltage divider in the circuit of the base **R1** and **R2**;
* the amplification coefficient of the floor by power **КР**;
* the conversion coefficient of the transformer;
* resistance of the primary and secondary transformer and;
* the inductance of the transformer mayor;
* the surface of the radiator for the transistor used, if it is necessary to ensure the operating regime of the transistor. 

# 3.2.1. Method of calculation of the floor

1. For the selection of the transistor it is necessary to determine the power **Р0** , which will be scattered on the selected transistor:

 ,

where - shows the coefficient of use of the transistor (= 0,35... 0,45); the more major the voltage of the power supply, the higher the value; - the power given up by the transistor: .

The yield of the transformer is expected within the limits of 0.7... 0,9.

We determine for guidance the value of the voltage that falls on the active resistance in the primary of the transformer and on the resistance **RE**

 .

In this case the maximum value of the voltage applied to the transistor

 .

According to the data obtained for **Р0** and we select after the guide the necessary transistor.

***Note.*** For the transistor selected from the guide we note the allowable value of the collector's current, the allowable value of the voltage at the collector, the maximum power that the transistor **РC.adm** can scatter. , the minimum value of the amplification coefficient after current, the initial current of the collector, the thermal resistance, the maximum allowable value of the temperature of the collector junction. It is necessary to draw on millimeter paper the families of the output characteristics, the input feature to the value and traced the allowable scattering power hyperbole 

 .

2. On the static output characteristics (common emitter coupling scheme) we determine the coordinates of the operating point P (see fig.3.2,a). For this we determine the voltage on the collector at values and the current of the collector

 ; .

Through the points obtained Р (, ) and 4 (; ) we draw the right load. In order to determine the working portion on the load line, we define the value of the rest voltage (as a rule) and the minimum current of the collector (- the initial current of the collector). According to the value, the position of point 2 and its coordinate is determined on the right of the load. It is necessary that . The maximum value of the amplitude of the output voltage . The operating range is placed within the limits of points 2 and 3. When choosing the operating regime of the transistor it is necessary to meet the condition

 .

The maximum current amplitude is determined by points Р and 2 or Р and 3.

It is worth mentioning that the initial placement of the operating point P (when the alternating signal at the input is not) in the class A amplification mode for the selected transistor must be halfway through the working portion on the dynamic feature. In this case, the variation of the input current (base current) correspond to proportional variations of the output current (collector's current). After this it is checked whether the chosen operating regime corresponds to the required power According to the assigned load line we determine

 .

If the operating regime is chosen correctly. If this condition is not met, then the inclination of the load line is increased (the current value for point 1 is increased).

It is necessary that the right of charge does not exceed the region, limited by the hyperbole of the permissible powers. Then the respective values for the minimum and maximum input current are calculated. These values are fixed on the family of input characteristics (fig.3.2,b)

 ; .

After points 1 and 2 of the input characteristic we determine the minimum and maximum voltage values based on the transistor (and ) and the maximum amplitude of the input voltage. Then we determine the power of the input signal 



and resistance of the transistor after alternating current

 .

UBEмаx..

t

IC

IC=P C.adm./UWhat

Ib5

Ib4

Ib3

IB2

IB1

UWhat

t

Uwhatмаx.

Urest.

UC.m..

UC.m..

I=EC/rB0

IC.max.

IC.m..

IC.m..

IC0.

IC.min.

1

2

3

P

4

UEC0

t

IB

UBE

UWhat =-5V

t

IB.max.

2IB.m.

IB.min.

Ube.min

2uintr.m.

1

2

а)

b)

Fig.3.2. Determination of the operating regime

of the transistor in the amplifier of

power coupled in the common emitter scheme

3. The resistance in the emitter circuit is determined by the value of the voltage that falls on this reнistior. It is assumed that for the scheme analyzed . In this case it is obtained 

 .

4. The capacity of the capacitor that shunts the resistor is determined according to the relation



(at the values the blockage capacitor can be removed from the amplifier circuit what power).

1. Resistance of the voltage divider by alternating current



must ensure the condition



Then

 ; .

1. The amplification coefficient of the floor by power

 .

7. In order to calculate the conversion coefficient of the power transformer according to the inclination of the load line (see fig. 4,a), the value of the collector load resistance after alternating current is determined

 .

In such a case, the conversion coefficient for the power transformer shall be equal to the

 .

1. The resistance of the winding of the transformer mayor

 ; .

1. Inductance of the transformer mayor

 .

10. If necessary, determine the surface of the radiator to cool the transistor

 ,

where - the permitted value of the collector junction temperature (according to the guide for electronic devices);- the allowable value of the ambient temperature in which the power amplifier operates.