

The Double-Triode as AM-Mixer

With only three receiving tubes, this circuit results in a full VHF/FM-Superhet with 6 AM and 9 FM circuits.

Good design lies not only in rational manufacture or in the utilization of spare building methods, but also in circuit technique, as the example of Grundig Kleinform-Super 80 U shows.

To achieve a high overall performance in AM and FM with a small tube count, a new front end circuit was developed for the VHF-FM implementation of this Super in a small format. It gives the receiver a sensitivity of 1 μ V in the VHF-FM band, measured at the antenna input at 100 MHz. The lowest sensitivity, measurable with the Grundig Noise Generator Type 370a, is $4.8 \cdot 10^{-11}$ W ($= 4.8 \cdot 10^{-11} \cdot 1.38 \cdot 10^{-23} \cdot 270$ K).

Reflex-circuit in FM

The cost-effectiveness that can be achieved with the ECC85 tube, which implements the Triode pre-amp stage, the additive mixer and oscillator stages, will be retained in this design. Since only one IF-amplifier tube (EBF80) follows the ECC85, the FM pre-amp tube was also utilized as an IF-amplifier; a reflex circuit technique known from several other Grundig – VHF/FM – building blocks, and thus two-stage IF-amplification was achieved.

The front end circuit thus entails four VHF/FM and two IF circuits (Figure 4). Further details can be observed in Figure 2. The preamp-tube operates with grounded-grid and the secondary of the antenna

input band-pass filter drives the cathode. The 5-pF-capacitor sets the input tuned capacitance. The grid capacitor measures over 150 pF to ground. The 100 Ohm resistance in the anode supply feed is exposed by the choke at RF frequencies and dampens ringing. This anode circuit is connected to the grid circuit of the self-oscillating additive mixer stage in a familiar fashion. The oscillator voltage is measured as approximately 2.5 V. The first 10.7-MHz band-pass filter lies in the anode circuit of tube system II. A feedback loop for the IF including 1.2 nF and 130pF capacitors increases the internal resistance of the ECC85-II. The secondary

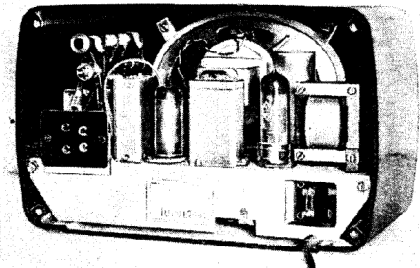


Figure 1: Rear view of the Grundig Kleinform Super 80 U

of the IF band pass filter is connected to the grid of the ECC85-I, where the IF is amplified. In addition to the voltage divider of 30pF/1.2nF, choke BV1976 and the 130pF condenser form a wave trap for the IF in order to eliminate any IF behind the ECC85-I.

The second 10.7 Mhz-IF band-pass filter

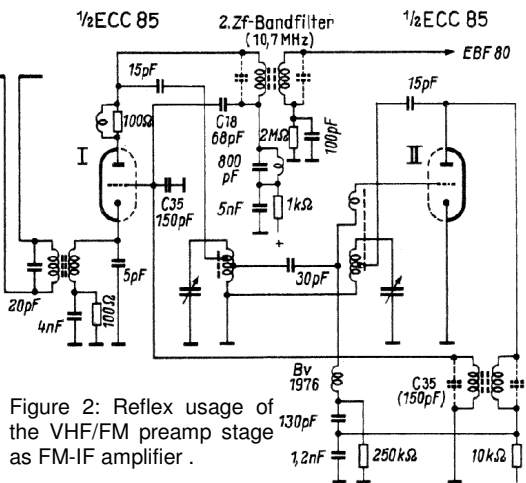


Figure 2: Reflex usage of the VHF/FM preamp stage as FM-IF amplifier.

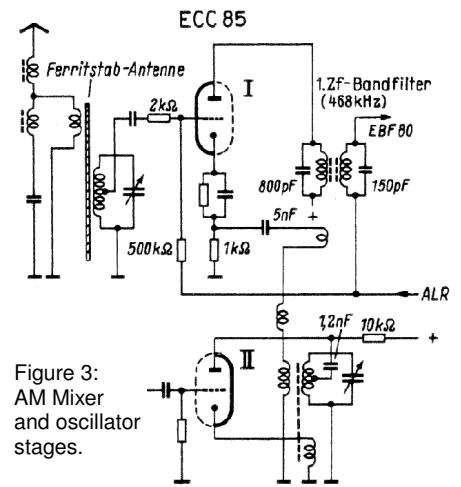


Figure 3: AM Mixer and oscillator stages.

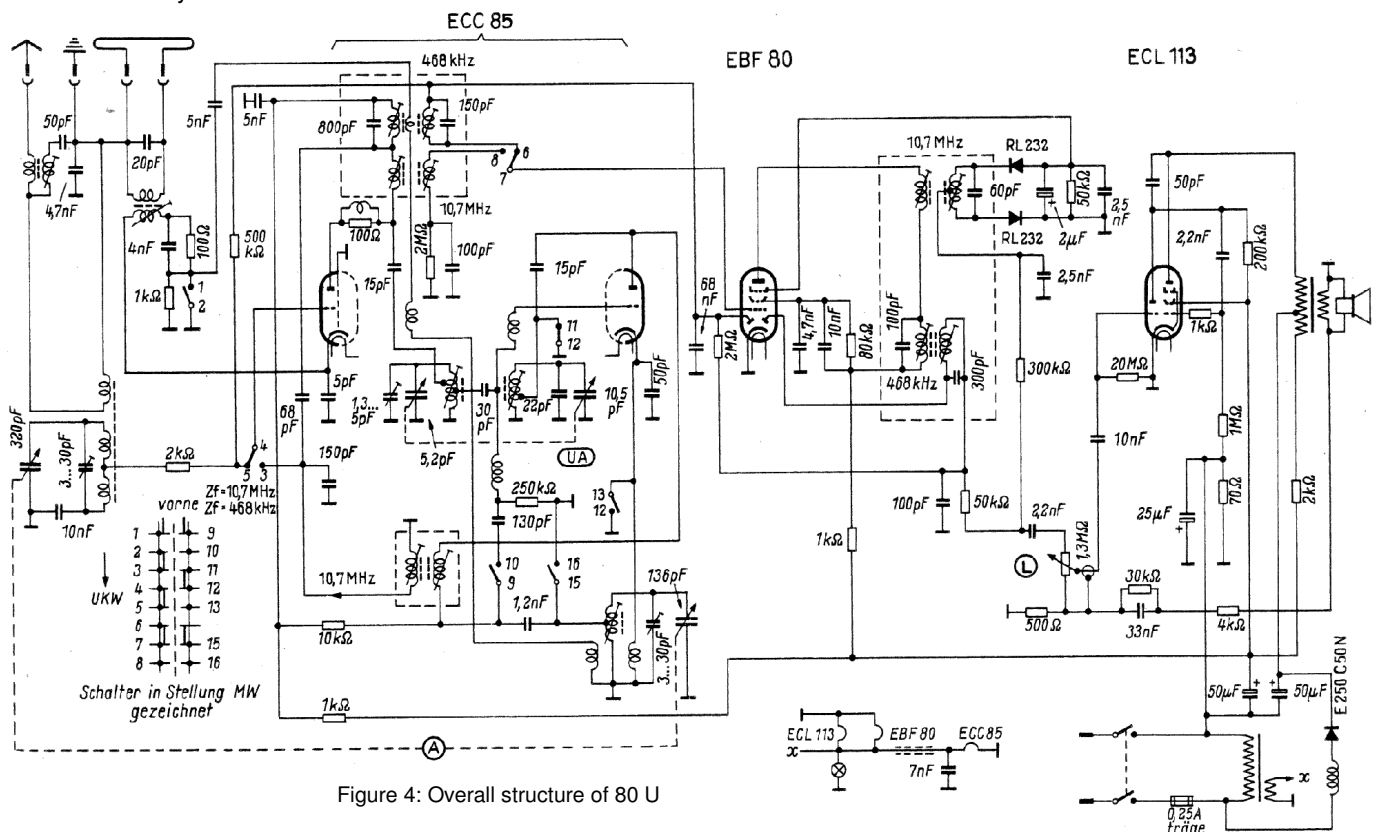


Figure 4: Overall structure of 80 U

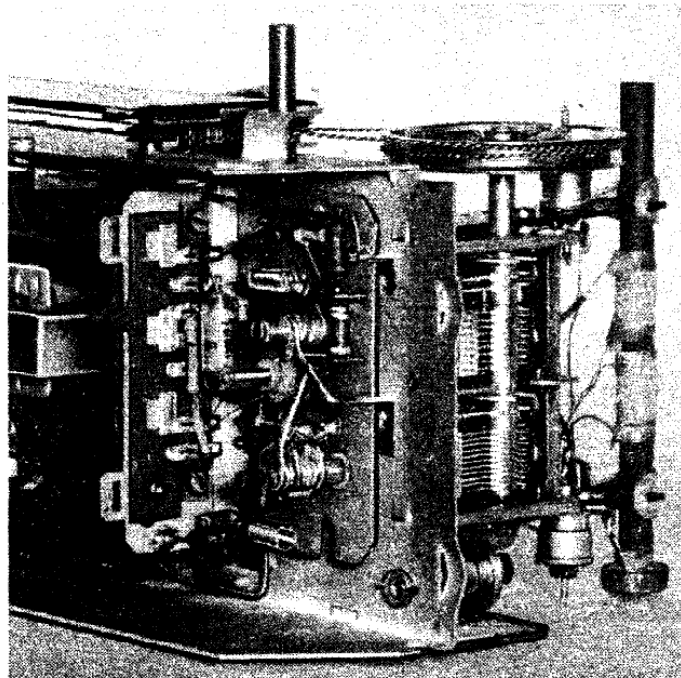


Figure 5: A view of the coils in the opened front end box.

lies in the anode circuit. The 68-pF capacitor, in concert with the 800 pF capacitor (of the AM band pass filter) and the 5-nf blocking cap, effectuates a neutralization of the 10.7-MHz amplification path.

Limiting Stage and the Ratio Detector

The secondary of the second IF band pass filter transformer, with 2Meg-100pF creates a grid-leak bias voltage for voltage limiting at the second IF stage EBF80. The following Ratio detector is equipped with two Germanium diodes and structured in the usual manner. A rimlock tube ECL113 is used in the two-stage Audio amplifier. Hum compensation occurs in familiar fashion with the help negative feedback from the output transformer (the steady-state hum at the feedback network connection to the volume

control amounts to only 2 mV). The choke ahead of the power rectifier prevents HF interference modulation.

Additive AM mixing with a Triode

The AM circuit input method is built on the experience in the construction of additive mixer stages. In principle, the additive AM mixer triode circuit linked to a separate oscillator stage was already used in the Grundig high end and big export radios. In the 80 U, the ECC85-I acts as a gain-controlled mixing triode and the ECC85-II as a separate oscillator with feedback to the cathode (Figure 3). The oscillator voltage (3.6 V amplitude) is injected through a coupling coil to a 1k resistor at the cathode of the mixer stage. Additional coupling with a small secondary coil of the IF band pass filter, which is in series with the oscillator coupling coil, effectuates an increase of the internal resistance of the mixer triode (analogous to the aforementioned VHF/FM-IFcircuit). The 2k resistance in front of the grid prevents high frequency parasitic oscillations. The IF band pass filter (468kHz), situated in the anode circuit, is designed to match the triode internal resistance with a 800 pF capacitor (reduction of circuit impedance).

AGC Regulation with Triode Control on AM

On AM, the AGC regulation voltage is driven to both the grid of the first triode system of the ECC85 and the EBF80. As confirmed by measurements, the gain control of the mixer stage does not introduce disadvantages.

The high mixer gain of the ECC85 system is appropriate to the medium wave band as well. 4.4uV input sensitivity (at 560 kHz) and mirror image rejection of 1:760 (at 560 kHz) are observed. The cross modulation performance of the gain controlled triode is in accordance with the multiplicative mixer stages seen with AGC hexodes.

Ferrite Loop-Stick AM Antenna

The 80 U receiver includes a built-in Ferrite Loop-Stick-Antenna, the core of which holds an input coil. The antenna coupling is highly inductive; the (external) antenna input coil is situated at the outer end of the Ferrite Loop-Stick. Parallel to the antenna coil is an IF wave trap circuit and in the routing to the antenna socket is a series coil for the linearization of the sensitivity over the entire AM band.

Limited Noise Radiation

The oscillator radiation (VHF-FM) reaches a maximum of 10 mV at the antenna input terminals. The propagation of oscillator harmonics is significantly less than 30uV at a distance of 30m. The lead wire inductance of the 20 pF capacitor in the VHF-FM input band pass filter, together with the 20 pF capacitance, creates a wave trap for the oscillator harmonics. Careful attention was paid to effective wire routing, including the band switch in a shielded box, in the mixing section during construction of the device (Figure 5). AM-FM band switching works over a lever system. Photos reveal further details about the construction.

H. Brauns.

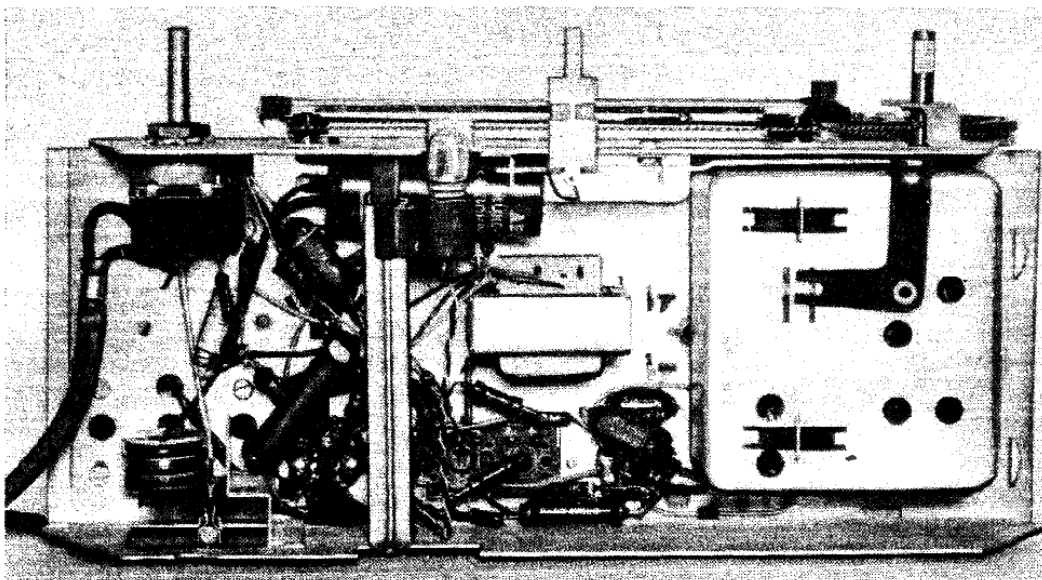


Figure 6: View under the 80 U Chassis, and coupling to the shielded high frequency box to the right.
Original Article by H. Brauns. Original scan in German by Bernard Nagel.

Translation by Yasemin Gocke. English editing by Joe Sousa and Prof. Dr.-Ing Dietmar Rudolph.

- **A few editorial comments.**

Prof. Dr.-Ing Dietmar Rudolph:

If you compare e.g. American and German Receivers also before WW2, you will find that most German radios use much fewer valves than American radios do. In the beginning of radio days the receiver manufacturers had to pay a fee for each tube socket in a set to Telefunken, which then was a leading tube manufacturer and held many important and relevant patents. All manufacturers of wireless sets had join the "Verband der Funk-Industrie" (association of wireless industry) where they got the "Telefunken Bauerlaubnis" (Telefunken permission to build radio receivers). So Telefunken got in 1924 0.30 M for each detector socket, 2.50 M for each tube socket, and additionally 0.20 M if the socket had a spring suspension. (after Günther Abele: Historische Radios, vol 1, Füsslin, 1996, ISBN 3-9803451-4-9, pp.24)

Loewe was the first who produced a combined valve with three systems inside (4NF), so the charge could be reduced because only one base was used. Similar were the tubes from TeKaDe (VT138, VT139). Later on combined tubes were developed.

Another method to save cost are reflex circuits. However, reflex circuits are critical to design and the aging of the tube affects its function much more than this would be for a circuit without reflex.

The Grundig 80U certainly is in accordance with the design from prewar German receivers. Even without paying a fee to a valve producer, the receiver can be produced more cheaply if fewer valves were used, and it can be made smaller. Because in Germany 220V AC is usual, a transformer is mandatory. Otherwise too much power was lost in a bleeder.

FM in the beginning was from 87,5 to 100 MHz. Below 87,5 MHz was the Police band and above 100 MHz there was a Military band. Later on first 100 MHz to 104 MHz could be cleared and after then up to 108 MHz could be dedicated to FM broadcast as international usual.

An explanation of neutralization certainly is helpful, especially since amplification of IF with a triode is unusual.

Neutralization around the mixer certainly means suppression of parasitic oscillations which can occur due to parasitic capacitance and inductance in the setup.

[A clarification of the reference to "Grundig Noise Generator Type 370a, is $4.8 \cdot k \cdot T_0$ " at the start of the article:

Spectral power density of noise is $S(f) = kT$, $k = 1.3805 \cdot 10^{-23} \text{ Ws/K}$ (Boltzmann Constant), T = absolute temperature in Kelvin (K), f = frequency.

Normal power spectral density of noise is $S_0(f) = kT_0$, with units $\text{W/Hz} = \text{Ws}$, where $T_0 = 290\text{K} = 17 \text{ deg centigrade}$ (normal temperature). Normal power spectral density is independent of resistance value.

The actual spectral power density of noise $S(f)$ may be expressed as $S(f) = X \cdot kT_0 = X \cdot S_0(f)$, and X is a factor which describes how much more the actual density is with respect to the normal density. Alternatively, $T = X \cdot T_0$ is called the noise temperature of the noise source.

A noise generator for measuring the noise figure X uses a diode with tungsten filament. When driven with its saturation current (which depends from the filament voltage), the voltage drop at a 50 Ohm resistor is the desired noise voltage. An ammeter for the anode current can be labeled directly with the noise figures X .]

Joe Sousa:

Triode neutralization is used around the first FM-IF stage. This is necessary to keep the triode from oscillating at IF frequencies. The impedance of the 10.7MHz resonant plate load at frequencies below resonance, is inductive. Plate-to-grid capacitance transforms this inductive load below resonance into a negative resistance at the grid. This negative resistance is what might have caused oscillations, when combined with the first IF resonant circuit driving the grid.

Conventional pentode IF amplifiers have no significant Plate-to-grid capacitance because of screen grid shielding, so are usually not neutralized. Nevertheless, the EBF80 IF pentode amplifier uses a very slight amount of neutralization with a capacitive divider in the plate and screen grid supply circuit, to neutralize the very slight amount of parasitic wiring capacitance from plate-to-grid.

The AM mixing triode uses some positive feedback to increase internal plate impedance, and thus increase gain at 468kHz IF. Positive feedback, in this case, is not needed for neutralization of plate-to-grid capacitance to prevent oscillation, because the grid circuit does not have a 468kHz IF tuned circuit might have oscillated. In this

case, the positive feedback increases gain by increasing plate impedance, and it can be thought of as carefully controlled regeneration.

Neutralization around a mixing triode is not needed because the plate load tank circuit is at a very different frequency of the grid RF tank circuit. The inductive impedance at the plate that would be seen as negative resistance at the grid by Miller plate-to-grid capacitance feedback, is shorted out at the grid for the IF frequencies where this feedback would happen. The quenching action of mixing also helps prevent buildup of oscillations.

In a radio with more tubes, much less care is needed with design. Each stage can be made to perform a simple, easily achieved function. In the amazingly elegant design of this radio, Every last performance enhancing trick was used at each stage.

Note that the excellent noise performance of this radio comes from the use of the best VHF triodes (ECC85), as was being done in all the best contemporary FM tuners. Using a dual triode at the front end brought other challenges, but with these were overcome with very good clever design.