Advanced 80m-ARDF Receiver – Version 4

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This is a slightly abbreviated translation of the original document in German 'Ein komfortabler 80m-Peilempfänger Version 4'

Conceptual Overview

The 80m-ARDF-receiver described in this document consists of two parts:

- A single conversion receiver with 460 kHz IF and product detector.
- A controller and user interface using an Atmel-Microprocessor, LCD-Display und rotary encoder. The operation is very similar to my 2m-receiver.

Highlights:

- User Interface is a rotary encoder and LCD-display
- Frequency controlled by processor
- Stores up to four frequencies
- Automatic attenuator
- Estimates distance to fox
- Shows current fox, time left for this fox, warns n seconds before end of transmission
- Stopwatch
- Shows battery voltage, low voltage alarm

The receiver is built into a tin-plate box of 16x5x3 cm. The ferrite rod and the electrical antenna – a piece of tape measure – are mounted on the top. On the front side from top to bottom are the rotary encoder, a toggle switch (Attenuator-Operate-Menu) and the display. The Forward/Backward-switch sits on the back, the phone-jack at the bottom.

The receiver is held in the right or left hand. The thumb operates the rotary encoder and toggle switch, the index finger the Forward/Backward-switch. The ferrite rod points in the direction in which you are running (minimum position). For the Forward/Backward-distinction the receiver is turned 90° away from you.

Technical Data:

Frequency Range:	3,490 – 3,660 MHz
Sensitivity:	200nV for 10dB S+N/N (coupled with DF1FO-loop)
	300nV for 75% S-Meter indication
RF-Bandwidth @ -3dB:	3,530 – 3,600 MHz
Mirror frequency rejection:	26 dB
IF/AF-Bandwidth:	1,3 kHz/-6dB, 4 kHz/-20dB, 8 kHz/-40dB
Attenuation range:	0 - 120 dB in 5 dB steps
Supply voltage:	5,5 – 10 V
Current consumption:	25 mA
Battery life:	> 10 hours (9V Alkaline Manganese)
Weight:	about 370g
Total cost of parts:	about 90 €

How the receiver developed

The receiver described here is the result of more than 3 years of development and testing. Version 2 was published yearend 2007, and several dozen receivers of this version were built in 2008. They worked fine, but also showed room for improvement in the areas of usability and reproducibility. The first perforated board prototypes of Version 4 were tested since the middle of 2008, and PCB versions since November. Yearend 2008 several OMs are busy building Version 4 receivers.

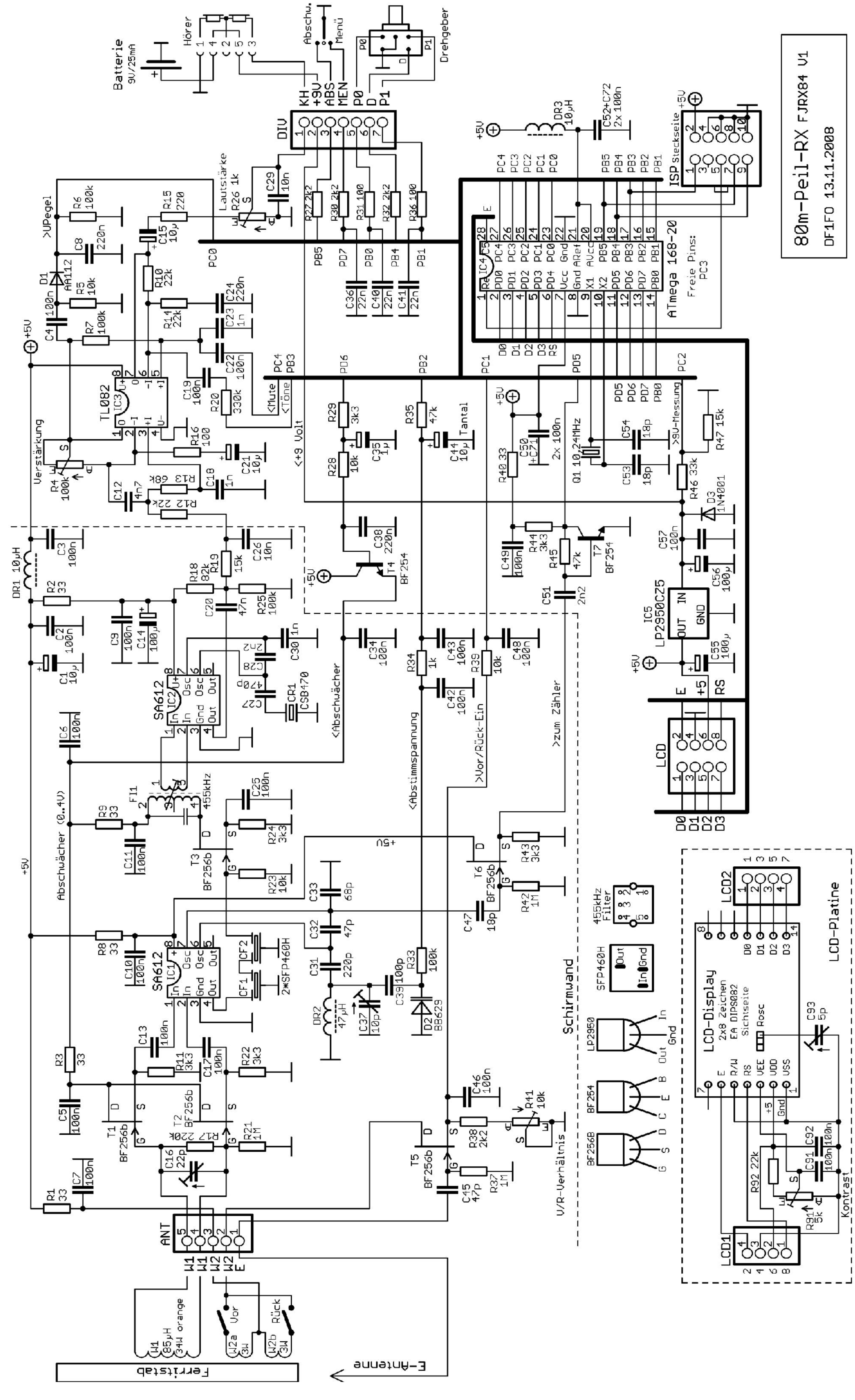
The biggest hardware change from Version 2 to 4 is the replacement of the TCA440, which is hard to get in good quality, by an SA612 and discrete RF- and IF-amplifiers. The second big change is the introduction of the automatic attenuator known from my 2m-receiver.

Feedback

Your comments, corrections, criticism, improvements and questions are always welcome. Please send an Email to DF1FO@darc.de.

Translation of some terms used in the circuit diagram on the next page

Abschwächer	Attenuator	Schirmwand	Shield
Abstimmspannung	Tuning voltage	Sichtseite	Front view
Drehgeber	Rotary encoder	Steckseite	Component side
E-Antenne	E-Antenna	UPegel	Level indication
Ein	On	V/R-Verhältnis	F/B-ratio
Ferritstab	Ferrite rod	Verstärkung	Gain
Lautstärke	Volume	Vor	Forward
Messung	Measurement	Zeichen	Characters
Platine	PCB	zum Zähler	to counter
Rück	Backward		


80m-Peil-RX FJRX84 V1
DF1FO 13.11.2008
ATmega 168-20
LCD-Platine
LCD-Display
Schirmwand
Ferritstab
E-Antenne

Circuit Description

See the schematic on the previous page and the translations on page 2.

The receiver is a **single conversion super-het** with an IF of 460 kHz**,** product detector and two stage AF-amplifier.

The antenna is a **ferrite rod**. The antenna circuit W1/C16 is tuned to 3,57 MHz, and is wide enough to cover the frequency range used by standard 80m foxes.

For the **Forward-/Backward-distinction** the signal from an electrical auxiliary antenna is coupled into the ferrite rod through W2a/b. Two push-button switches allow to test and compare both directions without turning the receiver. Alternatively a single (On)-Off-(On) toggle switch can be used instead of the two push-buttons. The F/B-ratio is optimized by cutting the length of the electrical antenna. R41 is used for a fine adjustment. The processor gets the information, that the F/B-antenna is active, through Pin PC1. This tells the processor to suppress the automatic attenuator and to enable an acoustic S-Meter function, to simplify the F/B-distinction.

Push-button and toggle switch version

The antenna circuit W1/C16 is connected to a symmetrical Source-follower **preamplifier**. This stage matches the high-impedance antenna circuit to the symmetrical mixer input. It has no voltage gain, but about 10 dB power gain. And, as described below, it is also used as ab attenuator.

The next stage is an SA612 double-balanced **mixer**. It also contains the **first oscillator** needed to convert the 3.5 MHz signal to 460 kHz. The oscillator coil is a fixed inductance choke. Two cascaded **ceramic filters** provide the required selectivity. These were originally intended to be used in AM-receivers, and are therefore too wide. An AF-low-pass-filter improves the selectivity, see below. Next comes the single stage **IF-amplifier** T3 with a conventional LC-filter.

The receiver **gain is attenuated** for strong RF-signals by reducing the operating voltage of the FETs in the RF- and IF-amplifiers (T1, T2, T3). The processor sets this voltage through a pulse-width modulator, and the emitter follower T4 buffers it. With this method 120 dB attenuation can be reached easily (80 dB would be enough).

After the IF-amplifier comes the **product detector** IC2. It is also realized with an SA612. The BFO frequency is 464,5 kHZ, the upper limit of the ceramic filters pass-band. So only the lower sideband is received. The BFO-frequency is set by a ceramic resonator.

The **AF-amplifier** uses a TL082 Dual-Op-Amp. Its left half is a 3rd degree active low-pass-filter with a corner frequency of 1,5 kHz, and also amplifies the signal about 500x. The **AF-low-pass** is necessary because of the bandwidth of the ceramic filters of about 6 kHz. The gain is set with R4 to compensate gain variations of the RF part. The AF-signal at the output of the low-pass is rectified by D1, read by the processor through an A/D-converter on Pin PC0, and used for the S-Meter and the automatic attenuator. The right half of the TL082 has a gain of only 2x. It limits the AF-signal and drives the headphones. The processor generates (with a programmable oscillator) various **tone signals**. The signal is fed though PIN PB3 into the AF-amplifier. When the processor grounds output pin PC4, the AF-signal from the processor is muted, so that only the signal tones can be heard. The AF volume is set with R26 to match the headphones used.

The **frequency is controlled** directly by the processor. The signal of the first oscillator is amplified by T6 and T7 to logic level, and fed through pin PD5 to a 16 bit counter in the processor. It counts the periods of the oscillator signal for 50 msec, so the resolution is 20 Hz. This results in pulse counts of about 155k. The 16 bit counter wraps twice (every 65k). Then the difference between the actual frequency and the desired frequency is calculated. Depending on the direction of the offset output PB2 – normally High-Z – is switched to High or Low for a time period that is proportional to the frequency difference. These pulses are integrated and stored in C44, and the resulting voltage controls the oscillator frequency through the VariCap D2.

The **attenuator voltage** is generated by the processor with a 5 kHz pulse-width modulator. Its output is pin PD6.
A two-stage low-pass converts the pulse-signal to an equivalent voltage. The relationship between PWM-values and resulting attenuation is stored in the processor as part of the alignment procedure. The processor increases the attenuation by 5 dB, when the S-meter reaches full scale. So when the receiver is turned to the maximum direction, it automatically adjusts the attenuator to match the momentary field strength. The **distance to the fox** is estimated based on the attenuator setting (= field-strength) and the output power of the fox (see Setup menu).

The field strength, that an 80m-fox produces, depends heavily on the length and matching of the antenna, the length of the ground rod or radial, and the conductivity of the ground. If the person installing the foxes does a good job and you have a little luck, the distance estimations can be quite precise. But on a bad day it could be totally off, so don't expect too much and remember: it is an estimation based on the available data, not a measurement.

The **processor** ATmega168, besides controlling the receiver, also handles the user interface. It consists of a rotary encoder, a 3-position-switch and a 2*8 LCD-Display connected to the processor. The processor also measures the supply voltage with an internal A/D-converter connected to pin PC2. The 10 pin connector ISP allows the in-system-programming of the processor.

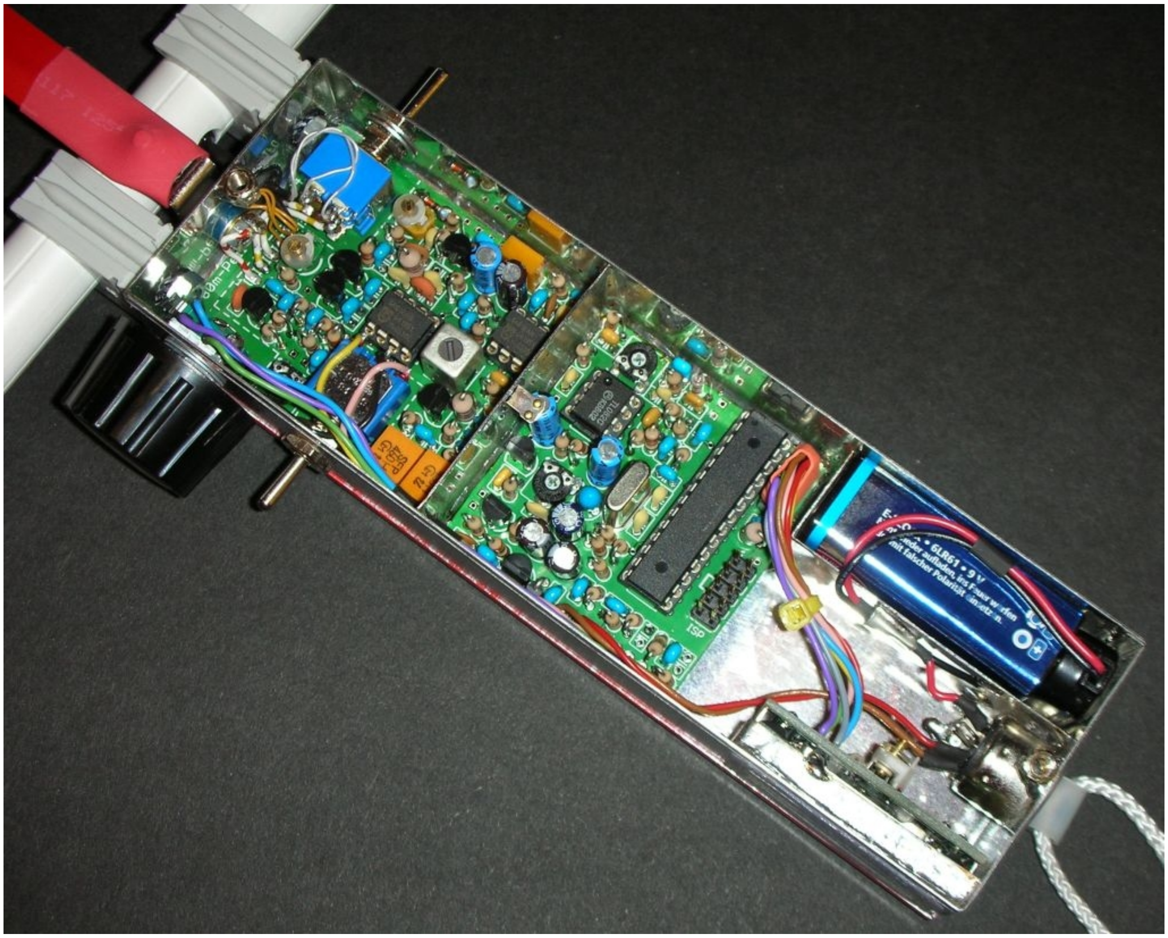
The **display** has an internal clock of about 250 kHz. Its 14^{th} harmonic is audible typically close to the most important fox frequency of 3,580 MHz. It is therefore shifted out of the receivers frequency range with C93.

The receiver is **turned on** by plugging in the headphones. The battery voltage must be between 5.5 and 10 Volts.
A low-drop voltage regulator brings it down to 5.0 Volts.

Mechanical Construction

The receiver is built into a standard **tinplate box** with interior measurements of 160*50*28mm. The box consists of a frame and two covers. The PCB has a size of 106 * 50 mm and is soldered into the frame. A piece of tinplate shields the RF part from the processor part of the board. It is shown in the schematic. The battery is held by a tinplate bracket soldered to the frame. The LCD display and some related components sit on a small 21 * 41 mm PCB. A reinforcement frame soldered around the display gives the 'front-panel' more stability.

I have spray-painted the frame in silver, and the covers in a color.



A total of four threaded studs are soldered to the middle of the short sides of the frame. The covers are screwed to them. For the component side cover I use thumbscrews for easy access to the battery.

This construction is mechanically stable, provides excellent shielding and accessibility. With the covers removed both sides of the PCB are easily accessible for measurements or experiments.

The **shielding** of the box and inside the box is very important, because two sources of noise are built into the receiver: the processor and the LCD display. I strongly recommend to stick to this proven design

The **ferrite rod** is protected by a piece of PVC tube and mounted on the receiver with matching holders.

Operation

The receiver is **turned on** by plugging in the headphones.

The **toggle switch** selects the mode: ‘Operate’ or ‘Menu’. By pushing the switch to the spring-loaded ‘Attenuator’-position the attenuation can be reduced.

Toggle switch to ‚Operate‘:

By pressing and turning the rotary encoder the **frequency** can be fine-adjusted in 100 Hz steps. *(The basic setting of the frequencies of foxes and homing beacon are done in the Menu mode.)* A double-click on the encoder switches to the next stored frequency, e.g. the homing beacon.

It is important, that the receiver is tuned to the **correct sideband**. If you press+turn (fine-tune) the encoder clockwise, the audio frequency of the signal should increase. Otherwise trun on through zero-beat, and the signal will get much stronger.

The **direction to the fox** is found by turning the receiver to the signal minimum. If the volume is too low to find the minimum, the attenuation has to be reduced. This can be done by clicking to ‘**Attenuator**’, this opens the attenuator in 3 steps: 50, 25, 0 dB. Alternatively the attenuation can be changed in 5 dB-steps by turning the encoder. Pushing ‘Attenuator’ long turns the automatic attenuator off or on again.

Even at full attenuation you will still hear a **little bit of noise**. This is due to the high gain of the stages after the last regulated stage.

To do the F**orward-/Backward-distinction** the receiver is turned to the maximum position, i.e. 90° from the minimum. The attenuator will automatically adjust to an S-meter indication between 50% and full scale, and the estimated distance is indicated. Now the forward- or backward-buttons are pushed. In one direction the signal strength will increase, and you will hear a tone generated by the processor. The frequency of the tone depends on the signal strength (‘F/B-Zoom’). In the backward direction the signal just gets weaker.

Toggle switch to Menu:

After switching to ‚Menu’ the display shows for 2 seconds the current frequency, stop watch and battery voltage. Then the ‘Menu’-mode is entered.

By turning the encoder one of the menu items or the Setup-menu can be selected. The menus and operation are very close to my 2m-receiver. All menus are left by switching to ‘Operate’. The table on the next page gives a detailed overview of the menus.

When entering the **Setup-menu** the first item shown is PFox. This makes it easy to adjust the assumed transmitter output power during a hunt. The following method for setting PFox works well, if all foxes have about the same characteristics: in a foxhunt according to IARU-rules the nearest fox is at least 750 meters away, and normally no more than 1 km. So set PFox at the start so, that the distance indicated for the strongest fox is 700m or 1km.

The functions in the **Calibration-menu** will be described in the alignment section of this document.

Operation Overview (Software-Version fjrx84 V1.3)

Switch	Function	Display
‚Operate‘	< > Attenuator +/-5dB <*> Frequency +/- 100 Hz ** Next Frequency # a Reduce Attenuation A Auto-Attenuator On/Off	Fox-Timer Distance S-Meter 1-4 Dots: Freq. #. * = Auto-Att. Off
‚Menu‘	< > Select item	Frequency Stop-Watch Battery Voltage

↓ Main Menu (Exit with Switch => Operate)

Menu Item	Function	
Change Freq.	* Start ==>	< > Freq +/- 1 kHz <*> Freq +/- 100 Hz * Next Freq. #
Clk Stop/Start	* Stopwatch Stop / Reset + Start	
Tmr Start	* Restart Fox-Timer <*> Change current fox # *1	
Setup-Menu	* Start Setup Menu ==>	< > Select item

↓ Setup Menu (Exit with Switch => Operate)

N Foxes	<*> # of foxes 1..10 (1 = Foxoring,) *2
T Fox s	<*> Fox transmit time 1..99 sec
T Fox ms	<*> Fox transmit time +/- 20 msec
P Fox	<*> Fox output power 1 µW - 30 W, dB only *3
N Freq	<*> # of frequencies used 1..4
T Alarm	<*> Alarmtime 1 - 30 sec before end (0 = Off)
F/B-Zoom	* Acoustic S-Meter for F/B distinction On/Off

Rotary Encoder	
< >	Turn
<*>	Push + Turn
*	Click
**	Double-Click

Switch to ‚Attenuator‘	
a	Click
A	Push long

Calibration-Menu Start: Turn on RX with * and switch to 'Menu'

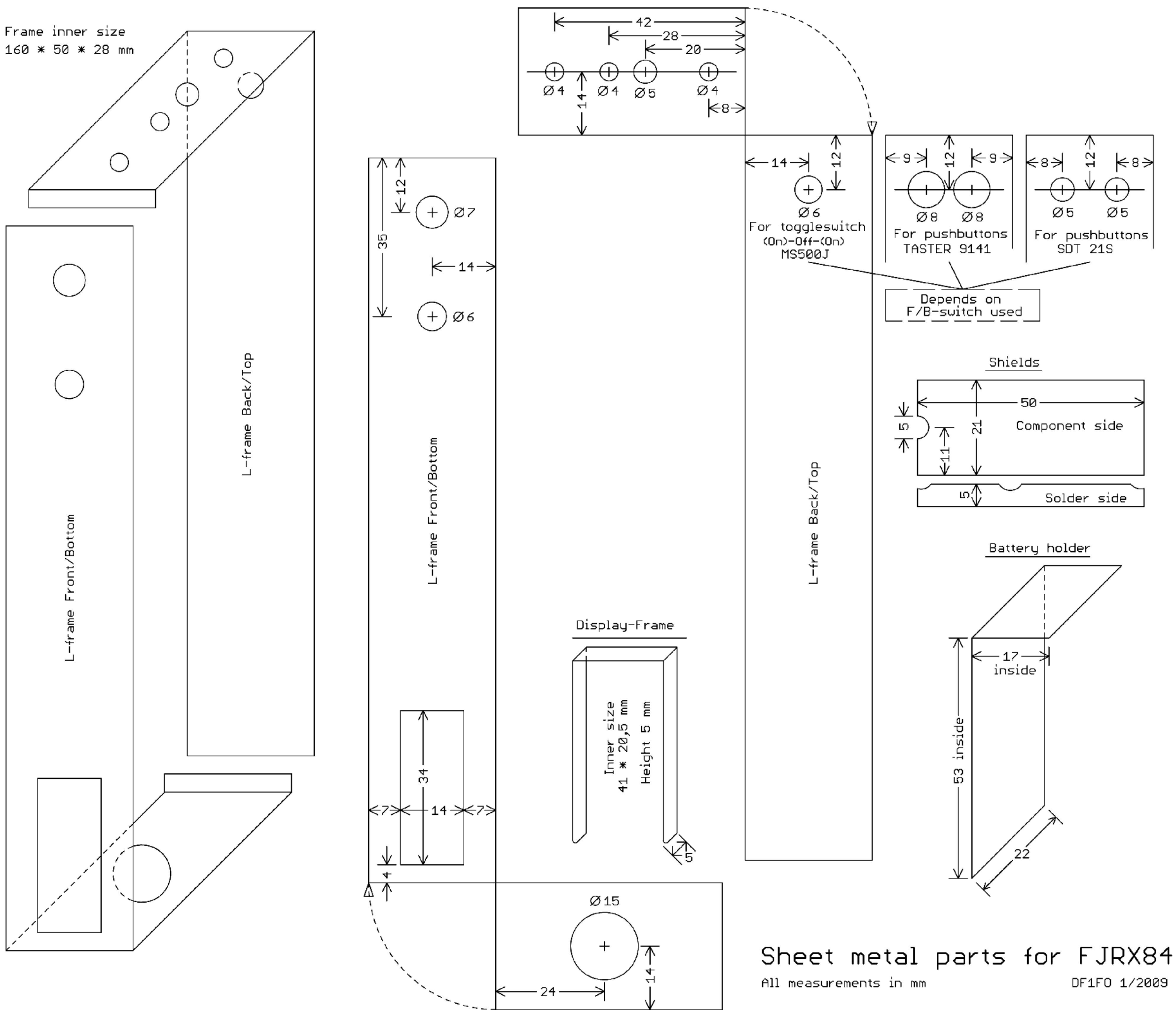
Language	<*> Select Deutsch/English/Nederlands
EEPROM Reset	* Reset all Calibration and setup values
Cal VBat	<*> Calibrate battery voltage measurement
CalF	<*> Adjust frequency offset +/- 0..9,9 kHz
Cal Att Start	* Calibrate attenuator in 13 10dB-steps
BatWarng	<*> Adjust battery alarm threshold 5,8..8,0 V
Cal Dis	<*> Adjust distance estimation –5..+5
FrqRange	* Frequency range 3,49-3,66 / 3,49-3,81 MHz
Save Cal Values	* Store calibration values to EEPROM

(*1): Restart timer at start of transmission of any fox with *, then set current fox # with <*>
(*2): For 'Foxoring' set NFoxes = 1, this turns off fox timer and alarm, display shows stopwatch instead of timer
(*3): ‚dB only' = no distance estimation, instead the current attenuation in dB is shown

Building the Receiver

Mechanics

The tin-plate box consists of four parts: two **L-shaped half-frames** and two **covers**. Before the half-frames are soldered together, several holes have to be drilled or cut.



Working with the 0,5 mm tin-plate requires some extra care. Use only good new drills and hold the half-frames well, otherwise they may coil around the drill. I use drills only for the holes up to 7mm. For the bigger holes and the display window I drill a 7 mm hole and do the rest with a set of good quality files. Depending on the F/B-switch used one of the three drill patterns shown above has to be chosen.

The frame is very weak in the area of the display window. Therefore I solder a 5 mm high U-shaped **reinforcement frame around the display**. I use a strip of 1 mm brass plate, 5 mm wide and 105 mm long. It is fitted so that it positions the display in the center of the display window. There should be a 0.5mm gap between the display and the frame bottom – this will be needed for the display PCB. The display reinforcement frame is soldered to the front frame.

The **DIN-jack** for the headphones is soldered to the frame. Its two mounting holes are countersunk for better solderability, the jack is held in place, and soldered to the frame with plenty of solder. Instead of the DIN-jack a standard 3,5 mm headphone jack could be used. In this case a small toggle switch must be mounted beside the phone jack (to turn the receiver on/off).

Now the PCBs are prepared. The **display board** is filed down to the edges of the copper ground plane to a size of 21 * 41 mm.

The **receiver board** must also be filed down to the edges of the copper plane. Now the board is carefully fitted into the frame, this will require some more filing. The frame is stabilized by installing the solder side cover. The four 5 mm studs give the correct position of the boards solder side – 5 mm from the solder side cover. The board should fit snuggly into the frame - without bending the frame apart. In the front/top-corner of the PCB a little extra has to be filed away because of the overlap of the frames. If two push-buttons are used as Forward-/Backward-switch, the area of the PCB marked 'V/R' and with a dash-dot-line must be cut out.

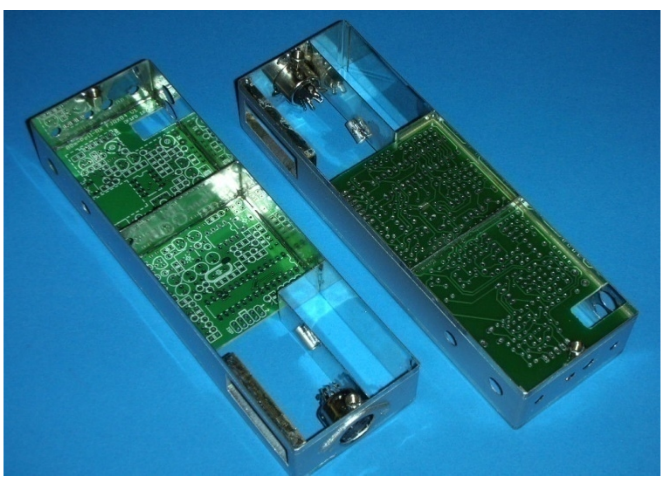
The **battery bracket** is made from a 22 mm wide strip of tinplate with 70,5 mm length. It is bent so that the battery compartment has an inner size of 17 * 53 mm. This should leave some room around most batteries, but sizes differ. The battery bracket is positioned flush with the solder side cover, this leaves 6 mm free on the component side for the battery cable.

Now the half-frames, the receiver board and the battery bracket can be **soldered together** with a few solder points. Once more check the position of everything and then solder everything together all around.

A **shield** is installed between the RF and the microprocessor part of the board. On the component side it is a piece of tinplate of about 21 * 50 mm. It is fitted and a half-round cutout is made for the wires to the encoder and toggle switch. Then it is soldered in on three sides. On the solder side the shield is about 5 * 50 mm. There are wires on the PCB connecting through the shield. The shield must be tapered at the ends and in the middle so that these wires are not shorted. Fit the shield and solder it in.

The **four 5 mm M3 studs** for the covers are soldered to the middle of the short sides of the frame, flush with the edge of the frame. This requires three hands or some ingenuity. The covers are marked 'Top Solder Side' and 'Top Placement Side', and two holes each are drilled that match the position of the studs.

Now the assembly should look like this:



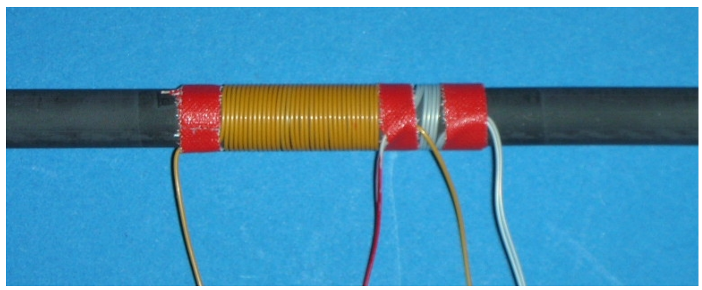
Next the frame can be **spray-painted**. Before painting, wash off all resin and fat with alcohol and roughen the surface with sandpaper. Mask off the edges of the frame that will be covered by the covers (about 3 mm on both sides of the frame), so that they remain blank for a good contact. Also mask off the inside of the receiver, so that the paint gets only to the outside of the frame. Put an old plug into the phone-jack.

The switches and rotary encoder are installed. If the ‘Taster 9141’ is used as Forward-/Backward-switch: fit it with a little epoxy glue.

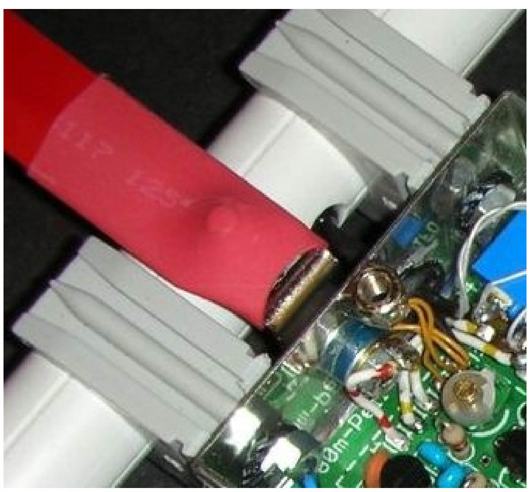
E-Antenna

The E-antenna consists of a piece of tape measure of about 20 cm * 12 mm, a bracket, an isolated feed-through, and two screws and nuts. For the feed-through I use a transistor isolation nipple and an M5 nylon nut. The bracket has 3 mm holes 10 mm from the corner. The heads of the screws are soldered to the bracket to make the installation easier.

Mounting hardware for the E-Antenna



Ferrite antenna W1=orange, W2=2*white



Mounting of E-Antenna and Ferrite antenna

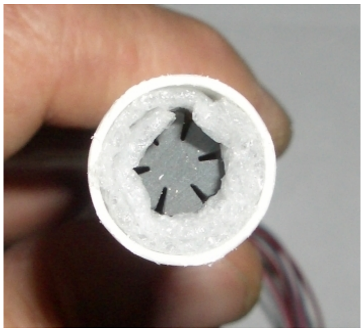
Ferrite Antenna

The **sensitivity of the receiver** depends heavily on the ferrite rod. The first basic rule is: the bigger (longer and thicker) the rod, the better the sensitivity of the receiver. The second basic rule is: many rods look good, but the ferrite material is not suited for 3.6 MHz use and the sensitivity is bad.

If you have a collection of ferrite rods with unknown data, you should test them before deciding which one you will use for the receiver. To test them you will have to put W1 on the rod, it should have 80 to 90 µH. Connect it to the receiver, peak C16, receive a defined test-signal (from a signal generator with magnetic antenna in a defined distance), and compare the results.

Most copies of this receiver use the rod 8*140mm offered by www.funkamateur.de , it is pretty good – only 3 dB under my best rod (which is 9,5*200mm). The winding numbers given in the schematic are for this rod. But if you are willing to experiment, you might find a better one in some dark corner of your shack.

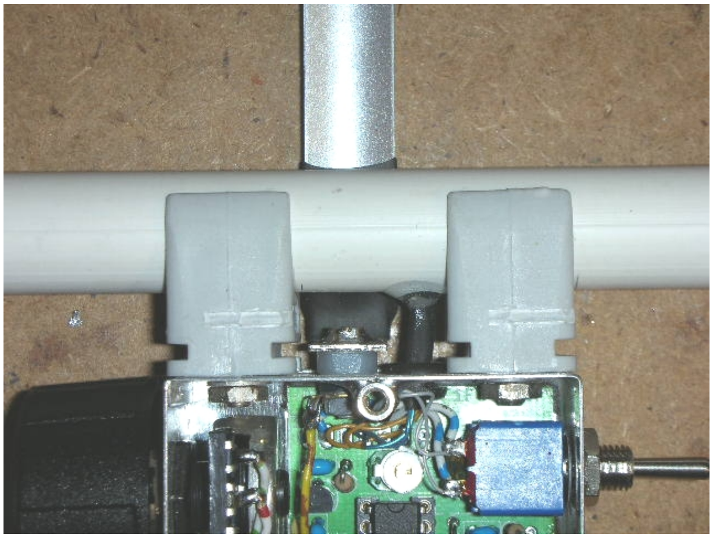
The **windings** on the ferrite rod are not critical. I am using thin isolated wire with 0.5 mm outer diameter (wire-wrap wire AWG30). Other thin solid or flexible wire or enamel-insulated copper wire (0.4 mm) can be used as well. W1 should have an inductance of 80 to 90 µH, the required number of turns is between 20 and 40, depending on the ferrite material and size of the rod you are using. W2 has 3+3 turns wound in parallel (= bifilar, see photo above). Three 3mm wide strips of self-adhesive tape hold the ends of the windings. There are no windings under the tape, so the windings have 3mm distance from each other. The windings are then secured with a thin layer of 2 component epoxy glue ('Uhu Plus').



The ferrite rod is protected by a piece of **PVC tube** with 16 mm outer diameter. The wires are fed through a 4 mm hole 5mm off the center of the tube. The rod is centered and protected at both ends with foam material.

A 20 mm piece of shrink tubing is shrunk over the 6 connecting wires.

The two **16mm brackets** for the antenna tube are mounted on the receiver with M4 screws and nuts. Some brackets are a bit too wide and collide with the covers, so it might be necessary to file off the corners of the brackets.



Only after the receiver (and antenna) have been tested and **found to work ok**, the following should be completed:

The ends of the PVC tube and the feed-through of the wires are filled with silicone rubber.

The ends of the tube are covered with caps.

The PVC tube is glued to the brackets, so that it cannot move around accidentally and rip off the wires. This requires special plastic glue. I use 'Pattex Blitz Plastik', cyanoacrylate glue with a special activator for plastic.

Display

The mechanical preparation of the display board has been described above.

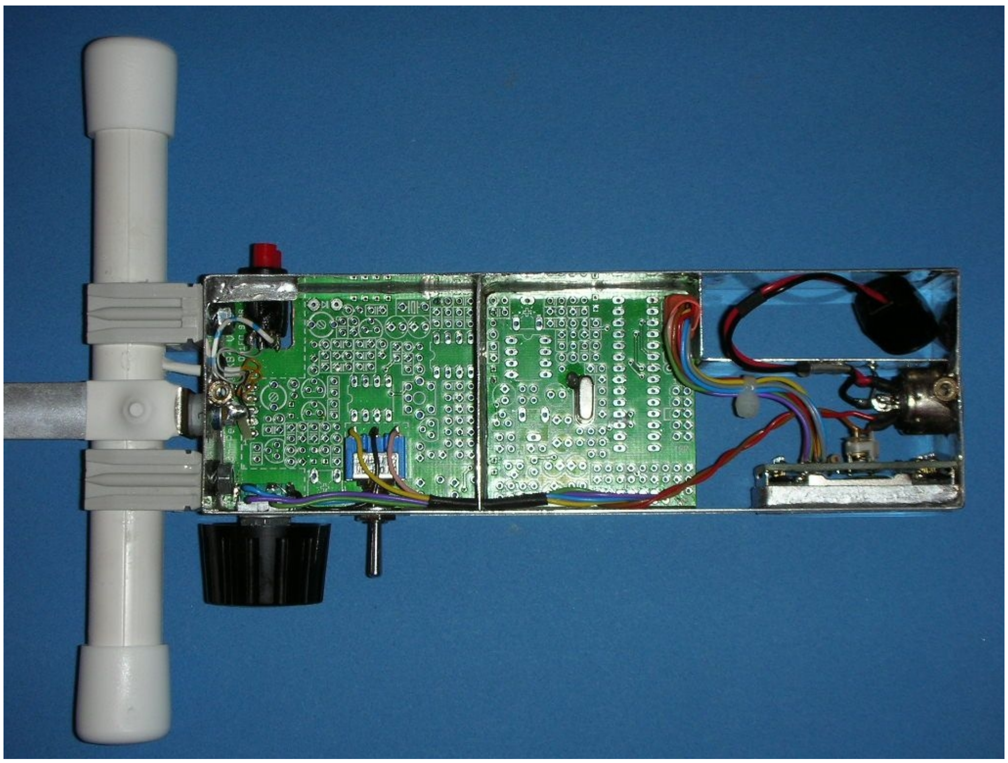
The components **C91-93 and R91-92** are placed on the **solder side** – the side without placement print. For the 8 connections to the receiver board 8 pieces of flexible wire are soldered in. The wires are 60 mm long, and 2 mm of insulation is removed at each end. After soldering to the board all wires are cut very short on the placement side to avoid any shorts to the display.

Now to the **preparation of the display**: looking at the pin side you will see that part of its metal frame are 4 holders that are bent in and hold the board. Solder the holders to the golden islands on the board.

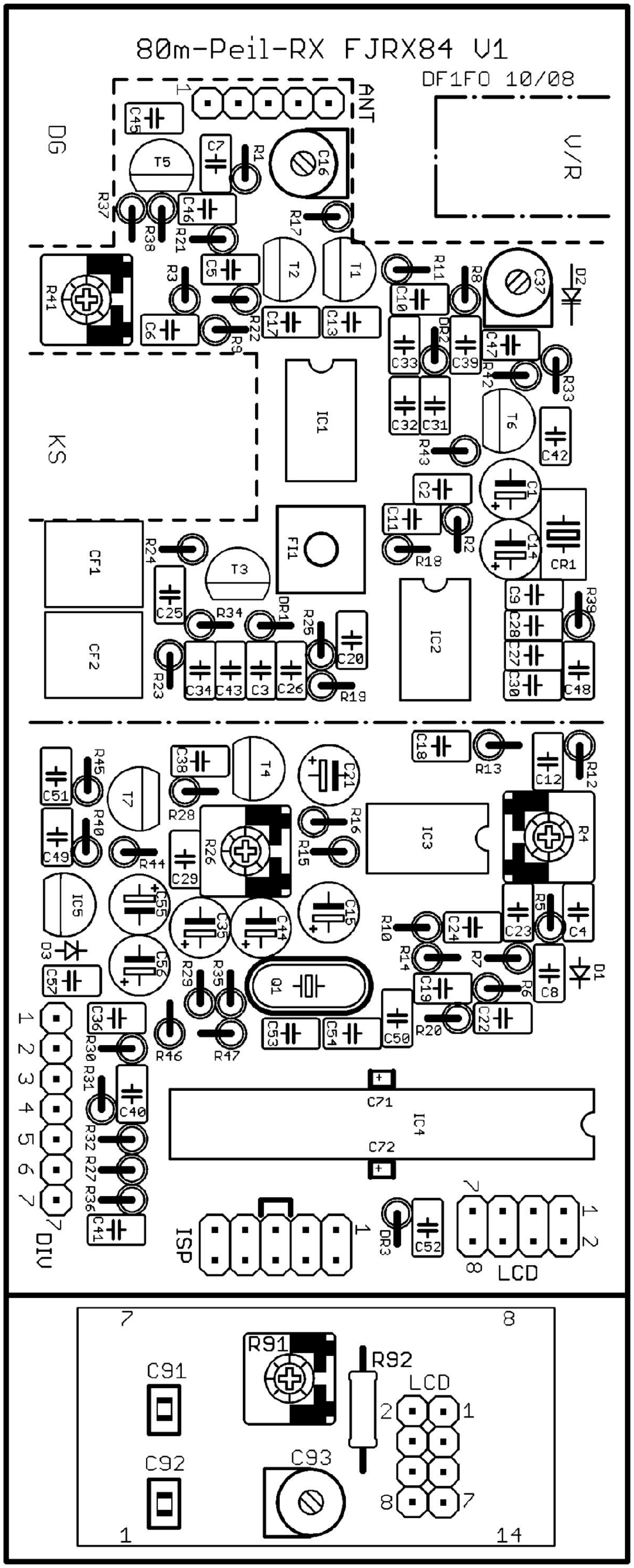
On one side of the display you can see a group of SMD resistors, and on the other side a **single resistor**. This single resistor sets the oscillator frequency. Solder a **thin wire** (about 0.2 mm) to the end of this resistor that points to the center of the display.

Now the display is placed on the display board, the thin wire goes through the square island near C93. The 14 display pins and the thin wire are soldered to the board. Finally the display frame is soldered to the ground plane on the board at the four corners.

The display assembly is mounted temporarily behind the display window. When the receiver is tested ok the display can be secured by soldering it to the display frame with 2 solder dots.



Placement



The board is double-sided, plated through, with solder stop mask and placement print

If you use 2 push-buttons for Forward/Backward: cut out the area marked with dash-dot-line

The SMD-Diode D2 is placed on the component side

Receiver board

Shield

C71 and C72 are SMD-Cs and are installed on the solder side between IC4 Pin7/8 resp. 21/22

Display board

Only the display is on the component side, all other parts are on the solder side!

Wiring and Board Assembly

All wire connections are made according to the circuit diagram. I use 0.14 mm^2 flexible wire. The **battery leads** are fed through a conductor sleeve soldered to the battery bracket for strain relief, and soldered to the headphone jack. The **display wires** are soldered to a 2*4 pin female connector that plugs into a 2*4 header on the receiver board.

Some other remarks on the wiring:

- For the **toggle switch** ‚Attenuator‘ is up, ‚Menu‘ down, and ‚Operate‘ center
- For the **display** a 2*4 male connector is soldered into the board, for **ISP** a 2*5 male connector
- All other connections are soldered directly (**without connector**) into the board.

The three **FETS T1-T3** should be **matched** to have similar source voltages. Therefore they have to be tested before assembly: connect Drain to +5V, Gate to Ground, and Source to a 3.3 kOhm resistor to Ground. Measure the voltage Source to Ground. Find 3 Transistors, for which the difference of this voltage is within 200 mV.
T5 and T6 are not critical.

Now the **board is assembled** starting from the antenna side. A few hints:

- The detailed parts list is at the end of this document.
- Use classical solder with 38-40%Pb and resin core. (No ROHS-solder!)
- The square solder islands are spare for later changes and not used.
- The very small round islands are vias and remain free.
- Sockets are used for all ICs, the ICs are plugged after assembly is complete.
- D2 is SMD, it is soldered to the component side of the board.
- The can of crystal Q1 is soldered to the island on the board with one solder dot.
- Capacitors C71 and C72 are SMD, they are soldered on the solder side between pins 7+8 resp. pins 21+22 of IC4.

To improve the shielding effect of the covers a contact is soldered to the middle of the shields on placement and solder side. I use **contacts cut from a relay**, bend them 90°, and position them so, that they make good contact with the covers (see photo on page 6).

To protect the display from rain and scratches a piece of clear plastic (from a blister pack) is installed in front of the **display window** with double-sided adhesive tape.

The three positions of the **toggle switch** are marked ‚Attenuator/Operate/Menu’ or just ‘A/O/M’. Everything else is self-explanatory.

Test and Alignment

All variable resistors are set to the center position. C16 and C37 are set to 50%, C93 to minimum C.
Plug in a **headphone**.

The receiver is connected to a **regulated power-supply**, a voltmeter on Pin 2 of the ISP connector measures the regulated voltage. Increase the supply voltage from 0 to 9 V, the regulated voltage should go up to close to **5.0 V** and the supply current to about **25 mA** (with a programmed processor).

*If the processor is **unprogrammed**: plug a programming adapter to the ISP connector, load AVR Studio 4 and the assembler source code fjrx84.asm, program flash, and program the fuses as described in the source code.*

Turn the receiver off and on again, you should hear a M**orse ‚HI‘** (**.... ..**) in the headphones. This indicates that the processor is running and its EEPROM is still blank.

Adjust the **display contrast** with **R91** for best readability. Test the function of toggle switch and rotary encoder.

To align the **frequency regulation** connect a voltmeter to the end of R35 that connects to C44 (it is accessible on the component side). Adjust **C37** so that the measured tuning voltage for the total frequency range of 3,49-3,66 MHz is within 1,5-4,0 V.

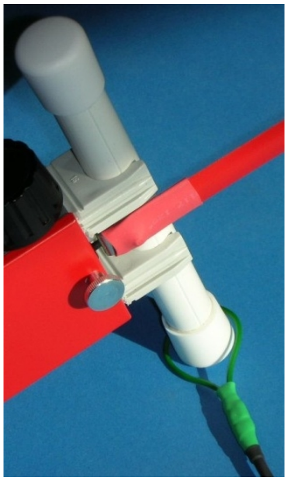
If the frequency regulation does not lock: check the counter input signal at IC4/11 with an oscilloscope. There should be 3 MHz square wave signal with an amplitude of at least 3 V. The duty cycle should be about 50% at the 2V threshold. The duty cycle can be corrected by changing R45.

Now the **receiver should be receiving** on the 80m band. *The frequency can be up to 10 kHz off, this will be corrected later.*

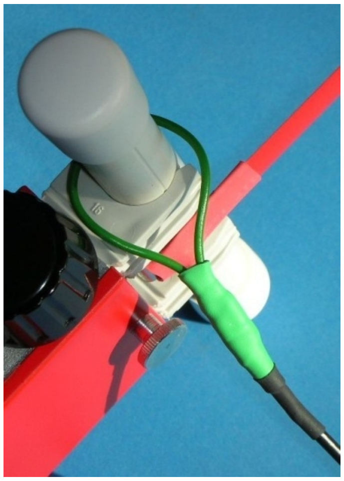
The further alignment of the receiver must be done during the day, when the band is quiet.

Coupling Loop

Completed Loop



Loose Coupling



Close Coupling

For the further alignment you need a **signal generator** with a stable CW output signal in the 80m band and a calibrated output attenuator with an output level range of 300nV to 300 mV. To couple the signal generator into the ferrite rod prepare a **coupling loop**. It consists of a piece of thin coax, 12 cm of flexible wire, a 51 Ohm resistor and some shrink tubing, for details see the photos above.

Put the coupling loop near the end of the ferrite rod (loose coupling. Set the signal generator level to 1 mV and the frequency of generator and receiver to about 3,570 MHz, so that the signal is audible in the receiver. Tune the **antenna circuit** with **C16** to maximum S-meter indication.

Now replace the power supply by a **9V-battery** and put the two **covers** in place to reduce receiver noise. Set the generator to 300 nV and push the coupling loop as far to the middle of the ferrite rod as the brackets allow (close coupling). Set attenuator to minimum by turning the rotary encoder to the left. Tune **FI1** to maximum S-Meter indication (the peak is pretty wide). **Adjust R4** so that the S-Meter shows ¾ full scale.

Adjust **R26** for a **comfortable volume** at 25% S-meter. The volume has to be pretty high, because you will be looking for the minimum volume at most times. *The relative volume of the signal tones can be changed by changing R20.*

Measure the **BFO-frequency** with a frequency counter connected with a high-impedance probe to IC2/7. The frequency should be 464.5 kHz. *If it is more than 500 Hz off, change C27.*

The **bandwidth of the input circuit** W1/C16 depends on the material of the ferrite rod. If the receiver sensitivity at 3,530 MHz and 3,600 MHz is more than 3 dB down compared to 3,570 MHZ, you have to reduce R17. Then re-check the alignment of R4.

The **display** has an internal clock frequency of 250 kHz. It generates **harmonics every 250 kHz**. The 14th harmonic is typically close to 3580 kHz. In addition there are weaker signals (subharmonics) every 50 kHz. The signals can be heard in the receiver, when the covers are off. The clock is moved down by carefully increasing **C93**, so that the strong signal is outside the reception range, and weaker signals are at 3510, 3560 and 3610 kHz. With the covers installed, these signals should be barely audible.

Now start the **Calibration menu** by turning on the receiver with toggle switch to ‘Menu’ and rotary encoder pressed.

Select the desired **Language** of the menu texts: German, English or Dutch.

Select ‘**Cal Vbat**‘. Measure the battery voltage with a digital voltmeter. Press+turn to adjust the voltage indication in the display to the value shown by the DVM.

Set the signal generator and receiver to 3,570 MHz. Select ‘**CalF**’. Press+turn to tune the receiver to the generator signal. The audio frequency should be 800 Hz to 1 kHz.

Install the covers. Select ‘**Cal Att Start**‘ and click. Couple the signal generator to the ferrite antenna with close coupling *(as described above)*. Set the signal generator to 300 nV, the S-meter indication should be ¾ *(this was adjusted before with R4)*. Click, increase generator level by 10 db, adjust attenuator by turning so that the S-Meter is back at ¾. Repeat 11 times until 300mV/120dB is reached. Click once more to complete the attenuator calibration. *Due to variations of the FETs it is possible, that the full attenuation of 120 dB (in the top range) cannot be reached. Since such a high attenuation is not needed in real life, set the attenuator to max (255) and forget it.*

Select ‘**BatWarng**‘. Here the battery voltage warning level can be changed. For standard 9V batteries leave it at 7 Volts.

Ignore **‘CalDis’** for now, we will come back to it later.

Select ’**FrqRange**‘. The frequency range of the software can be extended to 3.8 MHz. However this is not supported by the oscillator hardware, so don’t change it.

Select ‘**Save Cal Values**’ and click to store all settings to the EEPROM. From now on you will hear a different power-on tone-sequence, and changes in the setup-menu will be retained over power-off. If in the future you change any parameters in the calibration menu, you must always save them with ‘Save Cal Values’.

Finally you should go through the calibration menu once more and **write down all values**, so that you can re-enter them if they are lost (which of course shouldn’t happen).

For the following two adjustments you have to go **outside**.

To align the **Forward/Backward ratio** you need a fox with an exactly vertical antenna in a distance of at least 100 m. Cut the tape-measure-E-antenna 1 cm at a time, until you have a clear minimum in the backward-direction. Fine-adjust the minimum with R41. The resulting length of the tape measure depends on the ferrite rod, it is typically between 12 and 20 cm. If the minimum is in the forward instead of the backward direction, swap the leads of W2. It is important, that for this adjustment the receiver is held in the same position as in an actual foxhunt – typically in front of your breast, not your eyes.

The actual Forward/Backward ratio seen during a hunt depends on the height of the receiver over ground and the conductivity of the ground. But under all circumstances you should be able to clearly distinguish the forward and backward directions.

Select '**CalDis**'. Here a distance correction factor can be set, if the distance estimations are always too short or too far. You need a typical fox with typical antenna/ground in a distance of about 100m. PFox must be set correctly in the setup-menu, typically to 1W. Turn the receiver to the maximum direction, the attenuator adjusts automatically. Push+turn to set the indicated distance to the actual distance of 100m. Save setting with 'Save Cal Values'.

Now you are ready for serious fox hunting. Good luck and have fun!

Further Information

The most up-to-date version of all documentation and software is on my homepage www.mydarc.de/df1fo

AVR-Code-Development: AVR-Studio 4 (www.atmel.com -> search for ‚AVR Studio 4')
Free registration required
Make the following settings in Studio 4:

- ➔ Project -> Assembler Options: Assembler to „Version 2"
- ➔ Tools -> Options -> Editor -> „Tabwidth" 8

The Software is written completely in Assembler and available on my website: fjrx84.asm

AVR-Programmer: AT AVR ISP (Reichelt)

Circuit Diagram, Layout and the drawings were made with Eagle 4.15 (www.cadsoft.de)

Data Sheets for SA612 and TL082 can be found at www.alldatasheets.com

Data Sheet for ATMega168 (400 pages): www.atmel.com -> search for ‚ATMega168'

Appendix: Parts List

Most parts are available from Reichelt. In <..> order numbers from Reichelt or name of other supplier.

Parts on the Receiver PCB

CF1,2	SFP460H (Ceramicfilter 460 kHz)	<DF1FO>
CR1	CSB470 (Ceramic-Resonator 470 kHz)	<CSB 470>
FI1	455 kHz-Filter 7x7 mm black	<DF1FO or www.helpert.de>
D1	AA112 (Germanium Diode)	<AA 112>
D2	BB629 (VariCap Diode)	<DF1FO>
D3	1N4001	<1N 4001>
DR1,3	10µH Miniature Choke	<DF1FO or Conrad 535729>
DR2	47µH	<DF1FO or Conrad 535761
IC1,2	SA612 (Mixer) or NE612/SA602/NE602	<NE 612 DIP>
IC3	TL082 (Dual-Op-Amp)	<TL 082 DIP>
IC4	ATmega 168 DIL (Processor)	<Programmed: DF1FO>
-	IC-Sockets 3 * 8-pin, 1 * 28-pin narrow	<GS 8P, GS 28P-S>
IC5	LP2950CZ5 (Low-Drop-5V-Regulator)	<LP 2950 CZ5>
Q1	10,24MHz Crystal HC49U-V	<10,2400-HC49U-S>
T1,2,3,5,6	BF256b (FET)	<BF 256B>
T4,7	BF254 (HF-Transistor)	<BF 254>
ISP	Connector 2*5 male	<SL 2X10G 2,54 (cut)>
LCD	Connector 2*4 male	

Cs: up to 220nF ceramic, from 1µF electrolytic

C1	10µ/35V	C31	220p	R1	33	R31	100
C2	100n	C32	47p	R2	33	R32	2k2
C3	100n	C33	68p	R3	33	R33	100k
C4	100n	C34	100n	R4	100k var.	R34	1k
C5	100n	C35	1µ/35V	R5	10k	R35	47k
C6	100n	C36	22n	R6	100k	R36	100
C7	100n	C37	10p var.	R7	100k	R37	1M
C8	220n	C38	220n	R8	33	R38	2k2
C9	100n	C39	100p	R9	33	R39	10k
C10	100n	C40	22n	R10	22k	R40	33
C11	100n	C41	22n	R11	3k3	R41	10k var.
C12	4n7	C42	100n	R12	22k	R42	1M
C13	100n	C43	100n	R13	68k	R43	3k3
C14	100µ/16V	C44	10µ/16V	R14	22k	R44	3k3
C15	10µ/35V		Tantalum	R15	220	R45	47k
C16	22p var.	C45	47p	R16	100	R46	33k
C17	100n	C46	100n	R17	220k	R47	15k
C18	1n	C47	18p	R18	82k		
C19	100n	C48	100n	R19	15k		
C20	47n	C49	100n	R20	330k		
C21	10µF/35V	C50	100n	R21	1M		
C22	100n	C51	2n2	R22	3k3		
C23	1n	C52	100n	R23	10k		
C24	220n	C53	18p	R24	3k3		
C25	100n	C54	18p	R25	100k		
C26	10n	C55	100µ/16V	R26	1k var.		
C27	470p	C56	100µ/16V	R27	2k2		
C28	2n2	C57	100n	R28	10k		
C29	10n	C71	100n SMD	R29	3k3		
C30	1n	C72	100n SMD	R30	2k2		

Parts on the Display PCB

C91,92	100n SMD 0805	
C93	5p variable	
R91	5k variable	
R92	22k 1/4W	
X1	DIPS082 (Display 2 * 8 Chars.)	<LCD MO82 DIP>
-	Connector 2*4 female	<BL 2X10G 2,54 (cut)>

Antenna

Ferrite rod	<Funkamateur 8 * 140 mm>
PVC-Tube 16 mm, 2 Caps, 2 Holders	<Hardware store>
E-Antenna with isolated feed-through	
Rubber Feed-through, 3mm inner diameter	<Conrad 526908>

Other Parts

PCBs FJRX84 (Receiver and Display)	<DF1FO>
Toggle Switch for F/B SP (On)/Off/(On)	<MS500E>
or 2 Pushbuttons	<TASTER 9141 or SDT 21S>
Rotary Encoder	<STEC 11B01>
Knob 6mm, 28mm diameter, with cap	<KNOPF 28-6 SW, DECKEL 28M SW>
Toggle Switch Mode SP (On)/Off/On	<MS500D>
DIN-Jack 5-pole 180° for headphone	<MAB 5S>
Battery-clip for 9V-Battery	<CLIP HQ9V>
9V-Battery	<Aldi, Penny>
Tinplate box 52 * 162 * 30 mm	<DF1FO>
4 Threaded studs M3 * 5 mm	<DI 5MM>
2 Thumb screws M3 * 6 (for top cover)	<Conrad 998845 or 521859>
2 Screws M3 * 4 (for solder-side cover)	

Some pieces of tinplate, wire, solder, some bits and pieces...

Shopping List

R and C sorted by value with Reichelt order number (* = Value).

Ceramic-C

<KERKO *>
3 18p
2 47p
1 68p
1 100p
1 220p
1 470p

<X7R-2,5 *>
3 1,0N
2 2,2N
1 4,7N
2 10N
3 22N
1 47N
23 100N

<Z5U-2,5 *>
3 220N

SMD-C

4 X7R-G0805 100N

Variable C

1 TRIMMER 23508
1 TRIMMER 23109
1 TRIMMER 23209

Electrolytic

1 RAD 1/63
3 RAD 10/35
1 TANTAL 10/16
3 RAD 100/16

Resistor

<1/4W *>
6 33
3 100
1 220
1 1,0k
4 2,2k
6 3,3k
4 10k
2 15k
4 22k
1 33k
2 47k
1 68k
1 82k
4 100k
1 220k
1 330k
3 1,0M

Variable R

<PT 6-L *>
1 1,0k
1 5,0k
1 10k
1 100k

The following parts are available from DF1FO:

PCBs FJRX84	15 € (for set of 2)
Tinplate box	4 €
2 Ceramic Filters SFP460H	1 € (for 2)
VariCap Diode BB629	0.50 €
455 kHz-Filter 7x7 black	1.50 €
3 Chokes (2x10µH, 1x47µH)	1.50 € (for set of 3)
ATmega 168, programmed	4 €

Complete Set 'Special Parts FJRX84' as above 27,50 €. I do not offer kits.

Please send questions or orders by Email to DF1FO@darc.de .