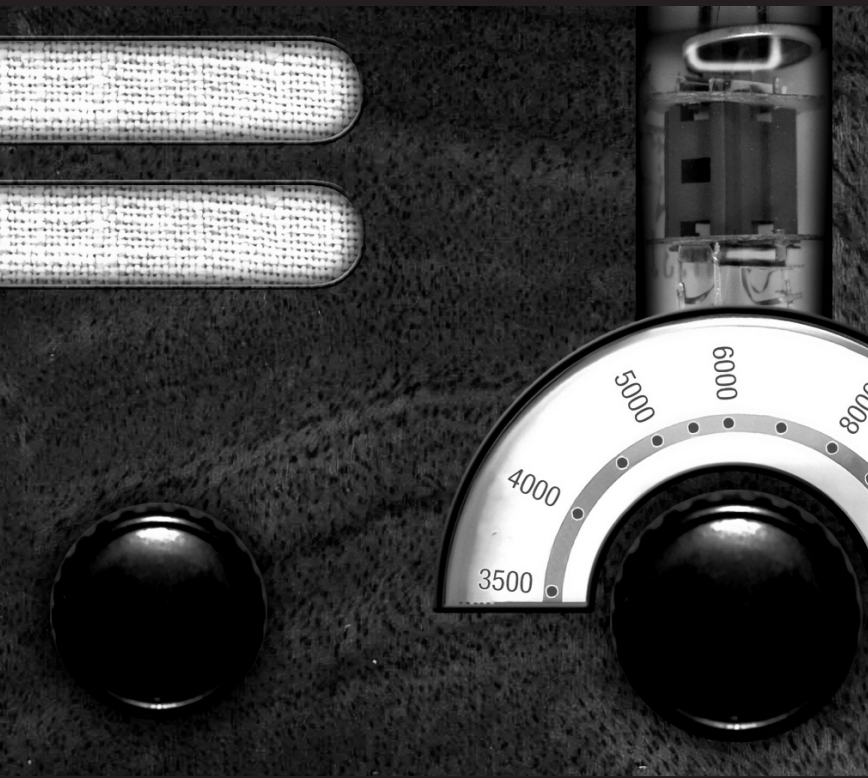
Build Your Own TUBE RADIO

Instructions

EIGHT
GREAT STUFF TO MAKE
2008



These instructions are available to view online at:
www.eight-innovation.com/dir/instructions

Build Your Own Tube Radio

This nostalgic kit builds a shortwave receiver with adjustable feedback. The principle of operation is inspired by the Audion tube from the early days of radio technology. 80 years ago, such a radio receiver could be found in many living rooms. The Audion was also used by amateur radio enthusiasts, in military communications and in marine radio.

An Audion is a one stage receiver which, unlike the later superheterodyne receiver, does not require an intermediate frequency. The adjustable feedback is the reason for the good reception performance of an Audion. By fine adjustment of the feedback you change the gain and the selectivity of the radio and can get the optimum reception for every situation. The receiver is not the easiest to use, but often reaches the reception performance of modern receivers and can sometimes even exceed them.

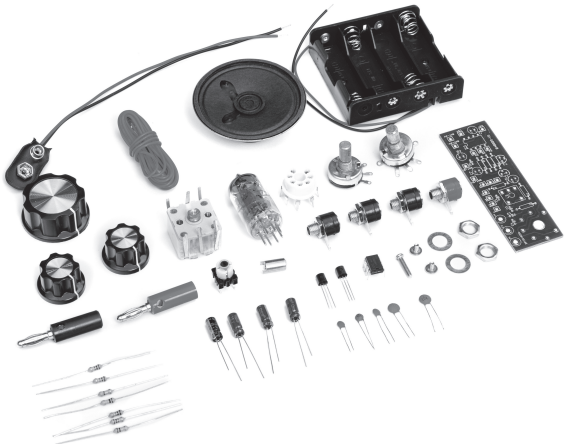
Take plenty of time for extended excursions into shortwave. Enjoy the mysterious glow of the tube cathode and the special sound. Listen to stations from many countries, especially in the evening. Adjust the frequency and feedback sharply and listen to the most distant stations.

The 6J1 tube was used in military communications technology for a long time. It's a special radio frequency tube with particularly low heating power. The radio works with a heating battery of 6 V and an additional anode battery of 9 V at an anode voltage of up to 15 V. The 6J1 is equivalent to the European EF95, which was also used in commercial and military technology but was never used in radio or television sets for domestic use. Only after the tube had been largely replaced by semiconductors has it become possible to use stocks from the old days of tube technology for experimental purposes as well.

For more information visit the author's website at:
https://www.elektronik-labor.de/Lernpakete/Roehrenradio4.html
There you will find reports of experiences, tips and tricks as well as help with possible problems.

Note: this website is in German but can be read in English using Google Chrome's page translate feature.

Components

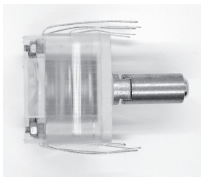
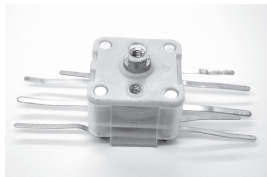


6J1 Tube
Tube socket
printed circuit board
Rotary capacitor 265 pF
Shortwave coil with ferrite screw core
Loudspeaker 8 V, 0.5 W
Feedback potentiometer 22 kΩ
Volume potentiometer 22 kΩ log with switch
Four 4 mm sockets
Two 4 mm plugs
Two-core cable with socket 2 m stranded wire
4x AA battery holder
9 V battery connector
IC1 Audio amplifier LM386 T1 NPN transistor BC547 T2 NPN transistor BC547

R1 100 kΩ (brown, black, yellow) alternatively 330 kΩ (orange, orange, yellow)
alternatively 1 MΩ (brown, black, green)
R2 1 kΩ (brown, black, red) R3 1 kΩ (brown, black, red)
R4 100 kΩ (brown, black, yellow) R5 470 kΩ (yellow, violet, yellow)
R6 10 kΩ (brown, black, orange) R7 10 kΩ (brown, black, orange) C1 10 pF ceramic (10)
C2 100 pF ceramic (101)
C3 10 nF ceramic (103)
C4 100 nF ceramic (104)
C5 10 µF electrolytic
C6 100 nF ceramic (104)
C7 100 µF electrolytic
C8 100 µF electrolytic
C9 100 µF electrolytic

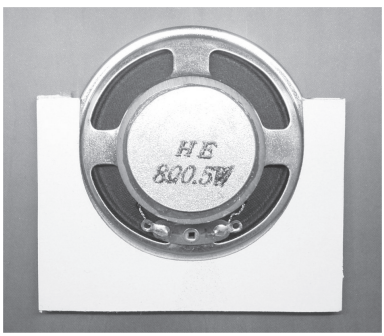
Mounting the controls

The variable capacitor is used to set the desired reception frequency. Place the extension axis on the rotary capacitor and screw it tight with the long 2.5 mm screw. When doing so, use pliers to hold the axle and avoid turning the axis hard to the stop. Later, the rotary capacitor will be mounted in the case with two small screws.


The variable capacitor

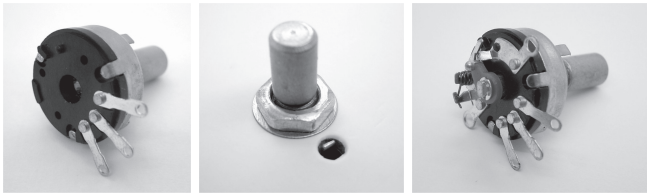
Install the speaker by sliding it into the cardboard slot. The connections should point downwards so that short connections can be made to the circuit board later.



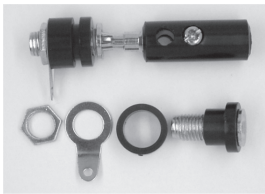
Loudspeaker

The volume control with three connectors is also the on/off switch. If you turn the shaft fully anti-clockwise, the switch opens. Insert the volume potentiometer into the left mounting hole. A metal small tab on the body of the pot prevents it from being inserted incorrectly. Fasten it in position with the washer and nut.

Mount the feedback control in the middle position in the same way.

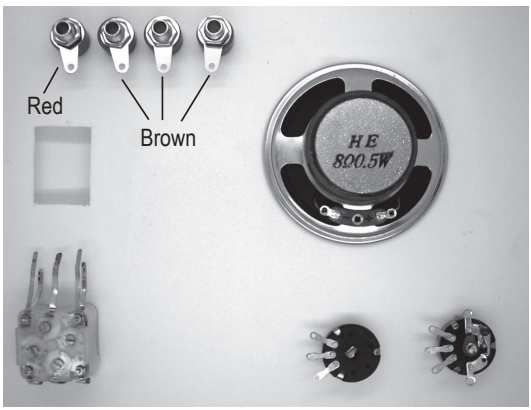


Volume control with switch and feedback control (pots)



Antenna sockets and plug

Insert the four connection sockets. At the outer edge the red earth connection should be mounted, next to it the three brown sockets as antenna connections.



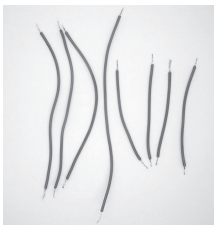
Arrangement of the controls

Soldering

13 wires are needed to assemble the radio. Cut pieces of wire to the following lengths:

2 pcs @ 4 cm / 3 pcs @ 6 cm / 4 pcs @ 8 cm / 4 pcs @ 9 cm.

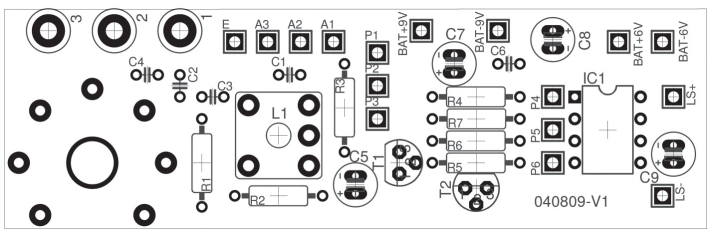
Remove 5mm of insulation from each end of the cut wires. The plastic insulation is relatively soft and can be pulled off with a little force using your fingernails. Twist the fine wire strands together with your fingers. Carefully tin the stripped cable ends. To do this, hold the hot tip of the soldering iron against the cable ends at the same time as the solder wire. The solder must completely encase the end of the wire.



Some of the prepared cables

If you don't have a lot of experience of soldering, tinning the cable ends is a good exercise where not much can go wrong.

Now to mount the components onto the PCB. The circuit diagram of the complete receiver on the last page of the manual is a good reference point.

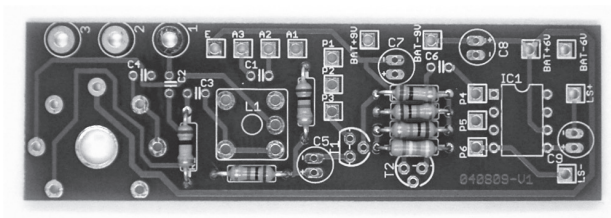


Components on the board

Assemble the board with the electronic components according to the assembly diagram.

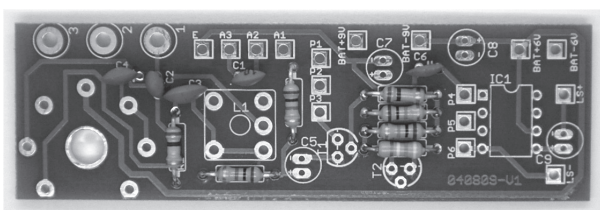
Attention: R1, 100 kΩ (brown, black, yellow) can still remain free, because it should remain replaceable. For this purpose, a cable with sockets will be installed a little later. Start with the other resistors: R2, 1 kΩ (brown, black, red), R3, 1 kΩ (brown, black, red), R4, 100 kΩ (brown, black, yellow), R5, 470 kΩ (yellow, purple, yellow), R6, 10 kΩ (brown, black, orange), and R7, 10 kΩ (brown, black, orange). Bend the connecting wires to fit, and insert them into the corresponding holes on the board. Solder both wires on the bottom side. Then cut off the wire ends with sharp pliers about 2 mm above the board.

Caution: Do not cut the wires too close to the board, as this may cause mechanical stress that will strip the copper tracks.



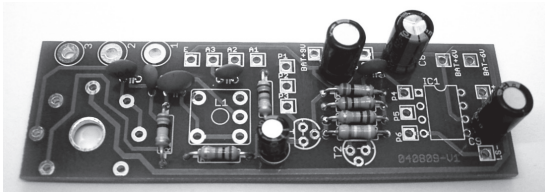
Install resistors

Insert the ceramic capacitors: C1, 10 pF (10), C2, 100 pF (101), C3, 10 nF (103), C4, 100 nF (104), and C6, 100 nF (104).



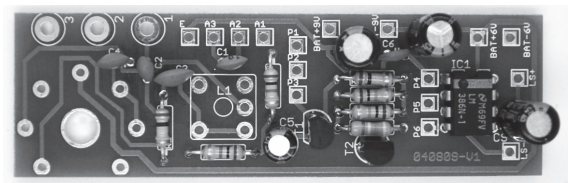
Insert capacitors

Insert the four electrolytic capacitors with 10 µF (C5) and with 100 µF (C7, C8, C9). Here the installation direction must be observed. Plus and minus are labelled for each electrolytic capacitor on the circuit board. The positive pole is on the longer leg. The minus pole is additionally marked by a white bar on the plastic insulation. To check: For C8 the negative pole points downwards, for the other three electrolytic capacitors, upwards.



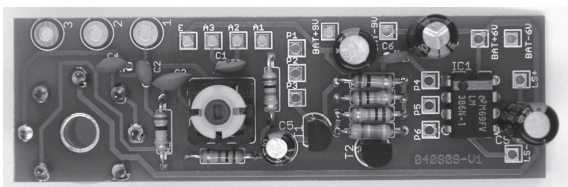
Insert electrolytic capacitors

Install the semiconductors. For the transistors BC547 (T1, T2), note the flat side of the housing in each case; the direction of installation is indicated by the labelling on the circuit board. The integrated amplifier LM386 is marked with a notch, which can also be seen on the labelling of the PCB. Pin 1 is additionally marked by a dot and must be close to connector P4.



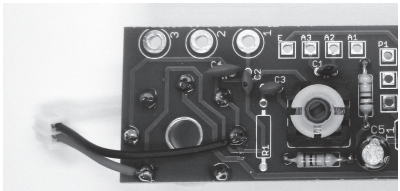
Install transistors and the IC

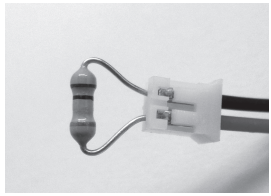
Fit the coil and the tube socket. The coil can only be installed in one orientation because one side has three connections and the other side only two connections. The tube socket must be fitted from the rear.



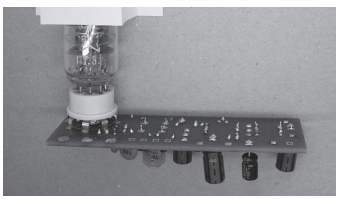
Soldering in the coil and tube socket

Now install the double cable with the socket for the exchangeable resistor R1. Shorten the cable appropriately so that it extends about one centimetre over the edge of the board. Solder the ends directly to the tube socket at pin 1 and pin 6, because this allows a shorter connection. Plug in the resistor with 100 kΩ already.

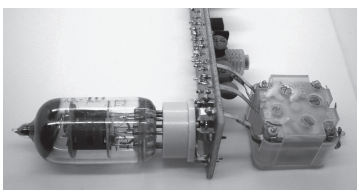




Now insert the tube into the socket. Check the accuracy of fit of the seven pins. In some cases, slightly bent pins must be readjusted so that the contacts are hit exactly. Make sure that the tube is inserted straight. Slide the board with the tube into position so that the tube is centred behind the viewing window in the case. The actual holder for the circuit board is the variable capacitor, whose connections must be precisely aligned.



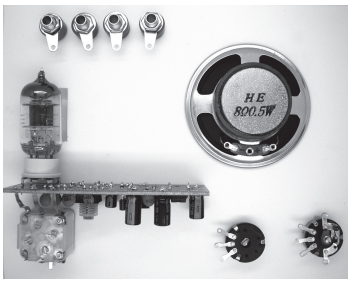
Next, solder the variable capacitor to the board. It has more connections than needed. Use the AM side with a total of five connections, while leaving the FM side with four connections free. The middle terminals are connected to the axis and provide the common connection for all parts of the variable capacitor. Additionally, there are trim capacitors that have their own terminals on the AM side (265 pF, large plate packs). Solder the rotary and trimmer connections together.



Connecting the circuit board and the rotary capacitor

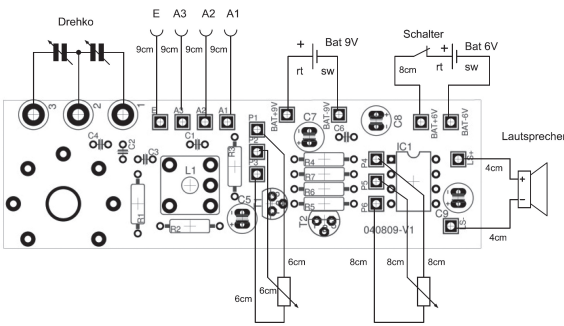
The rotary capacitor also acts as the mounting point for the circuit board. The long connections should be adjusted carefully. First solder only the middle connection and

adjust the position of the board again. Then solder the outer, long connections. Only then should the shorter terminals be soldered to the long terminals. This further fixes the position of the board. The double terminals are on the one hand necessary for the correct function of the rotary capacitor and on the other hand also ensure greater rigidity of the board mounting. Additional stabilisation is provided by the connecting wires to the loudspeaker on the other side of the board.

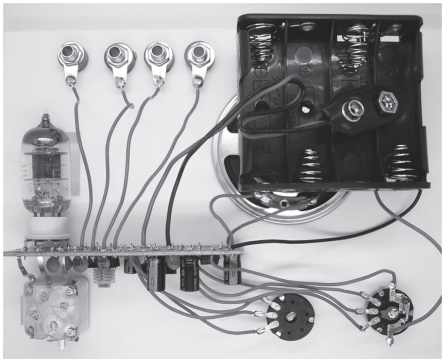


Mounting position of the board

Next, solder in the corresponding cables. The correct wire lengths are shown in the wiring diagram below. You can put the tinned wire ends through the holes from either side of the PCB and solder them like the other components. The black wire of the battery compartment must be soldered to the connection “Bat-6V”. The red wire leads to the volume control switch. The 9V battery clip is connected directly to the PCB. The two short wires to the loudspeaker can be replaced by hard wire to give the board additional stability if desired.



The wiring diagram



The complete wiring

Connect the circuit board to the antenna sockets, the loudspeaker, the feedback control, the volume control and the battery according to the assembly diagram. Now the radio is completely built up and can be tested. If you wish, you can write your name and the build date on the circuit diagram on the last page of the instruction booklet. You can then either copy or detach this page and glue it into the radio case for future reference. As with old tube radios, even after many decades, repairs are still possible because the circuit diagram can always be found in the radio.

Prepare the ground connection and the wire antenna. There should be about one meter left of your wire strand. Divide the section in half and screw on the 4 mm plugs. The ground wire (red plug) should be stripped at the end over a length of a few centimetres. This will allow you to make a conductive connection to an earth terminal. For example, use a water pipe or the heater as the earth conductor.

The first test

The radio requires four 1.5V alkaline cells and one 9V block battery. Turn it on and turn the volume control to medium volume. After a few seconds, you should see the red glow of the tube cathode. Connect the ground wire to E and the antenna wire to A1.

Turn the feedback control to the centre position and use the rotary knob to find a station. Turn the feedback control further and further up. The volume will increase, so you will need to turn the volume control back. Use the feedback control to find the setting that gives the best reception. This may change with the frequency setting, so

you will need to readjust the feedback control each time. If you set the feedback too high, you will hear loud whistling noises.

Look at the tube in operation from different angles. You can see the hot, red glowing cathode. The light is partially reflected by other parts of the tube. The brightness and colour temperature of the cathode give an indication of the condition of the heater battery. The tube heater needs 175 mA. Together with the power amplifier the receiver needs 200 mA. Alkaline batteries with a capacity of 2000 mAh thus achieve an operating time of up to 10 hours. If the cathode glow decreases significantly, the batteries should be replaced.

Reception practice

When tuning the frequency, you'll find separated shortwave bands with several stations. On shortwave, you can achieve a high distance even during the day, but many stations are only switched on in the evening. Below 4 MHz is the 75 m band, which is missing on many shortwave radios. Here, you can find a few interesting stations in the evening. The 49 m band at 6 MHz is densely occupied with numerous European stations. Some frequencies are used successively by different stations. The 41 m band above 7 MHz is used heavily only in the evening. In the 31 m band around 10 MHz and in the 25 m band around 12 MHz, distant stations are often heard. Often non-European stations can be received. Between the broadcast bands, there are numerous stations in CW (Morse telegraphy), SSB (single sideband talk radio), RTTY (radio teletype) and weather fax (picture radio). All of these stations can only be heard with the feedback on.

Finding the best setting for the feedback control requires some skill and practice. When tuning quickly across the broadcast bands, you can start by searching with the feedback turned up, hearing the individual stations with a strong whistle. Then turn the feedback down enough so that the stations can be heard clearly. If the feedback is adjusted optimally and the antenna coupling is not too strong, the Audion is very selective and has a narrow reception bandwidth of less than 10 kHz. This means that the tuning of the rotary capacitor must also be carried out very precisely. With strong stations the feedback regulates itself somewhat back, the bandwidth increases with it.

Test the receiver with different antenna connections and different antenna lengths. A long external antenna can be used at connection A3 with the least amount of coupling. If the antenna coupling is too strong, the receiver will not reach the oscillating point even when the feedback is turned all the way up, resulting in less volume and less selectivity.

Optimization

Most tubes still in use today were built several decades ago and come from old stocks. This is also true for the Chinese 6J1 tube in this kit.

After so many years, there may be changes in the original data that could degrade the behaviour of the receiver. Often an improvement can be achieved by adjusting the grid resistor R1 individually to the tube. For this purpose there are two resistors which have not been used yet.

If the feedback point is in the upper third of the range at the feedback control on all frequencies and the feedback starts softly, the Audion works best. Then the resistor with 100 kΩ (brown, black, yellow) is the best choice.

In other cases, the feedback starts very early and very hard, so that especially AM transmitters can no longer be received clearly. Then use the resistor with 330 kΩ (brown, black, yellow) or 1 MΩ (brown, black, green).

Calibrate the scale

The printed frequency scale ranges from 3.5 MHz to 12 MHz. To ensure that the displayed frequencies are as accurate as possible, you must calibrate the receiver. To do this, you need two radio stations with known frequencies at the bottom and top of the range, or a second radio for comparison.

First adjust the upper end using the trim capacitor on the rotary capacitor with a screwdriver until the station is at the correct position on the scale. Generally, the trimmer must be set to medium capacitance. Then tune to a transmitter at the lower range. Now adjust the ferrite screw core of the coil until the scale is at its exact position. The frequency becomes lower as the core moves further into the coil. At the same time, the upper setting may shift slightly. Repeat the adjustment at the upper end once again.

CW and SSB

Receive Morse code stations at the lower end of the 80 m amateur radio band from 3.5 MHz.

The feedback should be set just above the oscillation point. The frequency heard corresponds to the offset of the transmit frequency to the oscillator frequency of the Audion. For clear reception, the frequency must be set very accurately. More CW stations can be found in the 40 m amateur radio band from 7 MHz.

The usual radiotelephony mode in amateur radio is SSB (Single Side Band, single sideband modulation). In order to receive these stations, a separate carrier must be added with the feedback control turned up. Reception requires a very accurate adjustment of the carrier frequency. Since the receiver is not shielded, you can fine-tune it by bringing your hand closer. If you hear a voice with an unusual pitch, the frequency must be corrected slightly. Getting it right takes a little practice. You can find SSB stations mainly in the evening in the 80 m band between 3.6 MHz and 3.8 MHz and in the 40 m band between 7 MHz and 7.2 MHz. You can also find commercial SSB stations between the broadcast bands, e.g. the aviation weather service at 5.5 MHz.

With the feedback on, there is much more to discover. You can recognise machine telegraphs by their sound. The German Weather Service regularly sends weather fax pictures at 3855 kHz with 120 lines per minute. You hear a regular signal with two passes per second. For decoding such stations there are special devices and also PC software.

Explanation of the circuit diagram

The tube performs three tasks: Amplification, regeneration of the oscillating circuit and demodulation of the RF signal. The 6J1 pentode is operated with a connection between the screen grid and the anode in a triode circuit. The grid resistor R1 is connected to the anode to increase the grid bias voltage. Thus, a sufficiently large anode current is achieved with a low anode voltage. With the cathode at the center tap of the resonant circuit, amplified RF energy is fed back into the circuit. The tube operates in Hartley oscillator circuit. A received signal is thus amplified. At the same time, the grid diode rectifies the RF signal and thus demodulates it.

By adjusting the anode voltage appropriately, the gain can be selected with the feedback controller P1 so that the oscillator just does not oscillate. With this operating point, the tube compensates for all losses that occur in the oscillating circuit. The Q factor can be increased from about 50 to over 1000. At a receiving frequency of 6 MHz the bandwidth is about 6 kHz, so it is possible to separate signals which are close to each other.

At the same time, the feedback leads to an increase in the signal amplitude. RF voltages of several 100 mV can therefore occur at the control grid of the tube. The AM signals are demodulated by the grid diode in that the grid current increases and the grid voltage decreases with higher RF amplitude. The demodulated AF signal is therefore also present at the grid and modulates the anode current. The AF signal thus appears at the anode resistor R2. T2 forms an AF preamplifier for the integrated amplifier IC1.

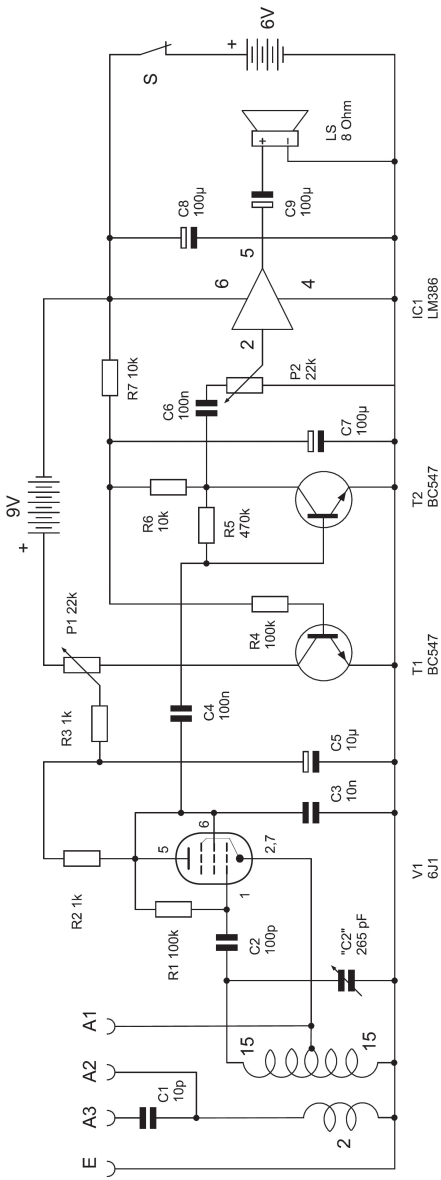
The radio uses two batteries. Four AA cells with 6V supply the tube heater and the AF amplifier. An additional anode battery with 9V is in series with the heater battery. The anode voltage is therefore up to 15V. Because the operating switch at the volume potentiometer has only one contact, the transistor T1 provides for the disconnection of the anode battery. In fact, when switched off, a voltage of 9 V is present at the anode, at the screen grid and at the control grid. However, since the tube cathode is cold, no current flows in this state. If the operating voltage is turned on, T1 becomes conductive and connects the lower end of P2 to ground. The operating current of the anode battery is less than 1 mA, so it normally lasts longer than the heater battery.

Imprint

SIMPLIFIED EU DECLARATION OF CONFORMITY

Hereby, FRANZIS Verlag GmbH declares that the radio equipment type Tube Radio, type number FRANZIS_ Radio_010, is in compliance with Di- rective 2014/53/EU. The full text of the EU declaration of conformity is available at the following internet address: www.franzis.de/conformity

www.eight-innovation.com


6V
S
LS
8 Ohm
C8
100µ
C9
100µ
IC1
LM386
P2
22k
R7 10k
C6
100n
C7
100µ
9V
R6
10k
R5
470k
T2
BC547
P1 22k
R4
100k
T1
BC547
R3 1k
C4
100n
C5
10µ
C3
10n
V1
6J1
R2 1k
R1 100k
C2
100p
"C2"
265 pF
A1
A2
A3
E
C1
10p
15
15
2