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The transistor pocket receiver Telefunken TR1

The transistors are ideal devices to work with small operating voltages in transportable devices due to their small size, economy, practically unlimited life span and their suitability, in particular for portable radios and pocket radios. Originally, the difficulties to use the transistors designed for audio frequency purposes also for high frequency were however not small and it required extensive laboratory tests, before the first German pocket radios equipped with transistors were ready to be manufactured, so that a limited number of units for a full-scale test could be built.

The following essay might interest our readers above all, because it probably discusses for the first time the practical application of such a device in details, in the German technical literature.

Only relatively little of the past tube technology could be taken over for the transistor pocket radios, since the tube are voltage amplifiers and the transistor are current amplifiers. As shown on the diagram (fig. 4), the equipment contains a mixer stage with separate oscillator. The mixer stage is followed by a 3-stage intermediate frequency amplifier. The rectification (detection) is achieved with the help of a gold lead germanium diode. The audio frequency tension arising at the volume control is sufficient, in order to control the audio frequency transistor OC604.

The function of the individual stages is described briefly in the following text.

Antenna circuit and mixer stage

Reception energy is captured by a high-quality ferrite rod antenna and fed to the base of the mixer transistor. The material of the ferrite rod antenna was carefully selected, so that the antenna can provide a relatively large effective surface (capture area) despite its small dimensions. For the tuning, a two-stage variable capacitor of 2 × 180 pF is used. The coupling of the reception frequency to the mixer transistor takes place after a strong downward transformation, since the transistor has a small input impedance of some 100 Ω. The gain for optimal adjustment is given through:

$$ü = \sqrt{\frac{R_e}{R_{AR}}}$$

whereby R_e is the input impedance of the transistor, R_{AR} the resonance resistance of the antenna.

The greatest possible current is supplied with this gain by the antenna to the transistor. In consideration of low noise, a somewhat deviating gain was consciously selected.

The oscillator frequency is supplied to the mixer transistor by way of a 3 nF capacitor into the emitter. The resulting intermediate frequency of 270 kHz is

Illustration 1: The new transistor pocket receiver is so small

brought from the collector over a co-tuned circuit to the intermediate frequency amplifier.

The correct placement of the operating point and the avoidance of inverse feedbacks for the intermediate frequency are of large importance to reach high mixing gain and small noise on the other two electrodes (emitters and base).

The optimal direct current operating point (emitter direct current about 0.25 mA) is reached by setting the base voltage with a voltage divider 6,8kΩ / 220kΩ and with the emitter resistance of 2,2 kΩ. Inverse feedbacks are avoided by sufficiently large and low-induction capacitors, which represent practically a short-circuit for the intermediate frequency. With such a mixer stage, noise values of approximately 10 kT_0 or less can even be obtained.

The oscillator

Since today the transistors manufactured in series by Telefunken have critical frequencies in the magnitude of approximately 800 kHz, and the oscillator must reach nearly 2 MHz, it creates here some difficulties. At the critical frequency, an angular phase shift between input and output of for instance 45° already takes place, which increases with increasing frequency.

In order to obtain from that point, the correct phase necessary for the feedback over the entire range from 770 to 1900 kHz, it is necessary to build into the feedback branch an opposite phase response. An accordingly small coupling capacitor of approximately 200 pF for the emitter of the oscillator as proven to be suitable. A safe oscillation for the whole range has been achieved even for the amplitude of the oscillator tension, which is supplied to the mixer transistor after attenuation of approximately 0.5 V into the emitter.

The question is obvious: why a self-oscillating mixer stage has not been used? If for example the reception frequency would be fed into the base of the oscillator, then a mixing would take place already there. It would be possible to take the generated intermediate frequency from the collector as it would have been from the mixer transistor. Such a circuit works actually to some extend. Nobody did make use however of this simplification possibility, it was instead decided to arrange an optimal dimensioning

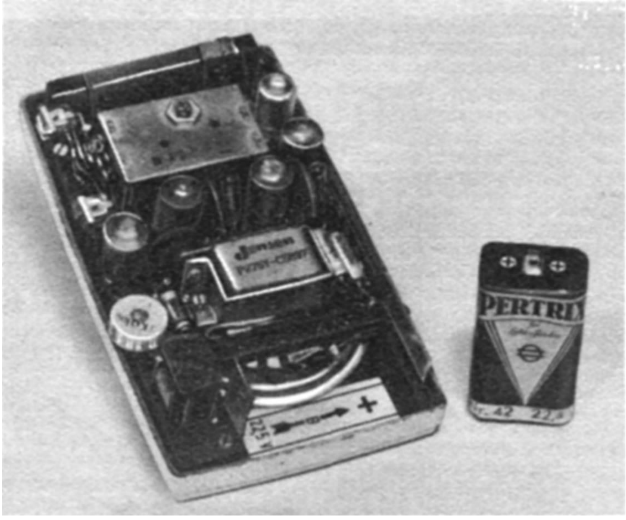

Illustration 2: Inside view of the 6 transistors Telefunken pocket receiver TR 1, beside the 22,5V battery

for both stages independently.

The emitter - coupling capacitor has to be as large as possible for the mixer stage, amount to be kept for the oscillator at 200 pF. With a self-oscillating mixer stage, a compromise would be necessary (small C = bad amplification and strong noise, large C = bad oscillation characteristics). By suitable measures, like absorber circuits and equivalent, these disadvantages can be avoided, but the separation of both functions is the best way, until high frequency transistors become available and are manufactured.

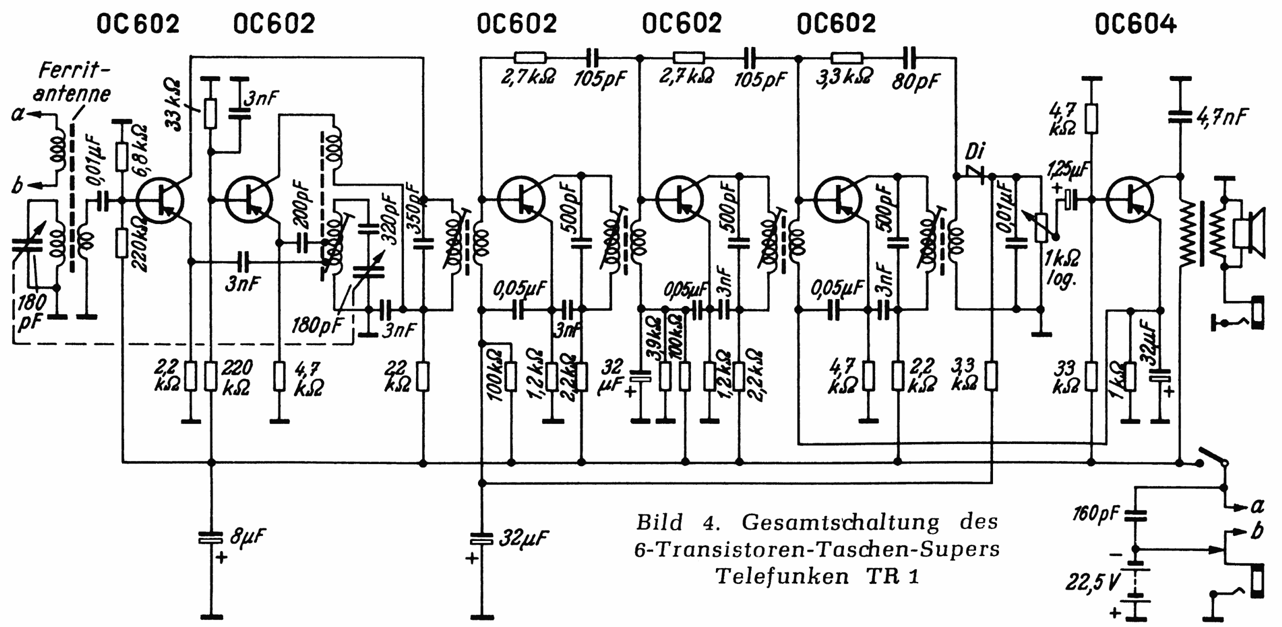

Bild 4. Gesamtschaltung des 6-Transistoren-Taschen-Supers Telefunken TR 1

The intermediate frequency amplifier

For the intermediate frequency amplifier stages there are in principle two circuit possibilities:
a) basic circuit
b) emitter arrangement

Basic circuit arrangement provides smaller amplification for low frequencies. This amplification remains linear up to approximately the critical frequency.
The emitter arrangement supplies a substantially higher amplification with low frequencies, but drops amplification considerably earlier already. The critical frequency in emitter arrangement is with (1 - α) . F_a.
In the area of the selected intermediate frequency of 270 kHz, the gain of both circuits is almost equivalent.

Preference was given to the emitter arrangement, because the dimensioning of the circuits is better and more favorable, the neutralization simpler and and more stable. For the basic circuit, the input impedance of the transistor lies very low, the output resistance extremely highly (about 1 MΩ and more). The collector oscillation circuit requires however, for optimal utilization of possible amplification, a so high resonance resistance that it is dampened by the preceding and the following up-transforming transistor to the same value on the desired range. High impedance circuits are however practically hardly available, so that the theoretically possible amplification in basic circuit can hardly be used.

On the emitter arrangement the input impedance lies approximately in the magnitude of 700 to 1000 Ω, the output resistance in the magnitude of approximately 70 to 100 kΩ, so that these difficulties do not exist here. Due to the necessary power adaption, according to the indicated resistance values, each stage must be stepped down about 10:1 to the next one.

Unfortunately the transistor exhibits a reaction of the output to the input. This effect is not unpleasant for co-ordinating the circuits, but it influences the stability of the amplifier, which can perhaps even oscillate. The amplifier must be neutralized [1]). The reaction can be compensated most simply by a RC element between the output and the input, which supplies a reaction with an opposite phase current to the input. The opposition of phases is reached by the fact that the signal comes from the secondary winding of the transducer. The correct value of the RC element for a neutralization depends on the data

Illustration 3: Transistor pocket receiver Telefunken TR 1; on the left top, the power supply unit

and thus of the operating point of the transistor. As an order of magnitude for the reaction in the transistor itself, a corresponding capacity value of 15 pF and a resistance of 20 kΩ can be taken. Due to the smaller tension on the secondary winding, the resistance is to be made smaller proportionally to the gain (linear) and the capacity has to be increased.

The direct current operating points are specified by holding the base voltages by voltage dividers and through resistances in the emitter inlet. The resistances in the emitter inlet work similarly as cathode resistor with tubes; they adjust dispersions of the individual devices and build a protection against overloading.

For the purpose of the automatic fading control circuit, the base DC voltage of the first intermediate frequency transistor is not constant contrary to the 2nd and 3rd intermediate frequency stage, but is changed as a function of the carrier amplitude. The regulation voltage is measured at the diode, parallel to the volume control and supplied after appropriate filter to the input of the secondary coil.

The regulation is very effective: with a change, a

[1]) See: The neutralization of an intermediate frequency stage equipped with transistor, FUNKSCHAU 1956, number 4, page 141.

mismatch of the operating point in the transistor initially arises between the input and output. With a changed operating point, a change of both the input and the output resistance occurs, in such a way that the gain of both circuits does not correspond to the changed operating point any longer. Band filters were not used due to space considerations and are not necessary, since in one hand low intermediate frequency circuits with higher quality could be used and on the other hand three intermediate frequency stages are present (normally two stages). The 3-stage intermediate frequency amplifiers supplies an amplification of approximately 90 dB.

Rectifier (detector) and audio frequency stage

A gold lead germanium diode was used as rectifier (detector), since these diodes have a particularly small internal resistance. A volume control of 1 kΩ (coupled with the main power switch) supplies the audio frequency to the last transistor stage, which delivers a maximum volume of approximately 22 mW. The loudspeaker has a diaphragm diameter of approximately 65 mm due to the small dimensions of the radio. Nevertheless the rendition is amazingly good, even if it does not reach the quality offered by the same equipment using a larger loudspeaker.

The power supply

The power supply normally comes from a 22,5V battery. The usual small hearing aids batteries proved to be relatively uneconomic. With a current consumption of the equipment from approximately 5 to 6 mA, it is possible to obtain an actual working time from approximately 12 to 15 hours. A somewhat larger type battery has been selected to allow, with nearly the same price, over 70 hours listening. The larger dimensions, unfortunately related to this choice, had to be taken in consideration.

Beyond that, Telefunken built a small power supply unit, which is plugged on the wall and delivers 22 V to the pocket device over a thin flexible cable. The connection to the unit is made with a small concentric plug, whereby the internal connection to the integrated battery is disconnected automatically. It is then possible to preserve the integrated battery when traveling, like for instance in hotel rooms, etc.

Further possibilities

This equipment represents an important step into a perfect new ground. It is difficult to foresee today how successful this development will be over the next years. We know however already today that, in the area of transistor development, transistors for different special purposes are manufactured, as for example high frequency transistors, power transistors etc.

We can also predict that the accessory industry might bring very soon a richer selection of products particularly suitable for transistor devices, exactly as it is the case today for accessories of tube devices with their larger dimensions and higher operating voltages.

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