Assembly instructions PE1JPD 23cm NBFM transceiver V4.0

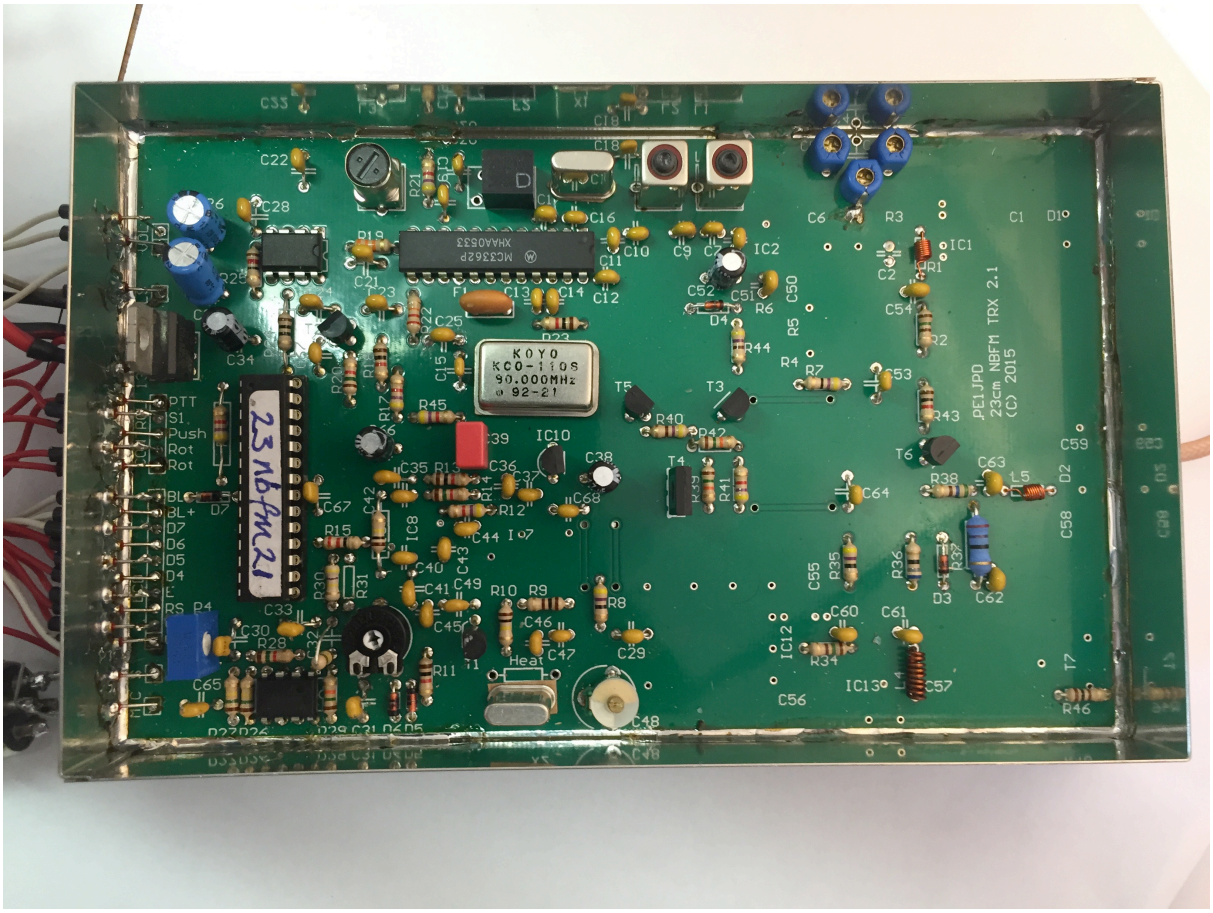


Figure 1 - Version v2.1 of the transceiver, later versions look slightly different.

Introduction

Thank you for purchasing the PE1JPD 23cm FM transceiver kit. This kit is a complete transceiver for the 23cm amateur band, from 1240 to 1300 MHz. The supported modulation is (narrow band) FM, and the frequency step is 25 kHz. It is designed for simplex and repeater communication. The noise figure of the transceiver is around 3dB, and the output power is up to 1W, more than enough for repeater usage if a proper antenna is used. The transceiver can be operated in VFO-mode or via 9 preprogrammed memory channels. For each channel, the shift and sub-audio CTCSS tone can be set. Via a toggle switch you can listen at the inputfrequency. (In the earlierversions of the trx this switch operated the shift, but this setting is now done via the menu).

The kit includes all the parts for the transceiver. You only need a microphone, a loudspeaker and an antenna.

Differences with last version

- Due to availability problems of the PLL chip ADF4113HV now the modern fractional N phase lock loop type ADF4153 is included. This chip is pin-compatible with the 4113, however not available in a HV (higher voltage) version. On the existing PCB v4.0 a few minor hanges have to be done.
- New, improved software.

Controls

The frequency is set by a rotary encoder, which is also used to select menu items and to set values in the menu. The LCD-display shows the current frequency (RX or TX) and an R or T in the top right corner when receiving or transmitting. The rest of the bottom line is used for the S-meter and the menu settings.

Schematic Diagram

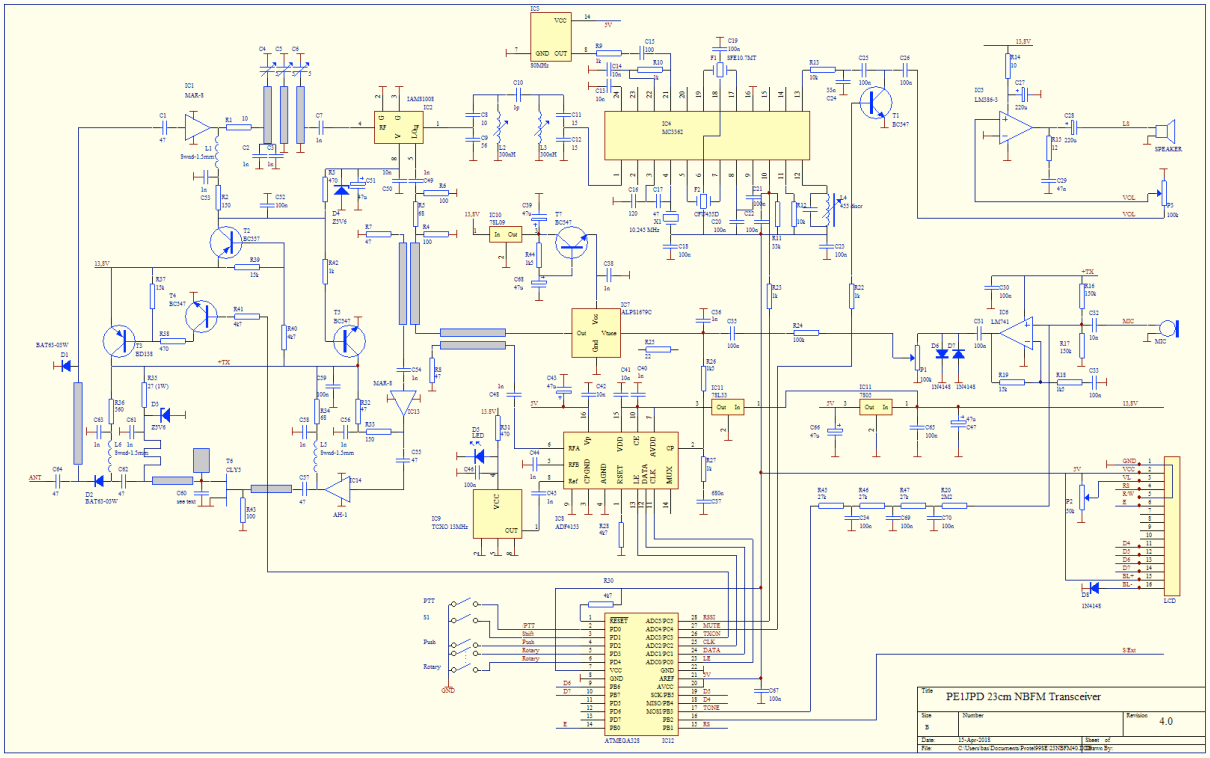


Figure 2: schematic diagram

Central part in the design is the vco (IC7) which oscillates from 1150 tot 1350 MHz. It is locked in a PLL using a ADF4153, a modern fractional N PLL from Analog Devices (IC8). The reference for the PLL is 13MHz, which is generated by a TCXO (Temperature Compensated Xtal Oscillator, IC9). The stability of this TCXO is very important since it determines the overall stability of the trx: 10Hz deviation at 13MHz means 10kHz deviation at 1300 MHz. The TCXO is fed with 3V stabilized by a (red) LED.

The PLL contains various counters and other settings to determine its operation:

- A R-counter, which is set to 5 to divide the 13MHz to 2.6MHz at which the phase/frequency comparator operates (the PFD frequency);
- A P-counter, a dual modulus prescaler which is programmed to 4/5;
- Three addional counter registers N, M(odulus) and F(rac), where the relation between these and the output frequency is programmed as: Freq = 2600(N+F/M).

N can be programmed between 31 and 511, and M and F up to 4095. So to program the PLL for an output of 1298.300MHz: N=499, F=900 and M=2600. As you can see, a step size of 1kHz is achieved this way.
Please refer at the datasheet for more information.

The PLL is programmed by a microcontroller from Atmel, an ATMEGA328 which also performs various other functions. The output of the vco is 5dBm, which is attenuated by 10 dB before it is fed into the receive mixer IC2, an IAM81008. This mixer has a gain of 8.5 dB and a noise figure of 17 dB.

The received signal is passed via a PIN-diode antenna switch to the RF preamplifier IC1, a mar-8 which gives around 20 dB gain. The amplified signal is passed via a bandpass filter on 23cm to the receive mixer. The bandpass filter has a attenuation of 3- 4 dB. The IF signal from the mixer is filtered in a bandpass filter at 69.3 MHz and fed into an integrated IF (IC4), an MC3362. In this IF IC, the signal is converted first to 10.7 MHz, by mixing it with 80 MHz from a standard computer crystal oscillator. After filtering in a SFE10.7 (50kHz wide) and amplified, the signal is mixed to 455 kHz and filtered again in a CDU455D (20 kHz wide), or CFU455E (15 kHz wide) and demodulated to audio. The audio is amplified by IC5, an LM386-3 up to audio level. On pin 10 of the MC3362, a RSSI signal is available and led into the microcontroller where it is used to calculate the S-meter signal and squelch. When RSSI is less than the preset squelch level (in the menu), the atmel shuts off the audio by shorting it to ground via T1. Of course, when transmitting, the audio is also muted.

When transmitting TX, the vco operates directly on the transmit frequency and the 5dB output is coupled via a -15 dB stripline coupler to the first amplifier IC13 (mar-8), which again amplifies it by 20 dB giving ca. 10dBm output. The second amplifier (IC14, an AH-1) amplifies 12dB followed by the fet CLY5 (+8dB) giving up to 30dBm output (1W). The two pin diodes D1 and D2 form the antenna switch: when transmitting, D2 conducts so the ouput of the PA is connected to the antenna. D1 also conducts and forms a short at het end of the quarter wave stripline, which is then transformed to an open end. When receiving, both diodes are shut off so can be neglected. This means the antenna connects to the input of the RX preamplifier.

During TX, the microphone audio is amplified by opamp IC6 and modulated on the tuning voltage of the VCO. When CTCSS is needed, the controller generates a square wave at the appropriate frequency, which is filtered by the lowpass consisting of R45/46/47/20 and C34/69/70.

Assembly instructions

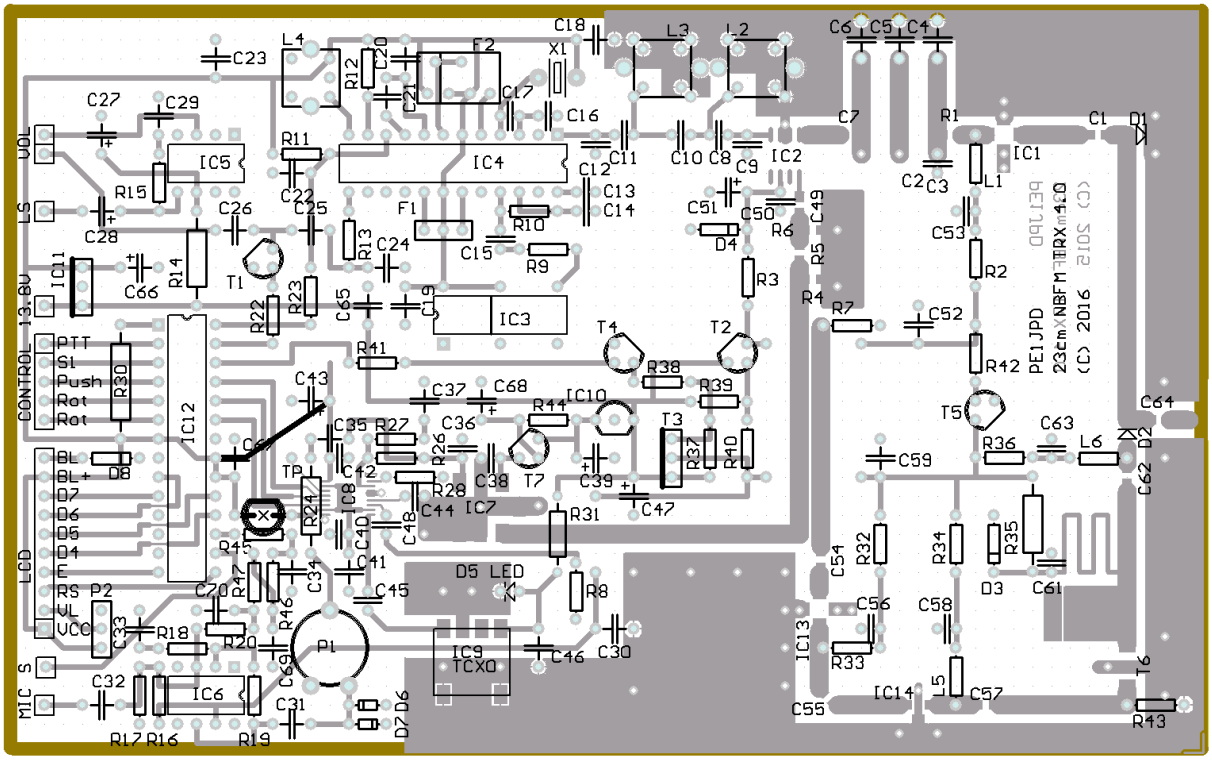


figure 3: top view of the board

1. In general, work carefully. Use just enough tin to solder a connection and let it flow thoroughly. Do not solder longer than strictly necessary and do not overheat the parts. Cut wires short.

2. The ADF4113 (IC8) is the smallest part of this kit. It is soldered at the bottom side of the PCB, where pin 1 is marked. There are different ways to solder this part:
   a. tin the pads on the board, solder the chip with 1 leg and check that it sits fine. Then solder all pins with more than enough tin. After that, remove the surplus tin with solder wick.
   b. tin the pads and fix the chip as in option 1. With a fine point solder every pin by itself.
   c. use flux. Tin the pads, add some flux and fit the chip with 1 pin. Then use a hot air soldering device to solder it.

   (I use the first method myself).
3. Solder IC2 on the board. Pin 1 is the IF output, so pin 4 at the side of C6. Be careful in soldering it, it appears to be a sensitive part.
4. The two mar-8 IC1 and IC13 have the dot at the input pin. This is for IC1 at the side of C1, and for IC13 at C54.
5. Pin-diode D1 has its marking (K) at ground side, and D2 at the side of C64.
6. Now solder the rest of the SMD part at the bottom side.
7. After soldering C2, solder C3, a 1n smd C at the bottom parallel to it.
8. Check that L2 and L3 are connected between the pads connected to C10/C11 and ground.
9. On the top side, only the Atmel has a socket (28 pins). The other IC's are soldered directly on the board.
10. Take care for IC3 and X1 that the pins are not shorted against ground. You could keep them a fraction above the print or use a small piece of paper in between.
11. The trimmers have their 'flatted' side at the 'hot' end. C5 is mounted the other way around, with its (cut) leg soldered to the pad at the top layer.

Now fit the pcb into the tin box:

12. Prepare the tin box by drilling at 12 mm from the bottom the 21 holes for the feed through C's. Drill these at 2mm, after which you press the C's in the hole with your thumbs, or with a pair of tweezers. At the other end, drill a hole of 3mm at 8mm from the bottom for the antenna connection.
13. Now fit the board in the tin box at a height of 8mm from the bottom/solder side. Put the two sides of the box in one lid to keep them 90 degrees. The feed through C's should be approx. 2mm above the pcb, and the hole for the antenna fits to the pad at the bottom side. File at the two opposite corners a fraction of the board to fit it between the bend corners. If necessary, file the other two corners a little bit round. Now solder the board on a few spots in the tin box, and check that it is fitted all right and that the box does not wiggle when set flat on the table.
14. Now solder the box to the board at a few spots and check that it sits ok.
15. Now solder the pcb to the box, especially at the antenna side and around IC13 and T7, on both sides. At the other ends of the board solder it to the box at a few places where there is room to do this.
16. Finally, connect the feed through C's to the pads on the board and fix a (SMA) chassis connector (not included) or thin coax.
17. Tip: use 3mm thin PFTE coax. Free 1.5-2 cm of the outer plastic and than tin the braid. Carve at approx. 7-10 mm from the end the tinned braid with a sharp knife, after which you can break the braid and remove it. Now free the inner conductor of the coax and solder it on the board and to the box.

Testing, tuning and troubleshooting

Be sure to verify specifically the pins of the PLL chip. You can do this with a multimeter with short (beep) function. Be absolutely sure that pin 15 and 16 do not short, because this is fatal for your chip.
After the connections all seem ok, power the transceiver up. You should hear noise and the display shows VFO 1298.375 MHz and 'R' in the upper right. To see this you will have to adjust the contrast potmeter on the board (P2). When you press PTT, a 'T' should show in the upper right of the display.

Start with the PLL. When in lock, you see this at the spectrum analyser, hear a stable signal with a scanner or measure a stable voltage at C36. If not in lock, check all connections of the PLL, but also of the C's around it. Also check the 13MHz reference signal at C45.

When the vco is on frequency, the receiver can be tuned. This should be done preferably stage by stage, starting with a 69,3 MHz signal loosely coupled into L2/L3. The discriminator is set to give optimal audio. Even better, connect a scope to IC4 pin 13 and tune the discriminator to symmetrical noise on the scope, in between the minimum and maximum which can be reached with this coil. A signal of exactly 69,3 MHz should be tuned to a signal just in the middle of the noise band visible without any signal.

The voltage at L1, the RFC at the rx mar, should be around 7V. When you measure lower than 4V the mar might oscillate and draws a lot of current. Try tuning the bandpass filter first, or remove R1 and check the voltage. To be safe, start with an higher value of R2 (like 220 ohm).

With an input signal at 23cm, the 3 Murata trimmers should be set to maximum signal strength on the S-meter, or via the speaker. These trimmers need careful adjustment. Again: solder these as tight as possible on the pcb since otherwise the maximum frequency can not be reached. When you hear no 23 signal at all, but 69,3MHz works ok, the mixer probably died...

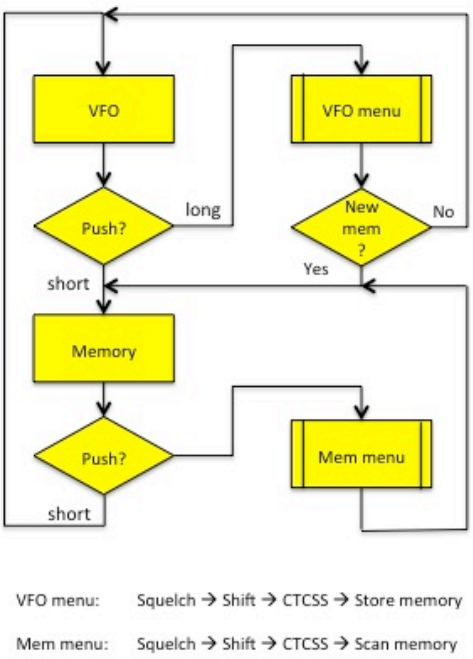
With a spectrum analyzer or frequency counter the output of the vco is checked which should oscillate at 1298 MHz when PTT is pushed. Without any tuning, you should have 400 mW output and when a small C of 0p68 is added between drain and source of T7 this should increase to 700mW. Tune the output with a piece of 8x8 mm copper foil to get maximum output. Use a matchstick to find the optimal position, and then solder it.

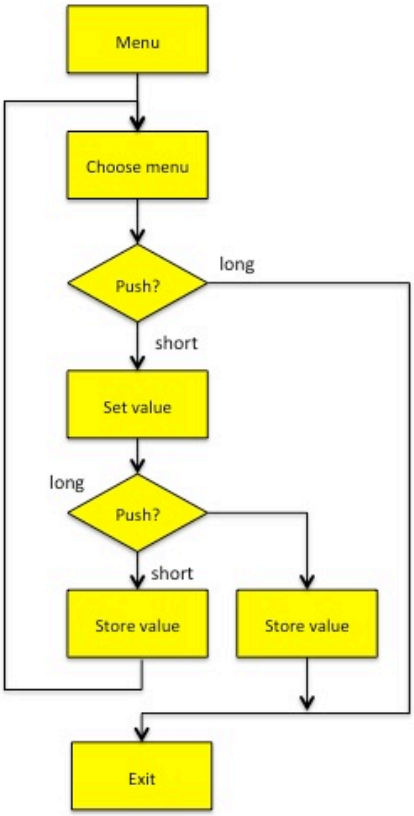
If the CLY5 draws too much current, the voltage over D3 drops under a few volt. Also, R35 (27 ohm) start smelling and maybe even smoking… This can be the case when there is no drive (AH-1 dead?) so in this case remove R35 first and measure the power at the outputs of IC13 and/or IC14. Also, you can increase R43 to increase the negative voltage at the gate of T6: the more negative, the less current. There is an optimum in negative voltage and output power.

The S meter is derived in software from the RSSI on IC4 pin 10. Therefore the rx should be aligned properly to get intelligent reading.

The amplitude of the CTCSS tone is not adjustable, if you need to change the amplitude vary R20: the lower this value, the higher the amplitude. But 1-2 Mohm should be ok. Also, the pitch of the modulation depends on the microphone, and by changing C32 and/or C35 the response can be changed.

Usage and menu



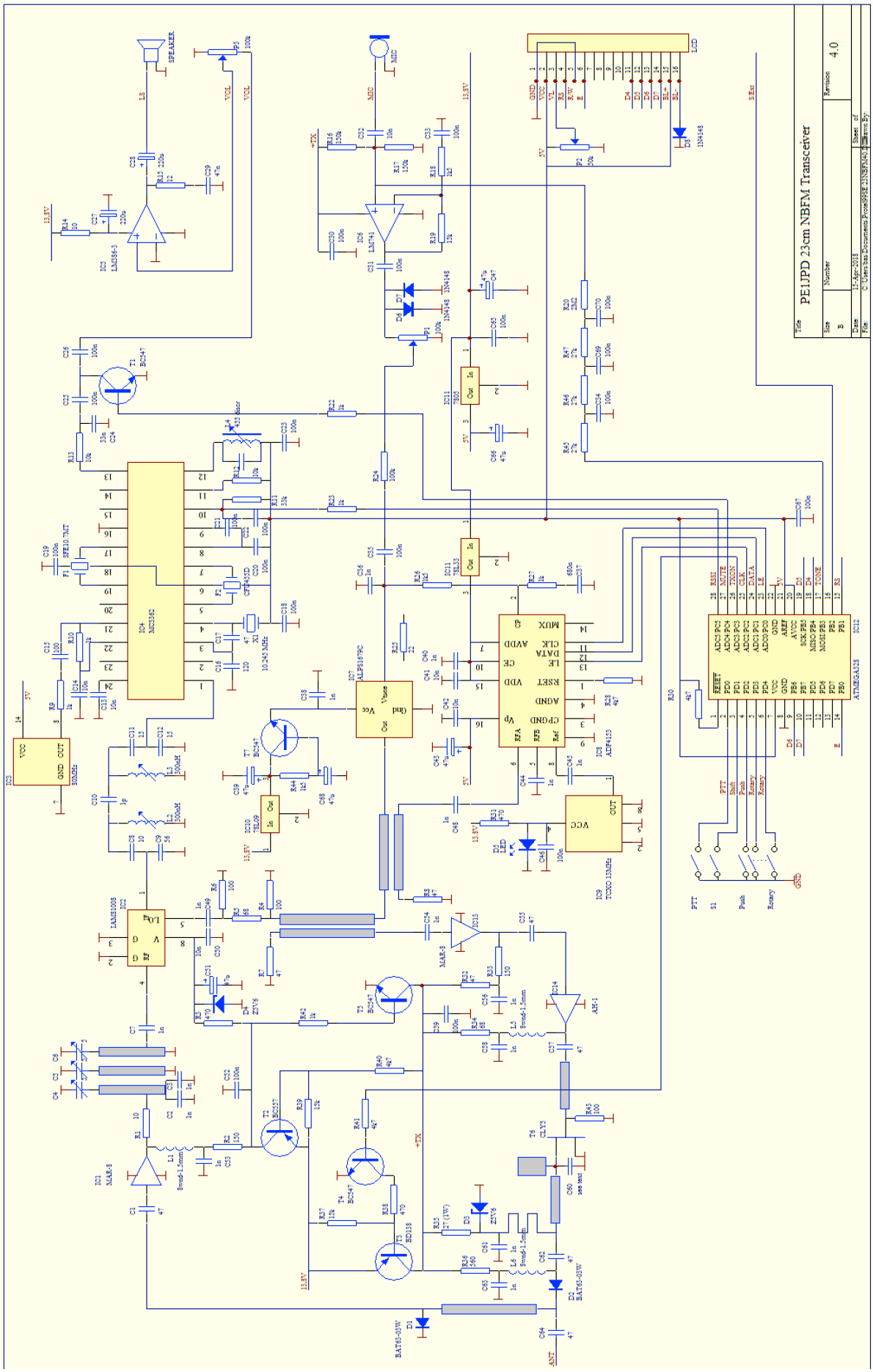


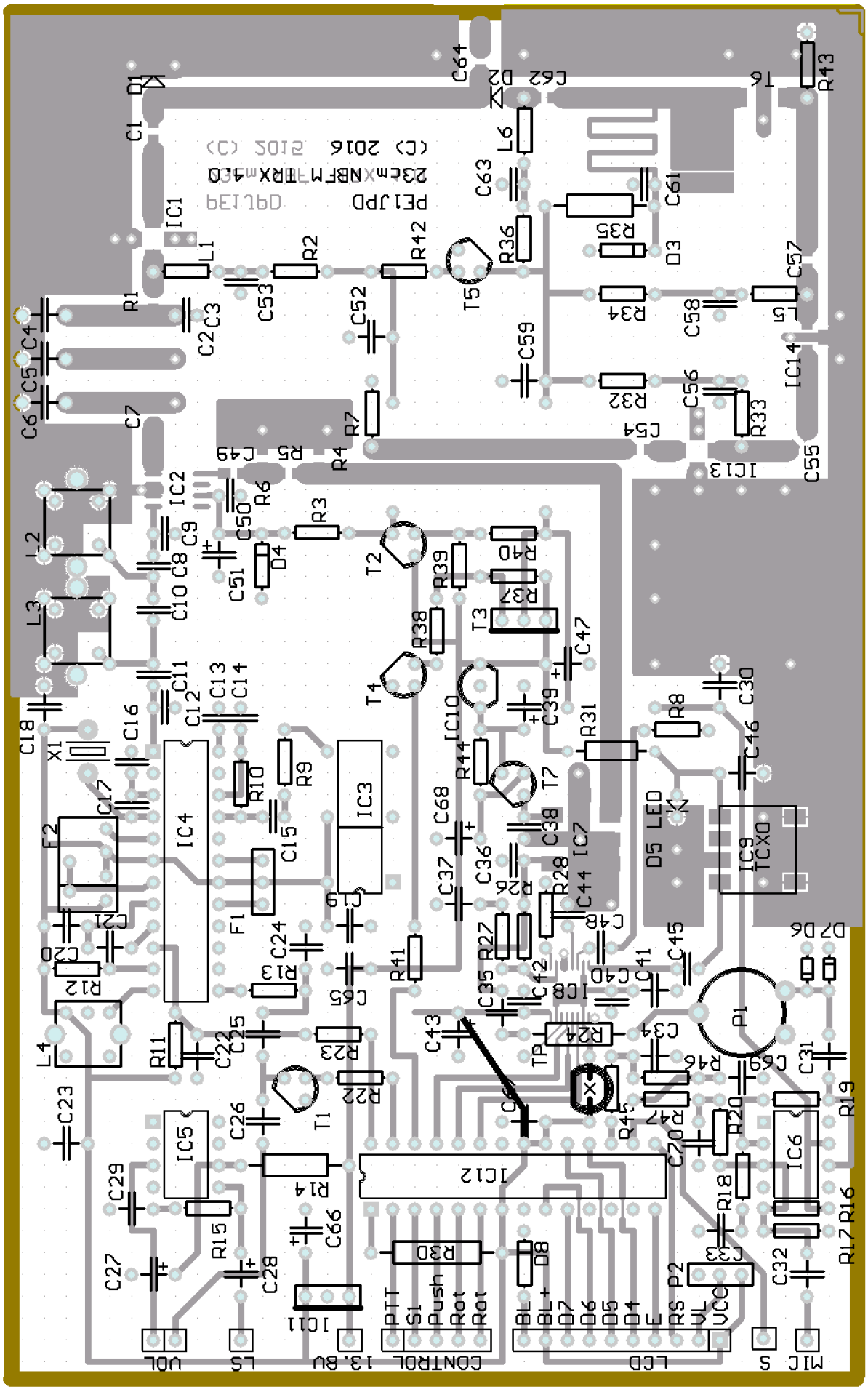
The transceiver has a VFO mode, in which you can tune to any desired frequency in the 25kHz raster, and a Memory mode, where you tune to preset memory channels. 9 Memory channels are available, and 1 VFO.
A short press on the dial switches between the two modes. A long press (>0.5sec) switches to the menu. This menu is slight different when entered from VFO-mode or from Memory mode.

When entering the menu, first choose the item you want to set: squelch, shift, step-size, CTCSS-tone or memory. When choosing, the current set value is showed. After a short press on the tuning, a '>' indicates you can now change the value.
When changing a setting in the memory menu, that setting is only changed for the selected memory channel, only the squelch setting is global. When in the VFO menu, settings are globally changed so that after that a memory store will also store the other values set (like shift and CTCSS tone frequency).

Although not connected to the outer world on the board, PD5 and PD6 are readout by the software for UP/DW pulses. This enables the transceiver for instance to correct for dopplershift of AO-92 when in L/v mode. When these are needed, please connect those pins via thin wire to additional feedthrough capacitors.

Schematic diagram




PE1JPD
23cm NBFM TRX 4.0
(C) 2016
VOL
LS
13,8V
CONTROL
PTT
S1
Push
Rot
Rot
LCD
BL-
BL+
D7
D6
D5
D4
E
RS
VL
VCC
S
MIC
D5 LED
TCXO

Part list

Reference	Part	#
IC1 IC13	MAR8	2
IC2	IAM81008	1
IC3	80MHz oscillator	1
IC4	MC3362	1
IC5	LM386-1/2/3	1
IC6	LM741	1
IC7	ALPS 1679C	1
IC8	ADF4113HV	1
IC9	TCXO 13MHz	1
IC10	78L09	1
IC11	7805	1
IC12	ATMEGA328	1
IC14	AH1	1
ICxx	78L33	1
D1,2	BAR63-03W	2
D6 D7 D8	1N4148	3
D3 D4	5V6 zener	2
D5	LED red	1
T1 T4 T5 T7	BC547	4
T2	BC557	1
T3	BD138	1
T6	CLY5	1
F1	SFE10.7MT 50kHz	1
F2	CFU455D2	1
X1	10.245 MHz crystal	1
L2 L3	300nH adjustable inductor	2
L4	455 discriminator	1
L1 L5 L6	RFC 8w 1.5mm	3
R1	10 (0805 SMD)	1
R5	68 (0805 SMD)	1
R4 R6	100 (0805 SMD)	2
R14	10	1
R15	12	1
R25	22	1
R35	27 1W	1
R7 R8 R32	47	3
R34	68	1
R29 R43	100	2
R33 R2	150	2
R38 R3 R31	470	3

R36	560	1
R9 R10 R22 R23 R27 R42	1k	6
R18 R26 R44	1k5	3
R28 R30 R40 R41	4k7	4
R12 R13	10k	2
R19 R37 R39	15k	3
R45 R46 R47	27k	3
R11	33k	1
R24	100k	1
R17 R16	150k	2
R20	2M2	1
R47 R46 R45	27k	3
P1	potmeter 100k log	1
P2	50k small standing	1
P3	100k small	1

C10	1p	1
C6 C5 C4	5p trimmer Murata	3
C8	18p	1
C12 C11	27p	2
C17	47p	1
C1 C55 C57 C62 C64	47p (0805 SMD)	5
C9	82p	1
C15	100p	1
C16	120p	1
C47	330p	1
C2 C40 C38 C48 C58 C53 C3 C63 C61 C56 C45 C36 C44	1n	12
C7 C49 C54	1n (0805 SMD)	3
C32 C14 C13 C42 C50 C41	10n	7
C24	68n	1
C29	47n	1
C70 C69 C34 C65 C67 C30 C33 C31 C19 C26 C25 C23 C18 C22 C21 C20 C52 C59 C46 C35	100n	19
C37	680n	1
C68 C47 C43 C66 C39 C51	47u elco	6
C28 C27	220u elco	2

-	feed through C's 1n	21
-	LCD 2x16	1
-	rotary-encoder	1
-	switch	1
-	IC-socket 28p narrow	1
-	PCB	1
-	1 tin box 100*160*30 mm	1