Swiss HF-LF receiver E44

Ulrich Fierz HB9AIK/VK2ANI

Switzerland was – as many other countries were – ill prepared for the beginning of WWII; rearmament only began a few years before, communication equipment was early 1930's technology and there was by far not enough of it. Most of it was either bought outright or built under licence. The receivers in use around 1936 were all still TRF designs despite the fact that there was a considerable entertainment radio industry producing a large number of sets – all superhets of course. During the early war years six(!) HRO receivers were bought and used in interception. More HF receivers were quickly requisitioned wherever they could be found, *e.g*. from radio amateurs. In the late 1930's, only after the appearance of products with superior performance such as the HRO, the local industry was tasked with the development and production of new military receivers and radio sets.

Receiver development [1]

Of interest here are two initial design contracts to two leading companies, which resulted in the actual production and issue of new LF-HF receivers. Both are based on the ideas of *J. J. Lamb*, both use the *National* PW-3/4 tuning capacitors and follow the *National* HRO concept to a certain degree.

The first was the E39 by *Autophon AG* **[2]**. This set uses 11 German steel valves and an original *National* dial with a PW-3 capacitor, combined with their proprietary coil drawers. It has a 1600 kHz IF with a crystal filter and only one RF amplifier. The system consists of two units plus a NiFe battery and is very heavy. Ninety nine units were produced and were used in interception and in a few heavy radio sets. It showed excellent performance and was much appreciated by the operators.

Figure 1. The E44 receiver with power supply/loudspeaker unit on top

The second receiver is the E41 by *Zellweger AG* **[3]** which started life as the station receiver in the 'light' radio set FL40 and was also part of the later set KL43 by the same company. It uses 12 K-series battery valves and a *National* PW-4 capacitor, combined with a locally designed linear dial and proprietary coil drawers. Two IF are used: 70 kHz for receive frequencies up to 750 kHz with a tone filter for CW and 465 kHz for the bands up to 60 MHz with a fixed crystal filter. The receiver consists of three boxes (receiver, coil box, power supply) and a battery. It weighs much less than the E39.

Above 3 MHz the sensitivity starts to decrease markedly and the receiver was not suited for interception work but suitable for the use in field radio sets (mostly ground wave and NVIS). Also the procurement agency KTA **[4]** was not happy with the coil drawers, but had to accept them as nothing better was available. An operational drawback was the various 'simplifications', such as the fixed BFO (LSB only) or the combination of different operator functions in single controls. This resulted in the receiver being graded below its actual performance by the users in the field. Still, through its wide use – stand-alone and in FL40, KL43 and M44 radio sets – a total of 327 receivers were produced, issued and used for many years.

The E44 is hatched

As, in 1942, the war did not seem to come to an early end, the lack of sufficient high performance receivers remained an increasing problem. Despite the difficulty of obtaining materials, a new project was envisaged.

Learning from the field experience with the above-described receivers and following developments abroad, the KTA and the military looked to the designs of the Wehrmacht receivers using coil turrets and frequency-calibrated dials, some with excellent performance. Initial requirements were discussed but no contract awarded.

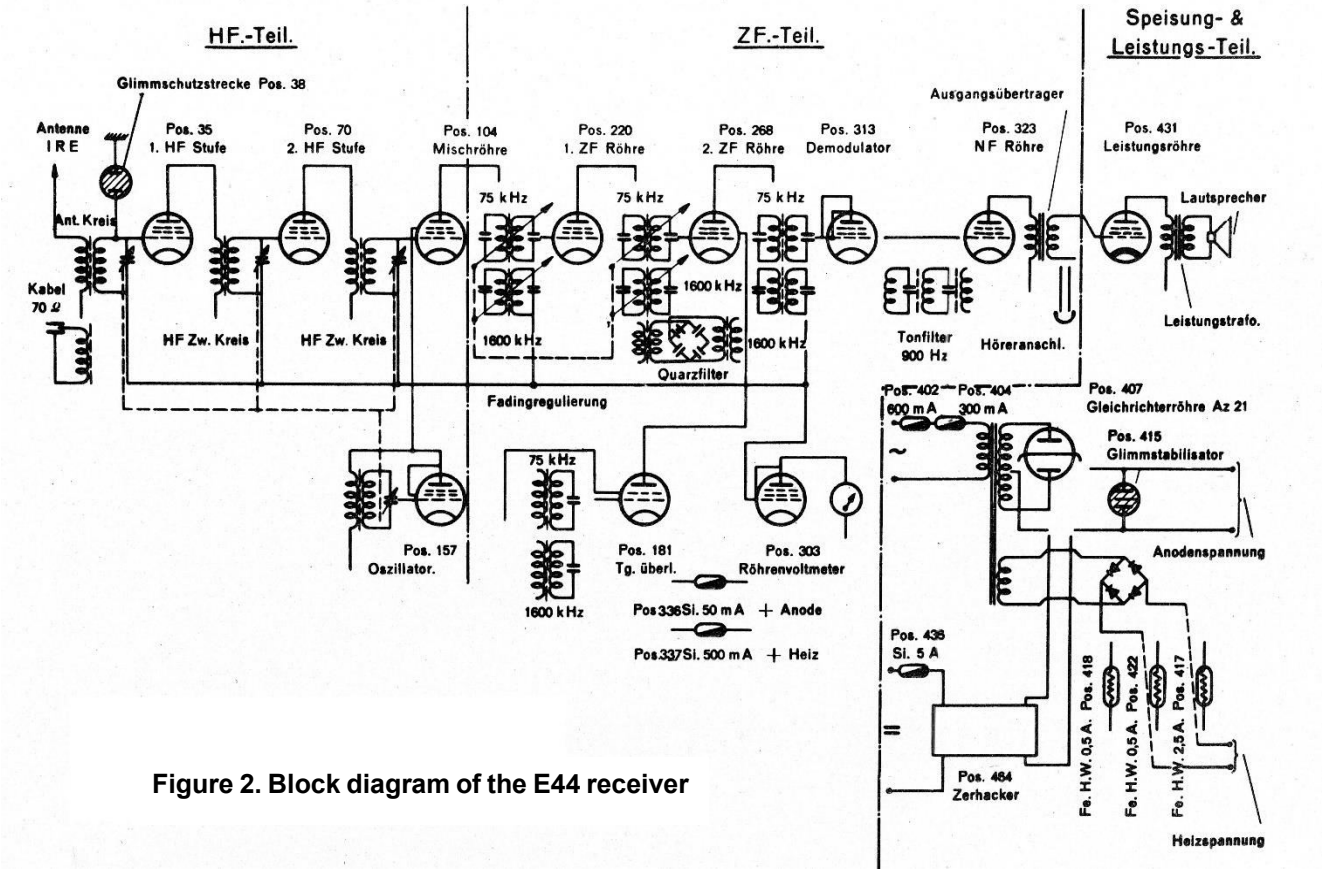


Figure 2. Block diagram of the E44 receiver

At *Autophon* the E39 design crew did not stand idly by and developed around the same time, on their own initiative, the receiver E52 (no relation at all to the German E52 'Köln') using *Philips* loctal valves. At this time, parts and especially valves from abroad were already very difficult to obtain and loctal valves were apparently still available (also used in many entertainment radios of the time–more on that later). The receiver took the KTA ideas into account and uses a coil turret, provides a calibrated dial and a lot of other features. It was presented as an improved successor to the E39 for interception and as station receiver of higher echelon radio sets. Key components such as the four-section tuning capacitor, the complete turret, the RF coils and all gears, *etc*. were designed and mostly manufactured in-house. Most other parts were sourced from local manufacturers.

The receiver E52M was extensively tested and formed the base of the initial contract (May 1944). This called to partially redesign this receiver and manufacture 38 units for an initial system at a price of CHF 7,396 – about £28,000 today. The new receiver was to have much better performance and be more accurate than the E41 and use less power and weigh much less than the E39 or even the prototype E52M. This was the start of the successful E44 project – a receiver said by some to be the most beautiful (**Figure 1**) but also most extravagant receiver ever built in this country.

E44 system configuration [5]

The complete receiver consists of two main units (**Figure 1**). The complete E44 receiver from antenna input to headphone output (24 kg), the power supply E44Z (19 kg) and the LF antenna transformer AT44. The E44Z box also contains an AF power amplifier with speaker, spare parts, headphones, power cables and a wire antenna. In operation the E44Z can be fixed on the top of the E44 (as illustrated in **Figure 1**) to make a compact receiving set. The two main units are contained in what was called a "Panzerholzkasten", *i.e*. boxes made of plywood and clad in aluminium on both sides. This construction, but mostly using steel, was often found in Wehrmacht radios.

Separate items are the two 6V NiFe battery cases (18 kg ea.) which were part of the system but not always used.

Functional concept

The E44 is a LF-HF single conversion superhet using two IF and covering 100 kHz to 37.5 MHz in 8 bands, primarily for A1 (CW) but also A2, A3 and A4 (Hell) emission.

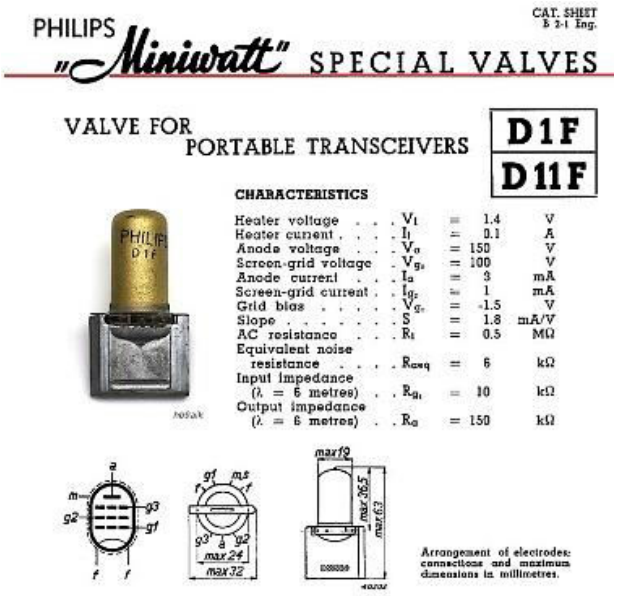
The block diagram (**Figure 2**) shows two RF amplifiers followed by a pentode mixer which is fed by a separate oscillator (triode connection). There are 8 coil sets on the four-chamber turret switch selecting the band, the proper dial and IF chain. The four-section tuning capacitor has three stators in each section (85/120/335 pF) to allow the selection of an optimum L/C ratio on each band. There are two antenna inputs: a 70 Ω coaxial connector and a high impedance banana socket. If the wire antenna is connected to the receiver *via* a 70Ω coaxial cable, the AT44 box is inserted. This box contains a relay and a matching transformer which is automatically switched in for frequencies below 800 kHz while all other bands are fed directly from the cable.

Two IF are used: 75 kHz up to 2 MHz and 1600 kHz for the higher input frequencies. There are two IF stages and a detector (diode connection). Two IF bandwidths can be selected ('narrow' ±2.5 kHz and 'wide' ±5.5 kHz). With the 1600 kHz IF, there is a Lamb crystal filter between the first and the second IF stage while with the 75 kHz IF, a 900 Hz tone filter is used. A tuneable oscillator produces the two beat frequencies, the BFO voltage is coupled to the suppressor grid of the 2nd IF amplifier. AGC is derived from the detector and applied to all RF stages and the first IF valve. AGC can be disabled and then a RF-gain switch is used, providing 5 steps of 20 dB. A separate valve (triode connection) is used as VTVM to drive the S-meter. The meter also allows one to check anode and heater voltages.

The AF amplifier inside the receiver is just a single stage producing output to two headphone sockets. A dual selenium rectifier can be engaged as noise limiter.

Construction concept

The circuit (**Figure 5**) is based entirely on 10 D1F battery pentodes (**Figure 3**) designed by *Valvo/Philips* **[6]** around 1940 for 'portable transceivers'. The D1F is of acorn-type glass construction and is specified up to 50 MHz. Its transconductance is 1.8 mS, exceptionally high for a battery valve, especially as it also has a remote cut-off characteristic. The D1F sports a zinc handle and is inserted 'head-down' into a special bakelite side-contact socket.



CAT. SHEET B 2-1 Eng.

PHILIPS "Miniwatt" SPECIAL VALVES

VALVE FOR PORTABLE TRANSCEIVERS **D1F** **D11F**

CHARACTERISTICS

Heater voltage	V_f	= 1.4	V
Heater current	I_f	= 0.1	A
Anode voltage	V_a	= 150	V
Screen-grid voltage	V_{g_2}	= 100	V
Anode current	I_a	= 3	mA
Screen-grid current	I_{g_2}	= 1	mA
Grid bias	V_{g_1}	= -1.5	V
Slope	S	= 1.8	mA/V
AC resistance	R_i	= 0.5	MΩ
Equivalent noise resistance	R_{aeq}	= 6	kΩ
Input impedance (λ = 6 metres)	R_{g_1}	= 10	kΩ
Output impedance (λ = 6 metres)	R_a	= 150	kΩ

Arrangement of electrodes: connections and maximum dimensions in millimetres.

Figure 3. Edited datasheet for the D1F valve [7]

The layout can best be appreciated from **Figures 4 and 6**. All LF and IF coils are put into 29 adjustable iron dust pot cores with a controlled air gap. Capacitive coupling, combined with light opposite inductive coupling are used in the IF strip; the 1600 kHz filters have coaxial glass trimmers for bandwidth adjustment. All RF/IF switches are ceramic, placed next to the coils and operated through linkages.

The chassis of the E44 consists of two joined die-cast aluminium sections with many screened compartments and removable covers. The left section contains the big turret assembly, the tuning capacitor and the 4 RF valves.

The right hand section includes the IF Amplifier with filters, AF amplifier, BFO, tone and crystal filters and the VTVM. Inside the many compartments a few tag boards are used (some on two levels) and many parts installed point-to-point. The result is not service-friendly at all, repairs are difficult. In an empty rear space is a spares carrier with 10 D1F valves (later reduced to 5) and many fuses.

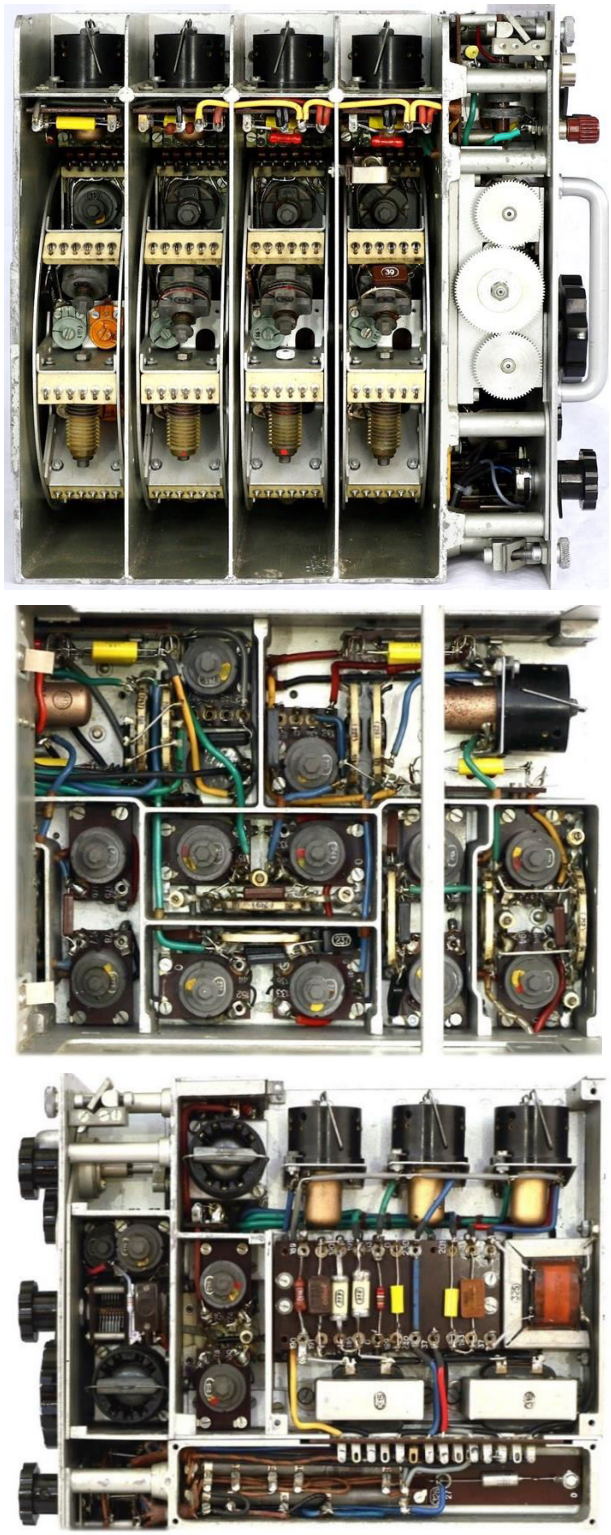


Figure 4. The RF turret top, IF filters centre, BFO, IF stages, detector, VTVM, AF stage bottom; all screening covers removed

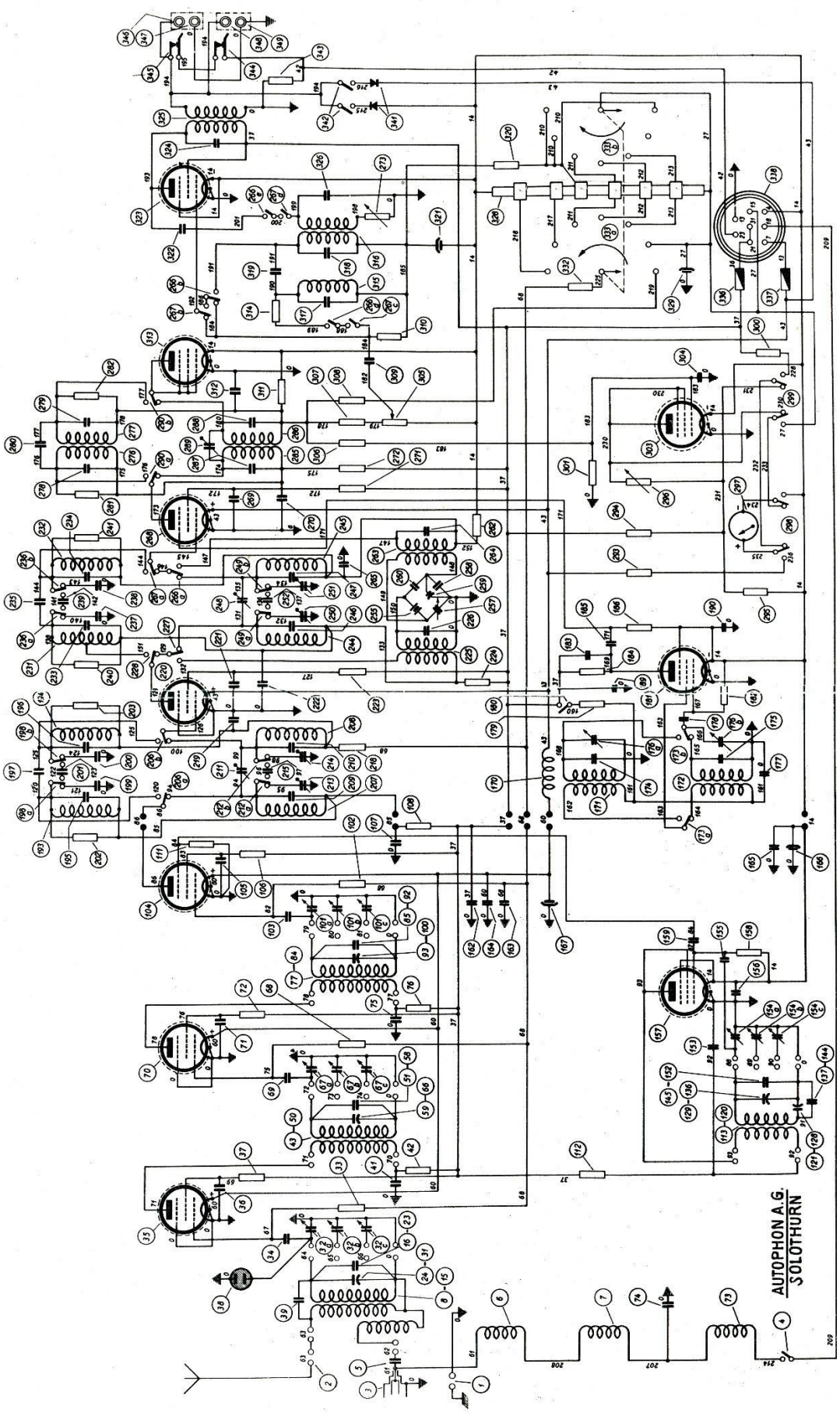


Figure 5. Circuit diagram of the E44 receiver

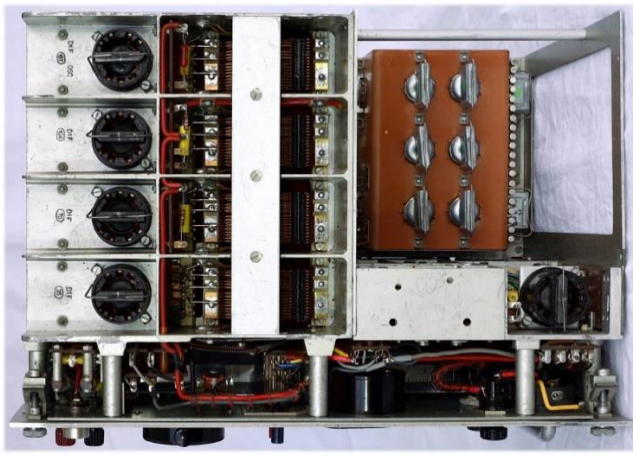


Figure 6. Top view of the E44 receiver

While the actual front panel carries almost no parts, the long dial, the tuning gears, the linkages to the various switches, all the controls, fuses, the power connector and some electronic parts are installed on the front side of the two main units. The dial and the tuning knob provide a logging scale in addition to the frequency markings. There are no dial lights.

The wiring is somewhat unusual, in cable forms and for short direct connections mostly solid 1.5 mmØ PVC-insulated tinned-copper wire is used. Only behind the front panel some 0.8 mmØ wire is to be found.

Great care was taken with the tuning gear and bandswitch/dial drum. The backlash-free tuning gear has a 1:24 ratio and an additional 1:5 fine-tune function, engaged when the knob is pulled. There are 9 (and maybe two more the author could not see) ball bearings for the shafts of the tuning capacitor with its reduction gears and for the coil turret with its drum dial and drive gears. All parts are of excellent quality – maybe the Swiss watchmaking experience shows.

Besides the meter, the front panel features a nice *Revue* 8-day clock (**Figure 1**). Different from, for example, the WS19 radios, the clock was permanently fixed to the receiver and part of it.

Power supply concept

The circuit diagram of the power supply unit is shown in **Figure 9** and the construction can be appreciated from **Figure 7**.

Two thirds of the box contain a conventional chassis with the power supply, AF power amplifier and speaker. A dual-use power transformer takes the AC input or the chopped input from the vibrator unit (**Figure 8**). The latter is a completely encased unit complete with filters and spare vibrator.

The HV supply uses a AZ21 and filter to provide 250 VDC to supply the system and includes a S150/40 stabilizer for the receiver anode supply voltage. The LV supply uses a selenium rectifier, filter and barretters to supply heater current to the receiver (0.5 A) and, when AC power is used, to trickle charge the 6-volt NiFe battery (0.5 A) or solely to charge the battery (2.5 A). To save power when operated from the battery, the EBL21 heater is not activated and headphone operation only is possible. Battery voltage is then used directly through one barretter for the heaters in the receiver.

The remaining space in the box is used for accessories and spare parts, there is also a hidden drawer containing valves that is only accessible with the power supply removed.

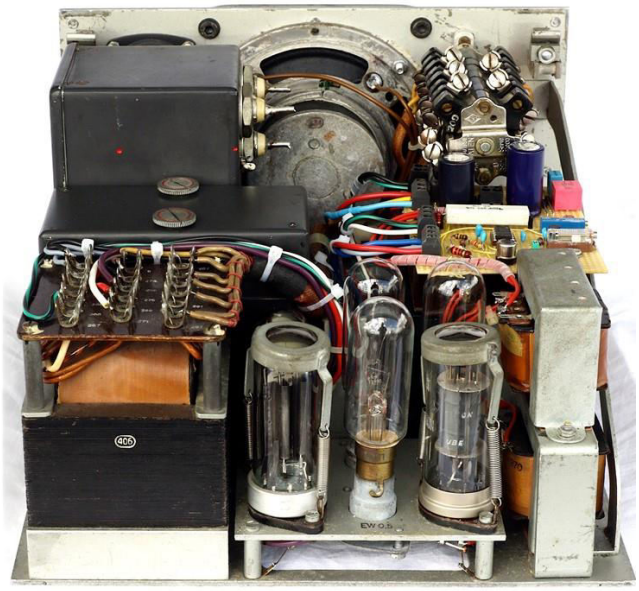


Figure 7. Construction of the power supply unit/loudspeaker. The vibrator unit is located on the left-hand side in the dark grey enclosure

Figure 8. The vibrator unit

Production of the E 44 system

Actual production started in 1945 and the last units were produced in 1951 to a total of 138 sets. However, the airforce ordered in parallel another 86 receivers known as E45. These were essentially the same design but with the addition of a ‘selcal’ unit to be used as an ‘alarm receiver’ mainly in AA units.

While sourcing of electronic parts in the late 1940’s was getting easier, procurement and production starting in 1944/45 presented serious challenges.

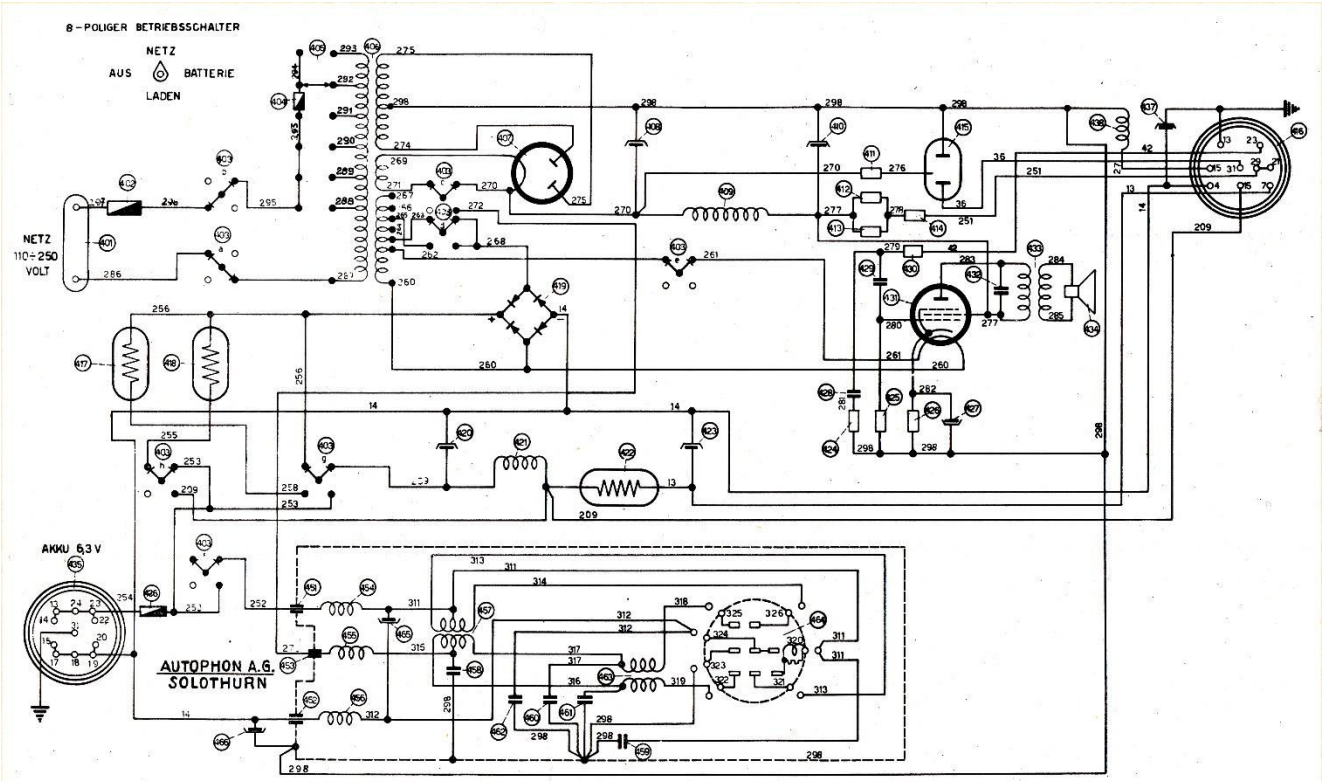


Figure 9. Circuit diagram of the original power supply unit E44Z

Search for (locally sourced) components

For a start, the Swiss time piece was easy – *Thommens* [8] was the 'standard' supplier of '*Revue*' clocks for military radios and larger manual switchboards in the 1940's and 1950's.

The capacitors were no problem either, *Condensateurs Fribourg* **[9]** had been producing mica, paper and electrolytic capacitors successfully for many years. They were found in almost all locally produced radios before and after WWII. Parts from this company were sourced for the E44.

The sources of the resistors are unclear. There are different types being used and the markings of value or of a manufacturer were removed and replaced by a stencilled circuit diagram number. A few colour-banded carbon composition units are present, but most are carbon film units of varying quality from more than one manufacturer. It looks as if anything acceptable was used at the time.

The supply situation for valves was very difficult and uncertain. Finally the choice fell on the special all-glass pentode D1F made by *Valvo/Philips*. Despite the fact that they were located in the Hamburg area and radio valve production was stopped in 1940 the company committed to supply the required quantity. As the main factory building remained almost undamaged, they could restart limited production quickly and the data sheet (**Figure 3**) is dated May 1945.

The 1600 kHz crystal for the filter was sourced from the US; it was made by *Cambridge Thermionic Corp. (CTC)* **[10]**.

The vibrator for the E44Z appears also to have been difficult to find. The fairly large 6-volt units purchased are Swedish, made by *Graham Brothers A/B* **[11]**.

Local valves in wartime [12]

Quite interesting is the history of the sources for the valves in the E44Z. The design called for a HV rectifier, an audio power pentode, a voltage stabilizer and three barretters. Who could manufacture and supply them locally?

The manufacture of entertainment radios in Switzerland was never stopped and new models came out every year, but the valve problem caused serious bottlenecks. Local activities were started and two companies invested in facilities to manufacture a set of key **[13]** *Philips* loctal valves: *Brown Boveri & Cie AG (BBC)* **[14]** and *Albiswerk Zürich AG (AWZ)* **[15]**. While *AWZ* redesigned them as metal valves and did not get past initial prototype mass production, *BBC*, who already made small valves of various kinds, used the glass design and was able to manufacture larger quantities. These are, for example, reported to have found their way into locally made *DESO* radio models **[16]** originally using side contact valves. In the E44Z, the choice was made to use a EBL21 and a AZ21 which could be replaced by a PDD1 and a GG1 made by *BBC*. In the end that was not needed – when production of the E44 started, *Philips* was able to supply the originals.

Neither of the two companies produced cold cathode valves, so another source was needed for the stabilizer. There was one company producing special cold cathode trigger valves: *Cerberus GmbH* **[17]**. Starting in 1943, *Cerberus* was custom manufacturing a voltage stabilizer needed for an airborne radio and now another type, S150/40 with an octal base, was produced for *Autophon*. Only much later did the company offer a range of stabilizers, but the E44Z problem was solved and this valve used.

For the barretters, the local telecom companies earlier approached a lightbulb manufacturer: *Luxram/Licht AG*. While they did dabble in valve manufacture in the 1920's, they did not then manufacture any. However, they now produced a range of barretters mainly for the military and some following *Osram* designs, and all the units in the E44Z were sourced from there.

E44 No. 141 and E44Z No. 141

The authors system (serial number) No. 141 (**Figure 1**) was accepted by the KTA on July 29, 1946 (date stamp). This might well have been the second run, but the author does not have a record of the numbering used. It appears to have been used last by air force personnel as indicated by some pencil marks above the dial. The system components list (used to check completeness when issued) found inside was last reprinted in 1971. No AT44 is listed on it.

The receivers were disposed of in 1984 after sitting on some shelves for years. As usual, the clocks had been removed from the sets – just the mounting screws left in place. The accessories, spare parts and operator manual were left inside but there was no AT44 and no batteries with the set when it was obtained by the author.

In 2001, while preparing for a show featuring working exhibits, refurbishment of many sets including this E44 was undertaken. Unfortunately this last receiver could not be completed in time. It remained partly disassembled, packed into boxes until now. Lockdown brought it back to life.

Refurbishment of the receiver unit

Two rare items needed attention before starting: the D1F valves and the front panel clock.

Sufficient tested D1F were found, some are D11F (version without handle) earlier mounted by MOD maintenance into salvaged handles. Even a few unused valve sockets were found and one taken to test the valves. The black clock with the proper support plate was acquired too, almost the perfect version – 100% if it had a fine chrome ring around the dial (according to the pictures in the manual). It should be noted that the luminous paint is lightly radioactive (γ<0.5 mrad/h @ 10 cm **[18]**). These questions settled, work could proceed.

The common yellow *Fribourg* paper capacitors are known to be leaky and were replaced back in 2001, but it was now found that one type of carbon film resistor was a long way out of value and needed replacement as well. Not all could be reached, removal of the 75 kHz coils to change the damping resistors would require disassembly of almost the entire IF filter section. The countless mica capacitors were all left original pending the test. There were a few old repairs to be cleaned up and one broken IF coil repaired and rewound. 520 turns of 0.1 mm wire; lucky the author bought a manual coil winder from China some time ago.

The tuning is as smooth as ever, the bandswitch/dial mechanism and the linkages all work fine. No wear was discernible on the parts and the grease in the bearings not even dried out. Just very light lubrication was applied. All switch contacts were carefully wiped with contact cleaner. The volume control needed replacement. Left in place were the meter potentiometer (cleaned, 5kΩ log) and two further internal units, placed so that any replacement would be a major operation.

The noise limiter, directly on the headphones output, consists of two biased selenium rectifiers and a switch and should limit at 2 Vrms. The switch needed replacement and the new limiter is a series combination of a BAX43 Schottky diode + 2.7-volt zener diode in each direction.

All the fuses were full of verdigris, two fuse holders were infected and all needed replacement.

The D1F have a problem with the cement used to fix the valve into the holder. It expands slowly around the rim, probably due to humidity, and pushes the valve up. Two valves were found where this had lead to a crack below the rim as the glass below still stuck to the holder. The visible excess was removed on all, hopefully to relieve the strain.

Refurbishment of the E44Z

Most of the work on the E44Z was done in 2001, removing the wiring, capacitors and all the battery functions. It was rewired and a voltage regulator for the receiver heaters inserted. These days the author would not proceed in the same way, but there it is. Unfortunately also, the regulator was too large and interfered with the hidden spares drawer.

A new solution was selected to overcome the known heater problem in the receiver. The D1F are fed in a 2x5 series/parallel arrangement with a 500 mA barretter and the operator manual states, should any function not work, you have to "*turn off the receiver immediately*". Why? If the heater of any D1F fails, the remaining 4 valves in the group will share the 500 mA and the heater voltage will go up, eventually taking a second D1F and then the remaining valves in the group will fail fast. The D1F now being rare, there needs to be a safer method to prevent such a disaster.

The author's new circuit (**Figure 10**) has a 500 mA current source based on a LM317K and overvoltage protection that shorts the heater circuit with a 2N6401 SCR. If one D1F fails, the heater voltage will go up by more than 300 mV and a LM393 comparator is used to detect a 200 mV rise and so trigger the SCR. Both current and trip voltage are adjustable. The circuit was built on a perforated board (**Figure 11**) and fixed on top of the HV capacitors and a heat sink occupies the space of the former LV capacitors. This version does not obstruct the hidden spares drawer.

The HV supply and the AF power amplifier circuits were restored to original configuration in 2001 and the selenium rectifier, the barretters and the screened vibrator unit left in place – unconnected, just as 'decoration'.

Conclusion

Tests on the receiver concentrated on the 1600 kHz IF and the HF bands using it. Aligning the narrow/wide bandwidth IF strip turned out to be rather complicated but finally the mandated performance was achieved. HF sensitivity was also as described and the receiver was ready for 'service' in the author's small museum display. An interesting project and a beautiful receiver. It will continue to function, likely for more years than the author – at least as long as there are working D1F.

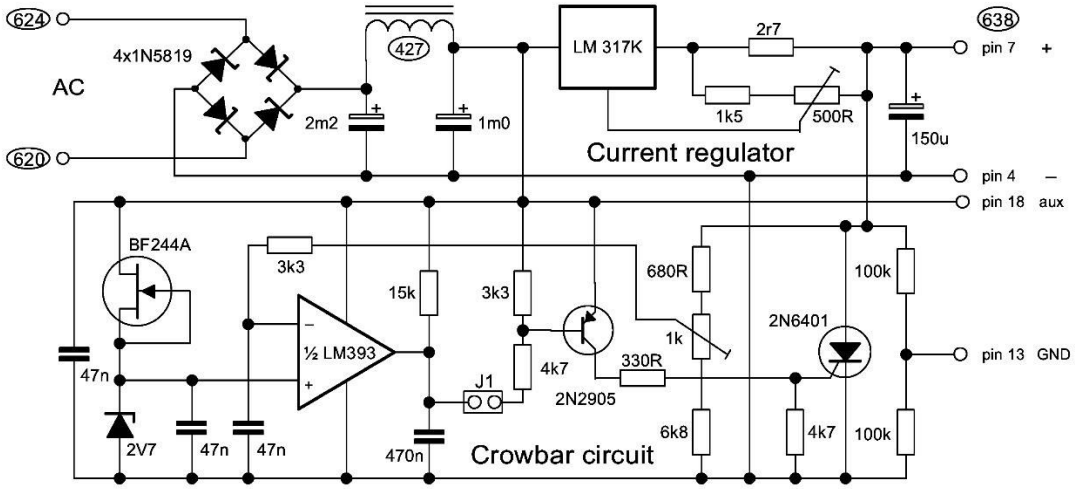


Figure 10. Circuit diagram of the valve heater current regulator

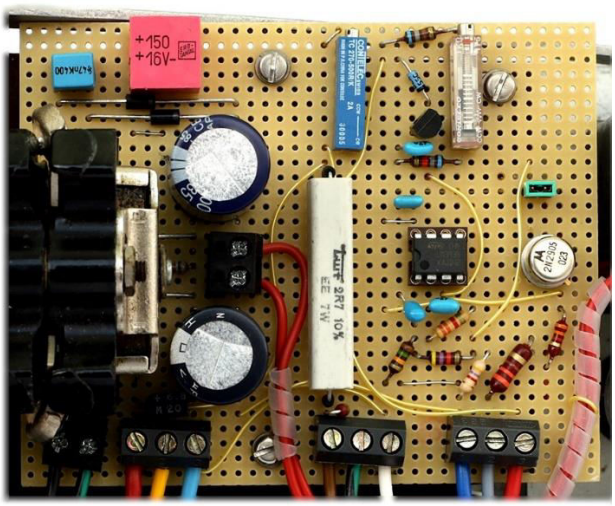


Figure 11. Layout of the current regulator

Notes

1. "Das Fernmeldematerial der Schweizer Armee seit 1875", 7. Folge, "Die Empfangsgeräte", Col. Rudolf J. Ritter, dipl. Ing., 1992, Bundesamt für Uebermittlungstruppen, (Communication equipment of the Swiss military since 1875, Vol. 7). Also "Technisches Reglement Nr. T 180d", "Die Empfangsgeräte", 1945, Swiss Army (an EMER on all Rx then in use).
2. Autophon AG, Solothurn, manufacturer of telephone, PABX and wireless equipment incl. entertainment radios.
3. Zellweger AG, Apparate- und Maschinenfabrik Uster, Uster. Well known for its electronic equipment for textile production and as manufacturer of telephone and wireless equipment.
4. Kriegstechnische Abteilung der Armee, Bern. The agency was part of the military, headed 1940 by Col. Robert Fierz, a relation of the author.
5. "Empfangsanlage E 44", "Revisions-Anleitung", Autophon AG, 1945, (receiving system E 44, maintenance manual). This original manual combines description, operation and comprehensive alignment and maintenance instructions.
6. Philips Valvo-Werke GmbH, Zweigniederlassung Hamburg, Hamburg-Lokstedt, D.
7. Edited from an "Internet Archive" (archive.org) copy and photograph by the author.
8. Thommens Uhrenfabrik AG, Waldenburg. Manufacturer of "Revue" watches. A separate branch also produced cockpit instruments for the air force.
9. Condensateurs Fribourg S.A., Fribourg. Leading manufacturer of a wide range of capacitors.
10. Cambridge Thermionic Corp., Cambridge, Mass., US.
11. Graham Brothers A/B, Stockholm. Primarily a leading manufacturer of elevators and their controls. Producer of electromechanical components.
12. "Schweizer Elektronenröhren 1917-2003", Eduard Willi, HB9YQ, 2005, self-published. (Swiss electron valves 1917-2003). The singular reference work on this subject.
13. BBC made TH1 (ECH21), PDD2 (EBL21) and GG1 (AZ21), AWZ also EF22 copies.
14. AG Brown Boveri & Cie, Baden. Large company in the HV energy production and distribution sector. It then had a growing RF business, building e.g. (broadcast) transmitters, mostly proprietary RF (power) valves and rectifiers of various sizes.
15. Albiswerk Zürich AG, Zurich-Albisrieden. Manufacturer of telephone, switching and wireless equipment (incl. entertainment radios). Production of military radios, partly under licence from Telefunken.
16. For example: Deso, Dewald & Sohn, Deso AG, Zurich. Models e.g. 451B or 452C using a ECH21, ECH21, EBL21, AZ21 configuration to replace ECH4, ECH4, EBL1, AZ1.
17. Cerberus GmbH, Bad Ragaz. Pioneering producer of ionisation chamber fire alarms and special cold cathode valves for the required trigger amplifiers.
18. Measured with a SV500 radiation meter using the γ-sensor (ex-Bw, Eberline Instruments, Erlangen). Note: a small lead disk in front of the clock can be used as a screen if required.

Company names and locations are given as they were during WWII.

All photographs and the scans from the original manual are by the author.

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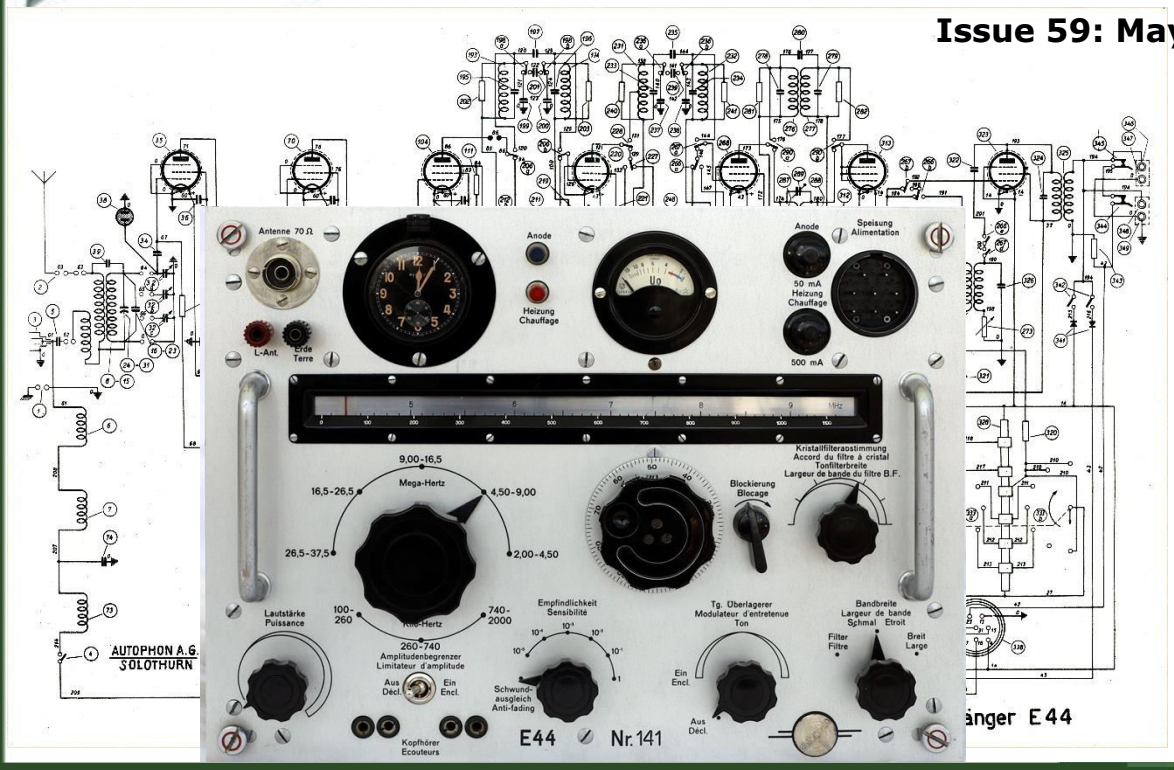

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