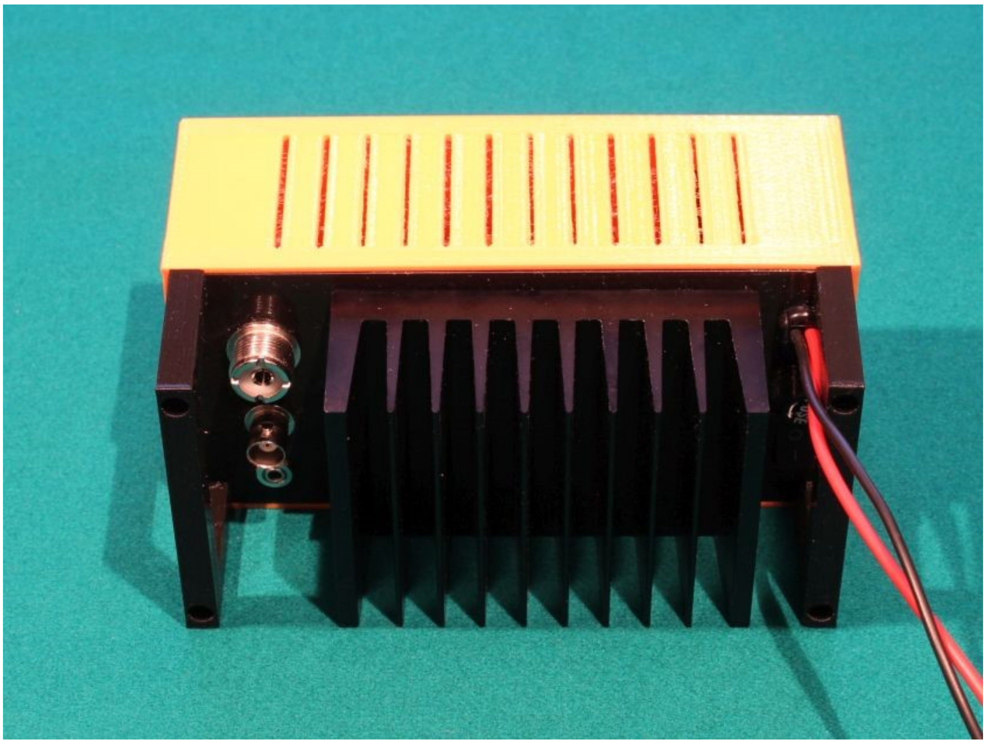
50 W HF amplifier

English version



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Motivation

In February of 2018, I published some detailed instructions[1] in German about a DIY amplifier based on a bargain Chinese kit. Since then I received a lot of feedback and comments. These included the request for an English version of the instructions or parts thereof.

With this document, I address the issue, but ask for the reader's forbearance that I don't translate my original instructions in full length. Rather I provide guidance for key issues and actions, which shall help prospective builders to avoid pitfalls and succeed with their project. In doing so, I especially refer to the figures ("Bild") depicted in my original document.

Accordingly, this document has to be read in conjunction with my original document in German, which is published on my website[2]. I strongly advise to read the document at hand in its entire length before starting to build the amplifier.

Building the kit

The kit[3] underlying this whole project is available for less than 20 €. The PCB (Fig. 1) is of good quality and in a handful of shipments I had no missing parts, sometimes there even are a couple of parts in excess. Not included in the kit is the heat sink which is essential and strictly no powered test may be performed without one. Choose your preferred model and vendor, but if you intend to use my 3D printed enclosure design[4] (see below) the heat sink must not be wider than 110 mm and higher than 80 mm. The model which I use[5] provides a heat conductance of 1.5 K/W and I consider this adequate for the PA. I provide a pattern (Fig. 3) for drilling the heat sink on my website.

If not directly soldered to the PCB, one will also have to come up with plugs for the provided sockets (PTT, optional: ventilator). I made mine by cutting the fillets from some BKL plugs (Fig. 2).

Soldering the parts is quite straightforward and takes about 2 to 3 hours of time. Please follow the schematics in figure 21 and the traces on the PCB. Yes, there are many SMT-parts but none of them is very difficult to solder. There are some building instructions on the internet including YouTube videos so I confine myself to those actions, which are not obvious or covered somewhere else.

The PCB as provided includes four other parts, which will be needed later on for building the two transformers T1 and T2. These have to be cut from the PCB at the marked (figure 4) positions before any soldering is done. These parts are the sides of the transformers. The have to be soldered to the respective metal tubes provided in the kit. Use a soldering iron with 30 to 60 W and a wide chisel (5-8 mm). Soldering flux helps a great deal. Two sides and two corresponding tubes make up one transformer. Try to have the sides as parallel as possible. It is advisable to wind the transformers only after they are soldered to the PCB.

All parts are soldered to the top side of the PCB. For the relay this implies to bend the pins (which are intended for through-the-hole mounting) 90° sideways away from the body of the relay.

Do not solder the two IRF530 transistors, R4 and R5 at this stage. If you add R6 (see Annex A, very advisable) don't solder as well. These parts will be added only after the PCB and the transistors are attached to their final positions on the heat sink.

The transformers T1 and T2 are classic style with a primary and a secondary winding, where one side is center tapped. This center tapped side is not wound with wire but is provided by the metal tubes soldered into the structure. For those style of cores one turn is defined as going through one tube and returning through the other. Accordingly the metal tubes count for 0.5 turns only (see schematics, Fig. 21).

For T1 the other side is wound with 2 turns of the provided wire. Starting from one of the small solder pads to the left side of the transformer (check with Fig. 6) the wire is run through the corresponding tube, back through the other tube (1 turn), once more through the first tube and finally back through the second tube again (2 turns). Now the wire is cut to length, the isolation removed and each end is soldered to one of the pads.

T2, the larger of the two transformers is wound very much the same, but with 3 turns and the wires soldered to the pads on the right side of the transformer.

The choke ("INDUCTOR" in the schematics, Fig. 21) is built with two turns on a 2-hole ferrite core, identical to the core of T1. There is a short length of enameled copper wire provided in the kit, but I prefer to use some stranded wire with a thicker isolation. Check with Fig. 12.

After all parts (exceptions: IRF530 and R4 to R6) are soldered, the PCB is mounted directly to the heat sink using short M3 screws. Before tightening the screws, the two rubber isolating pads for the transistors have to be put in place, holes centered with the drilled holes for the transistors.

Next prepare the two IRF530. They have to be handled with some care, as they are ESD sensitive. So try to keep them, yourself and the soldering iron on the same potential, for example by frequent grounding. Ovoid the mistake I made with my first kit, when I bent the pins of the transistors down to PCB level immediately after they left the body. This way they crossed other traces with different potential on the PCB with little to no distance – not good! I advise the following procedure: Keep the pins straight until they are over the beginning of the respective soldering pad, then 90° down and back 90° to the original direction at the PCB level for the length of the pad. Cut at the end of the pad. This should be achieved by bending down (which is the metallic side of the body) 90° approx. 1 mm after the thickened part of the pins end and back 90° to the original direction already 1 mm further on. Always bend all three pins together with suitable pliers.

Insert the white isolators in the holes of the transistors and tighten them to the heat sink while aligning the pins to the pads on the PCB. If everything is in place, cut the wires at the end of the pads and solder them well to the PCB.

Only now solder the feedback resistors R4 and R5 and the impedance matching resistor R6 (see Annex A). Solder the power leads and the HF-Input ("IN") and HF-Output ("OUT") connectors. For the later I prefer to solder short pieces of RG 316 (see Fig. 5) as I will use them to connect the filter-PCB later on anyway.

The kit is now finished. Before performing the smoke test, check thoroughly for shorts and perform a detailed visual inspection.

The following checks are best done with a current-limited supply at 12V and set to a maximum current of 2 A. If no current limitation is available insert a high power 10 Ω resistor in the power line and monitor the current.

Terminate HF-out with an adequate dummy load (better save than sorry) and leave HF-in open or, better shorten it.

Now check the jumpers. JP1 must be set in order to bypass the filter-PCB. The PTT jumper is left open for the very first test. PTT is low-active and will later be triggered by the transceiver.

Apply power. There should be no significant current drawn. Now set the PTT jumper. You should hear the relays beeing activated and the current should read some tens of mA.

Next adjust the bias for the transistors. This voltage is best measured between the large soldering pad to the left of T1 (see Fig. 6) and GND. It is adjusted with the trimmer VR1 and should be set to a value of about 2.7 V. The current drawn by the amplifier should now read about 20 to 25 mA. Check the transistors, R4, R5 and R6. None of them should get hot, even after a couple of minutes.

After completing the idle test successfully several useful tests can be performed, depending on your interest and equipment. One of those is measuring the input impedance which should be better than 2:1 on all bands from 40 m to 15 m and only slightly higher on 80 m if you added R6.

For checking the amplifier at work a suitable input source and a power supply capable of delivering about 8 A at 13.6 V is necessary. Also keep in mind that a dummy load, attached to the HF-output and capable of absorbing up to 50 W is strictly necessary now. It is highly recommended to use a pure sine signal, 50 Ω impedance and adjustable power from about 0.5 to 2 W for input. Frequency is not very important, but starting in the 20 m band might be a good idea. If there is no suitable test source available, most transceivers in "Tune" mode should do. Start with 0.5 or 1 W and frequently check the current to the amplifier as well as the temperature of the transistors and the resistors R4 and R5. If you do have the equipment (e.g. Oscilloscope) monitor the output, but be prepared to see some non-sinus wave forms.

Low Pass Filters

The amplifier without any suppression of harmonics does not qualify for operation under most legal systems (like FCC Part 97). It has to be followed by (a) suitable Low Pass Filter(s), before any signal may be radiated by an antenna.

In chapter 3 ("Aufbau der Tiefpassfilter") I present suitable 7-element Chebyshev Filters for operating from 40 m to 20 m. I designed a PCB for 2 filters including the relays to switch those filters in and out (Fig. 8). The filter PCB has the same dimension as the amplifier PCB and can thus be stacked on top and mounted with the same screws (M3 x 35 mm). It runs on the same 12 V power supply as the amplifier and is controlled manually by a simple 2-way switch. In case more filters are needed, two or more of the filter PCB can be stacked on top of each other. Connect either "A" or "B" to the "+" pin in order to select the respective filter. If none is connected the HF-signal bypasses both filters.

The PCBs are double sided for through-the-hole soldering of the parts. The exact parts values and a schematic (Fig. 7) for 40 m/30m and 20 m filters are given in the original document. As are the number of turns on Amidon T68-6 cores to wind the required inductors. The capacitors should be high quality like mica-capacitors. From my website Gerber-files for the PCB can be downloaded or alternatively I provide pdf-files for etching them according to the toner-transfer or some other method.

Measured and published data for the filter characteristics confirm that the low pass filters successfully suppress harmonics and keep the impedance at 50 Ω.

Enclosure

A bespoke enclosure for the amplifier and one filter PCB was designed (Fig. 11). The 3D model is available for downloading for private use[4]. Such an enclosure can be printed on any 3D printer. The design offers very convenient mounting and servicing of the electronics, especially since all connections are fitted on the back plate (Fig. 13).

A 3.5 mm audio plug is connected to the PTT on the amplifier, so T/R switching can be controlled by the transmitter via a standard audio cable.

The enclosure includes protective clamps for the connections on back side and spacers between amplifier and filters. M3 nuts on the inside are used together with screws to tighten the back plate with all the electronics to the protective hood. See figures 12 to 14 for instructions how to put the parts together.

There is on ON/OFF switch situated at the back as well as fuse holder (use 10A fuses). A switch with ON/OFF/ON positions can be mounted on the front side (drill/cut a hole according to your part at hand) to activate the suitable filters for the bands in use.

Measured data

Chapter 6 ("Betriebsparameter") deals with some measured data for the finished PA.

Table 1 shows the most important parameters, measured with 2 W of input signal power and a supply voltage of 12,8 V. The gain is between 12 and 13 dB and the efficiency something between 40% and 45%.

Harmonics suppression (Table 2) is (with the possible exception of the 3rd harmonics for the 20m band, where the antenna and/or tuner get a job) sufficient for interference-free transmissions.

The handling of the amplifier is rather straightforward. Connect HF-in (from the transmitter), HF-out (to the antenna), PTT (from the transmitter, typically some ACC port which has to be active low) and power. Select the filter according to the band you want to work and power on.

The PA must be run into a SWR not significantly exceeding 2:1.

At the end of my original document I present some modifications and future ideas:

Annex A

Measurements and comparisons to comparable amplifiers imply that there should be a resistor of about 18 to 22 Ω and capable of withstanding at least 1 W soldered at the position "R6" (Fig. 20). However in the kits I built there was never such a resistor included, so I had to buy this one separately.

It is only with this resistor present, that the imput impedance of the PA gets 2:1 or better. So this modification is highly recommended.

Annex B

Sometimes the IRF530 included in the kits seem to be of minor quality. You might want to exchange them with original parts bought from your preferred dealer.

Annex C

Replace the IRF530s by one power MOSFET like the MRF186. The amplifier PCB is ready for this, but the values of R4 to R6 probably have to be modified and the choke changed to 1 turn.

I have not done so until now, but this modification is top of my list and I will report on my website as soon as I have built and tested such a modification. I expect this to bring the PA significantly closer to 50 W (maybe at some slightly higher supply voltage). The downside is, that a MRF186 will cost at least about 10 €, which – in respect to the original kit – significantly increases the cost.

Annex D

This annex deals with using more than one filter PCB. Basically these PCBs can be stacked and serially wired. Thus it is easy to include more bands and potentially automate the switching process. Anybody step forward?

Annex E

In this annex some ideas for modifying the connectors and including status information are presented.

It might be a good idea to have a LED on the front panel indicating power on and another one showing when the amplifier is activated (TX). For the later pin 1 of the relay on the amplifier PCB could be used, together with a series resistor of about 760 Ω.

Annex F

This is a bill of material ("Materialliste") for all parts used in the PA. It is also available in extended form for downloading from my website[6]. However the quoted sources serve predominantly the German speaking countries, so they might not apply for your area.

All in all this PA can be built for slightly less than 50 €, where a significant part of the cost has to be attributed to the ferrite cores and the mica capacitors. Maybe there is the most potential to reduce cost even further.

Bezeichnung	Art.Nr. Conrad	Art. Nr. Reichelt
DIY Kits 70W	-	-
Heat sink		V 7331G
Resistor 22 Ω/2W	1474539	2W METALL 22
RG-316 coax cable	1179842	-
Switch ON/OFF	1587515	WIPPE 1801.1146
Switch ON/OFF/ON	1587513	WIPPE 1808.1103
Fuse holder	1587496	PL 126001
Fuse	1576515	TR 10A
Strain relief		KAZU 42
3,5 mm stereo-connector		LUM KLB 4
BNC-connector	1564888	UG 1094U
PL-connector	1579410	SO 239 SH
PCB for LPF	*www.aisler.net* *www.itead.cc*	
Amidon-cores T68-6 (6x)		T 68-6
Enameled copper wire 0,8 mm	605604	KUPFER 0,8mm
Relay 12V, 2 states (2x)	629500	HFD2 12V
Diode, 1N4148 (3x)	564851	1N 4148
Connector 2 pol.		PS 25/2O W
Connector 2 pol.		PS 25/2U W
Connector 3 pol.		PS 25/3O W
Connector 3 pol.		PS 25/3U W
Mica-capacitor different values		CY 22-2 xx CY 22-3 xx

1 *http://www.oe1cgs.at/wp-content/uploads/2018/02/50W-HF-PA.pdf*
2 *http://www.oe1cgs.at/50w-hf-verstaerker/*
3 Many sources. I bought from and can recommend: *https://www.aliexpress.com/item/DIY-Kits-70W-SSB-linear-HF-Power-Amplifier-For-YAESU-FT-817-KX3-Ham-Radio/32807365037.html*
4 *https://www.thingiverse.com/thing:2768290*
5 *https://www.reichelt.de/profilkuehlkoerper-75x100x40mm-1-5k-w-v-7331g-p22279.html*
6 *http://www.oe1cgs.at/downloads/*