

HF SDR S/H Sample and Hold Transceivers AVALA-01 and ADTRX-2- Make Them Simple as Possible with Outstanding Performances

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I read carefully discussion and comments about my SDR designs (especially at Russian SDR forum <http://forum.cqham.ru>). The discussions gave me some new ideas how to improve my SDR designs. I made big effort to make something new and better and I didn't spent to much time in practical testing my SDR designs in the air. My free time at last time was filled with articles writing and CAD calculation. I had pretty big feedback to the mine work I received a lot of E-mails. But I had to admit that there aren't big number practical suggestion and proposals how to do or how to improve something in my SDR designs from users.

DR2A SDR receiver is my best design if we are talking about IMD (inter-modulation) free DR (dynamic range) IP3 in and 1 dB compression point (please read article about additional measurements done by Norbert DG1GPN and me at site). I decided to improve DR2A and results are two new receivers DR2A+ and DR2A++. I shall not explain what I do to improve performances read article about them please. My first SDR transceiver ADTRX-1 was built in time of leak adequate freeware software for transmission. At the beginning of 2006 I made a lot of experiments and result is SDR transceiver ADTRX-1. It has a lot of possibilities for transmission. From the other side ADTRX1 boards set is too much complicate with a lot of connections between 3 or 4 proposed boards and transceiver receive/transmit control isn't comfortable too much in practical use. Also some mine ADTRX1 SDR user noticed some imperfection in practical use.

New SDR transceivers AVALA-01 and ADTRX-2 are based on DR2A+, DR2A++, DT2A1 designs please read about them in previously published articles. I made comeback to the 74HC4066 ICs as better and faster S/H than it is 74HC4053 used in ADTRX-1. Initial idea came from Sergey UR0VS who made one band 7 MHz SDR transceiver based on my design ADTRX-1. He simplified mine design with relays use and he used same S/H IC as detectors and modulators. This approach simplified also software image rejection adjustment. Some SDR OMs made measurements with ADTRX1 and concluded that I had been declared too much output levels for transceiver with acceptable audio distortion. Reason for that is that cheap TL084 can't drive low 50 Ohms impedance such as S/H modulator. To reduce harmonics in audio modulation signal coming from SB drive output level must go down to the ADTRX1 output levels -10dBm-6dBm not as I declared -2-3dBm. This necessary action will also decrease carrier suppression to levels less than 40 dB. This limitation is not cased by S/H modulator problems but with TL 084 specification that min load impedance has to be 500 Ohms or more. Max output level from TL084 in ADTRX1 is 8V_{peak-peak}. To overcome problems with load resistive divider at TL084 output has to be realized with more than 20 dB attenuation. 74HC4066 S/H modulator can easy handle levels up to the 17dBm max. Good acceptable level with min distortion is about 10dBm. I redesigned S/H modulator audio drive with adding output buffer stage to the TL084/82 outputs. Output stage I realized with complementary generally purpose bipolar TUP/TUN PNP/NPN transistors BC556/BC646 or similar. To minimize number of components I am using complementary pair in class A with idling current from 5-10mA. If we are using voltage higher then 12-13 V and pairs with very big gains it is necessary action to increase 4K7 resistors in transistor bases to 5K6 to obtain good thermal stability of outputs complementary BC546/BC556 pairs. With higher idling current transistors are increasing uncontrollable current to their own distraction. Relays switching also improve audio isolation and crosstalk between receive/transmit path limited with finite CD4053 isolation. It is realized at similar way as it is done in famous SDR 1000. For testing ADTRX1 I used 16 bit SB card with 48 kHz sampling rate. Now I bought better 24 bit SB card Audigy 2NX with 96 kHz sampling rate. Better SB card enable me more possibility and because of that I have to enable wider useful bandwidth in both receiving and transmission paths. Control logic is simplified and it is maximum compatible with Duncan's M0KKGK transceiver software front PTT/KEY control. Duncan's software is working very nice with last version of my favorite Patric's

F6CTE MULTIPSK all digital mode freeware software. I added CW monitor to enable SDR operation with only one SB card (some software like new Rocky 3.3 transceiver will not enable transmission with only one SB card). Unique PC control setup is enabling operation in all 3 software PowerSDR, M0KGGK and Rocky. It is possible IAMBIC key operation connecting paddle from back panel or PTT/CW control. When we have one SB card during SSB/Digital operation it is necessary to turn of CW monitor output to headphones with one toggle switch. Unique PC control I done according to very nice article written by Guido PE1ENZ please read it. It is very important to notice that all pins of control from back side are "flying" type take care when you connecting paddle for IAMBIC operation or PTT/CW control. Please do not connect to the ground!

I am using next setup at serial port:

Pins female D9 at PCB

4 DTR always high

5 GND

6 DSR PTT/dot connect to DTR

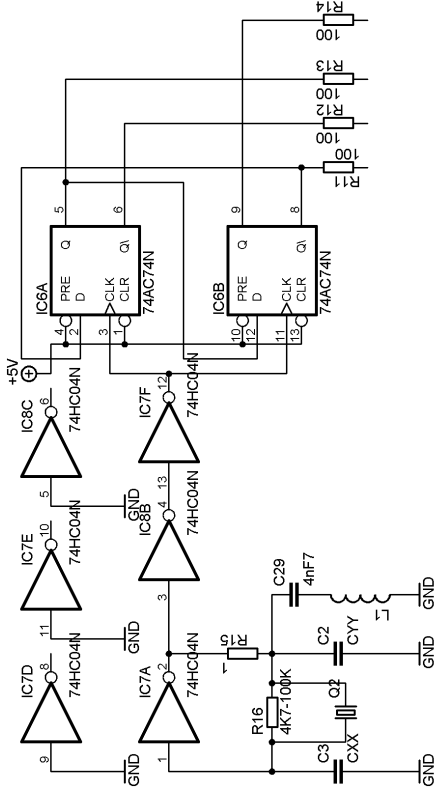
7 RTS TX high

8 CTS dash connect to DTR

All other pins are not connected!

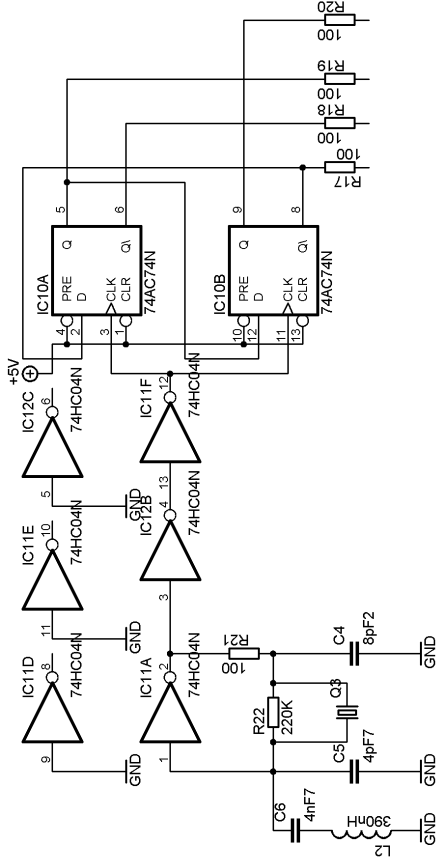
AVALA-01 SDR transceiver is ADTRX-2 transceiver with added whole HF QRP output power amplifier 2.5-5 W and RX preamplifier. This HF preamplifier improved MDS and overall RX noise figure. IP3out of realized preamplifier with 2N3866 or better 2N5109 is +38 dBm gain 15 dB(roll off less than 1dB at 50 MHz) and NF ~5dB with 80mA. The preamplifier is much simpler and it is unconditionally stable amplifier compared with common type used in many designs with output transformer 1:4. It is now possible to make choice between several RF+AF gain position such as +20, +36, +46 and +60 dB. Minimum detectable signal and max input signals are now between -133dBm and +5dBm of course not at the same time. This change enable that transceiver DR and sensitivity specification are comparable with any today commercial transceiver higher grade class. Maximum output power from new SDR transceiver ADTRX-2 is with new S/H IC is 10dBm now. The same drive power is possible to use for driving output power amplifier 2N3866+IRF510 (VN67AF). This amplifier is my modification of QRP+ transceiver output stage which I used successfully few years ago. If we build in 2 parallel FET transistors output power can reach 10W. It is maximum power for this design and relays. To obtain max frequency power I left possibility to use not only 1:4 but 1:9 output transformers ratio also I some cases much better choice. For FET long and safe operation life it is necessary adequate heat sink. The best solution for heat sink is copper ribbon 2mm thick but Al ribbon will be good solution also. The driver transistor is working in class A with 95mA. 1dB compression is around 23Bm with 11 dB gain (IP3out ~41dBm) and heat sink is imperative for it. See how I realized this in photo prototype. FET (IRF510) is working with idle current ~500mA and for 5Wout it consume around 1.1A from power supply.

Both transceivers are realized on single side PCBs with classic size through-hole components. I also enable transceiver improvements with use new modern components especially 74LVC series. 74LVC 74 enable operation at 50 MHz in connection with for example AD9951 DDS as LO generator with Fref 520 MHz (3 times 170 MHz reference oscillator). I simplified output LP filter at power amplifier output that is useful as input BP (band pass) filter. See simulation at the article end. Realization is simple as possible with only 2 coils. If we are using AVALA 01 as general band transceiver it is possible built in



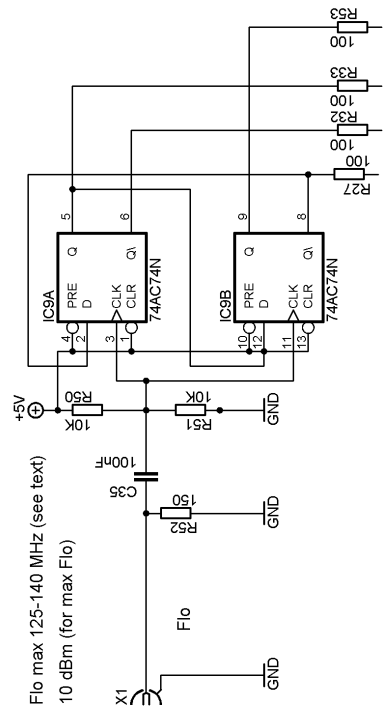
Q UP TO THE 130 MHz OVERTONE MODE WITH IC 74AC04

F=39MHz CXX=10nF,CYY=27nF L1=1500nH R=4K7
 F=58MHz CXX=8.2pF,CYY=12pF L1=820nH R=4K7

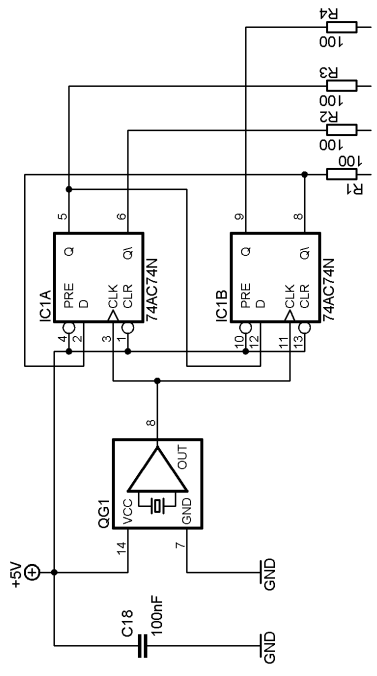


Q UP TO THE 130 MHz OVERTONE MODE WITH IC 74AC04

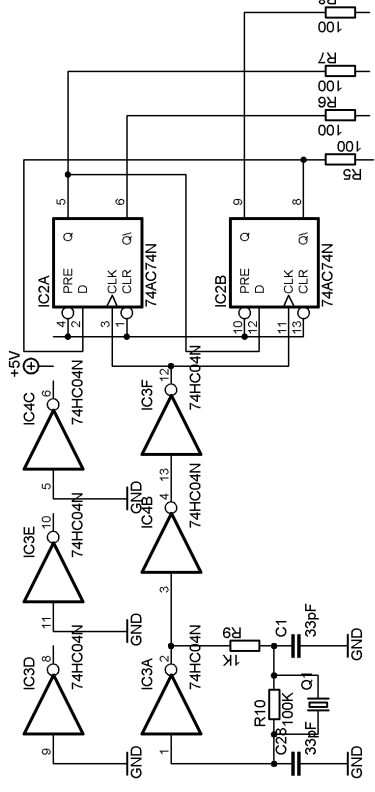
VALUES FOR 5th OVERTONE 115-120 MHz



Flo max 125-140 MHz (see text)
 10 dBm (for max Flo)



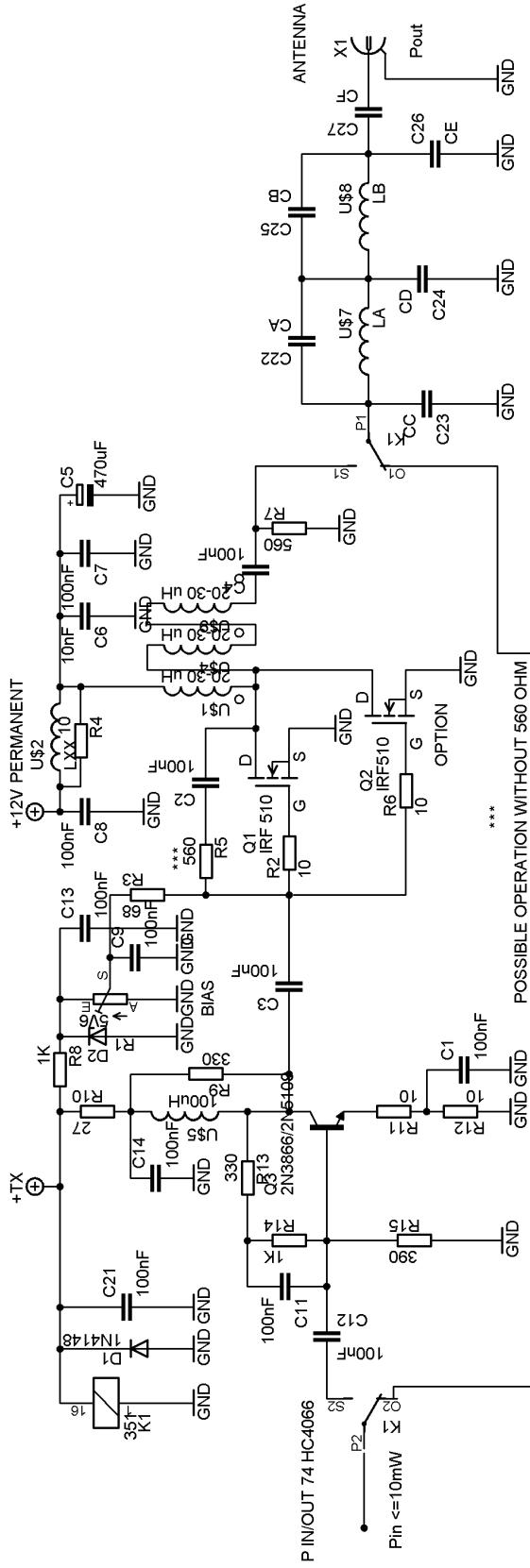
Q UP TO THE 30 MHz FUNDAMENTAL MODE



Q UP TO THE 30 MHz FUNDAMENTAL MODE

DIFFERENT OSCILLATORS FOR AVALA-01 ,DR2A+ AND DR2A++ -YU1LM

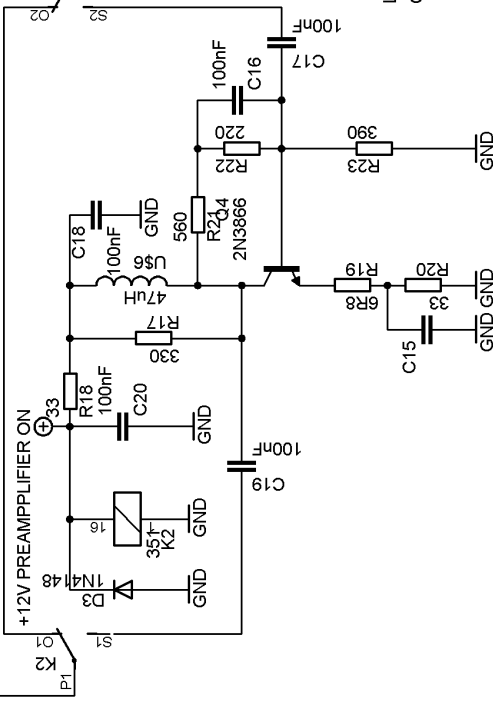
POWER AMPLIFIER 1.5-30 MHz (50 MHz) 4.5-3.5 W(2 W 50 MHz) SINGLE TRANSISTOR(TRANSFORMER 1:4)
WITH 2 PARALLEL FET Pout 6-10 W(TRANSFORMER 1:9)



POSSIBLE OPERATION WITHOUT 560 OHM

BAND	LA	LB	CA	CB	CC	CD	CE	CF
1.8 MHz	3.35	5.86	240	360	2700	3300	91	1000
3.5 MHz	1.8	3.35	120	150	1000+330	1800	100	470
7 MHz	.91	1.84	56	68	680	910	39	270
10 MHz	.57	1	47	47	470	470+150	27	180
14 MHz	.48	.84	27	39	330	470	18	120
18-21 MHz	.286	.544	22	12+12	390	270	22	100
24-28 MHz	.29	.53	12	15	150	180	3.3	68
50 MHz ****	.1	.16	18	22	100	180	12	39

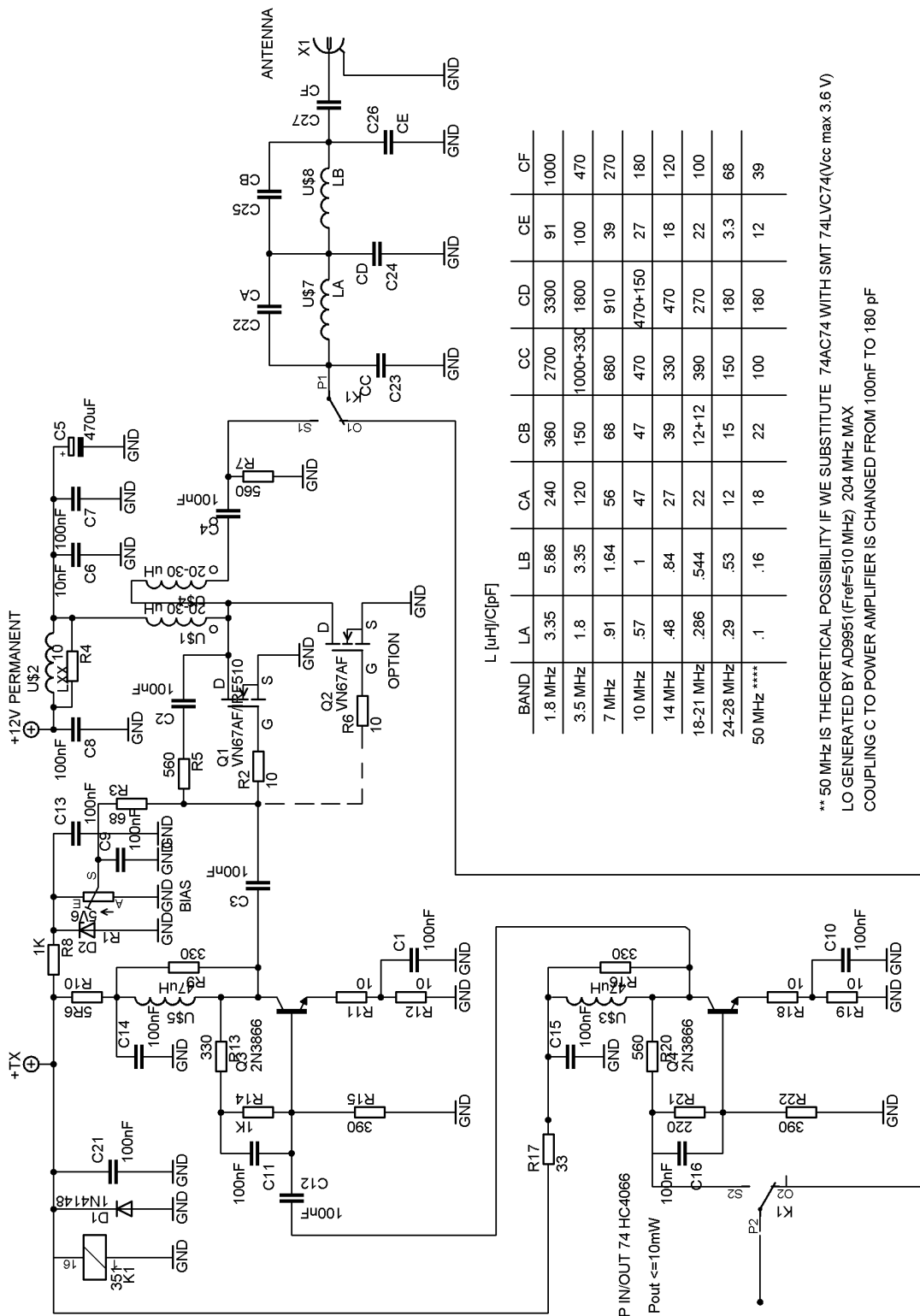
L [uH]/C[pF]



*** 50 MHz IS THEORETICAL POSSIBILITY IF WE SUBSTITUTE 74AC74 WITH SMT 74LVC74(Vcc max 3.6 V)
LO GENERATED BY AD9951(Freq=510 MHz) 204 MHz MAX
COUPLING C TO POWER AMPLIFIER IS CHANGED FROM 100nF TO 180 pF

AVALA-01 POWER AMPLIFIER AND RECEIVER PREAMPLIFIER YU1LM/QRP

POWER AMPLIFIER 1.5-30 MHz (50 MHz), 2.5-3.5 W(1 W 50 MHz) SINGLE TRANSISTOR
WITH 2 PARALLEL FET Pout 3-8W

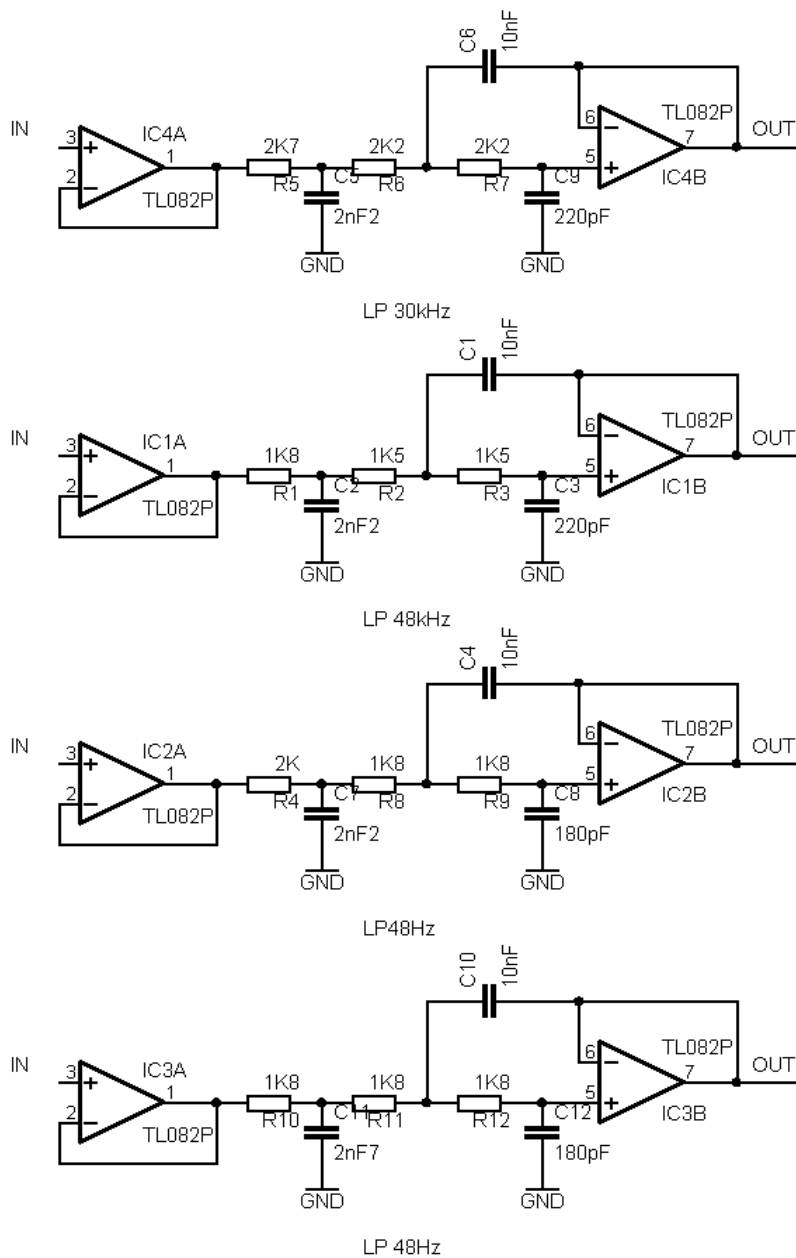


** 50 MHz IS THEORETICAL POSSIBILITY IF WE SUBSTITUTE 74AC74 WITH SMT 74LVLC74(Vcc max 3.6 V)
LO GENERATED BY AD9951(Freq=510 MHz) 204 MHz MAX
COUPLING C TO POWER AMPLIFIER IS CHANGED FROM 100nF TO 180 pF

All relays are OMRON G5V2 12V (1A relays) or similar.

only LP for 30 or 50 MHz and than add band filtering on new board with BP/LP for every band and built in LO generator such as DDS AD 9... series. LO and filer band control is possible from PC with software as Robert's WA6AFQ is. On board is single LO frequency generator realized with AC(HC) gates with possibility to work in fundamental and overtone mode I simplified this design to the maximum.

AVALA-01 POWER AMPLIFIER AND RECEIVER PREAMPLIFIER YU1LM/QRP



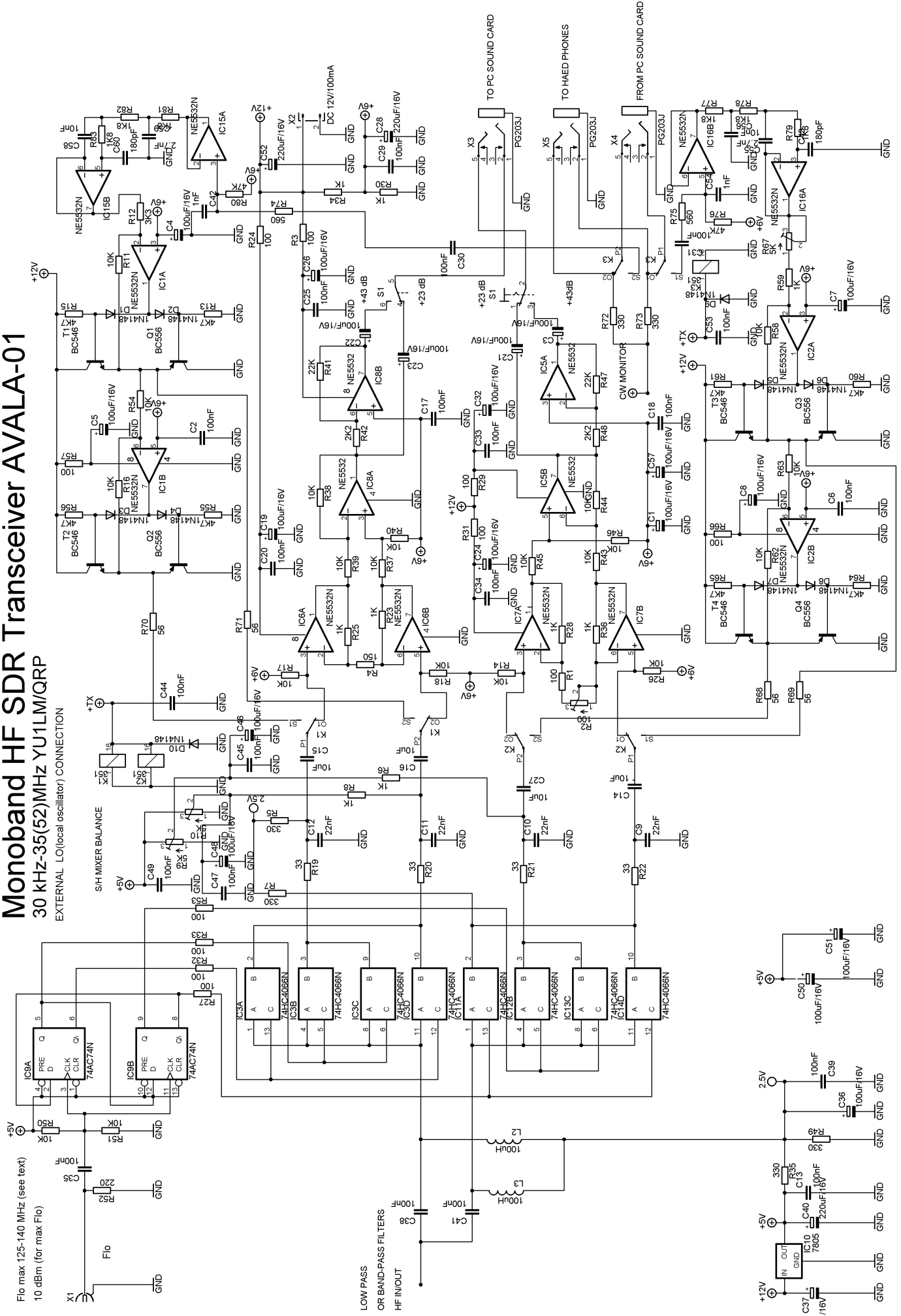
SDR transceiver has AVALA-01 input audio LP (low pass) picture above it is removing unwanted noise from SB card and PC in region 100 kHz and more. I calculated different LP versions to enable all to choose one realization according to the available components. It is important to notice that both I/Q branches must be the same and that built in components are matched very well. Unmatched components will cause phase/amplitude errors and because of that image rejection will be poor and lower than it is possible. Image rejection is changing as we change transmitting frequency from 0Hz to +/-24(48,96)kHz. These errors are bigger when we are approaching to the -3dB roll off frequency. Attenuation at the 100 kHz is around 15 dB and it is enough for clear RF output spectrum. Even better results are possible if we reduce RX/TX bandwidth to the 48 KHz (+/- 24kHz) (with 96 and 192 KHz SB sampling rate even) then spectrum is extremely clear no evidence of SB and PC noise. Bigger SB sampling rate will reduce RX noise but also the sharpness of filters (BP and LP) in software!

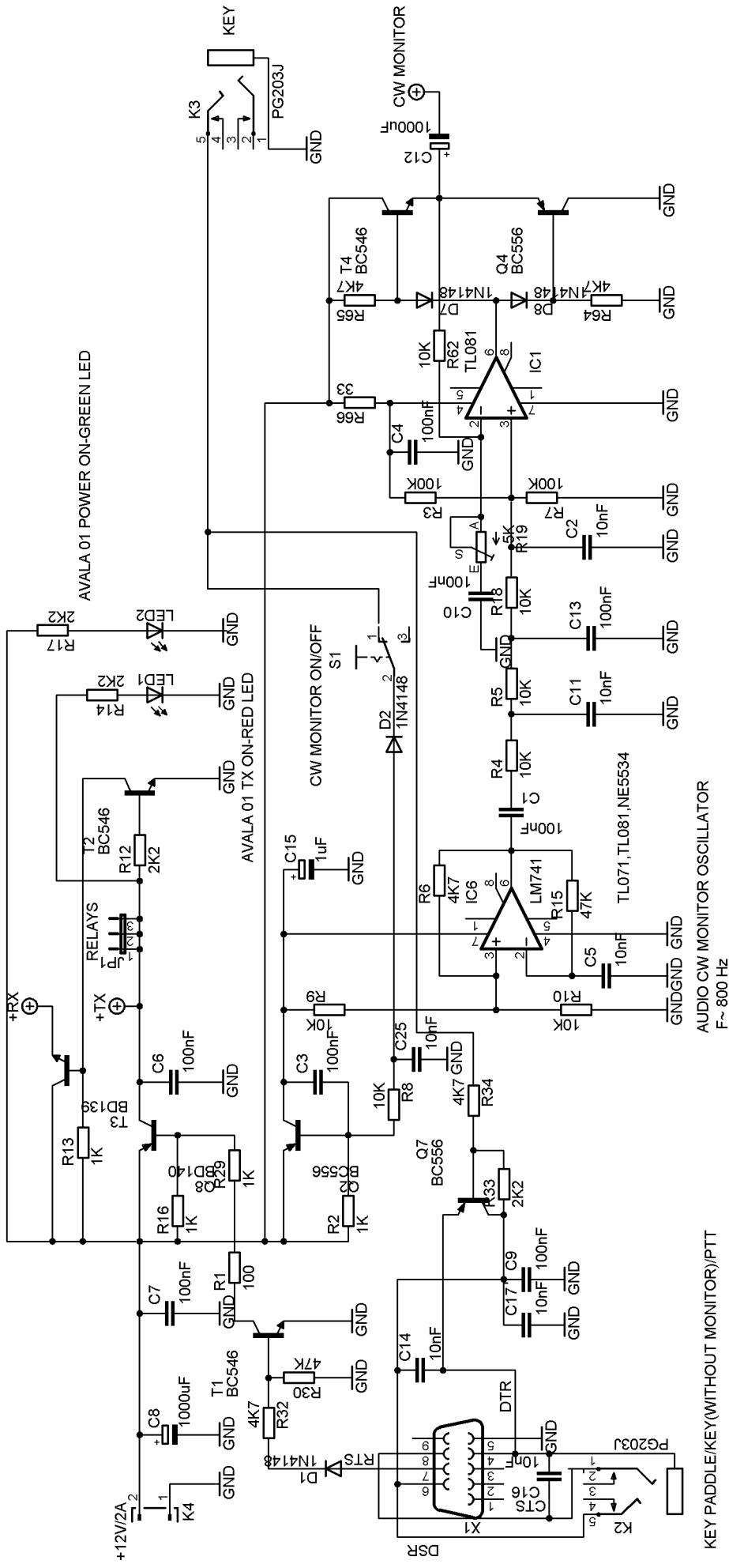
At first sight AVALA-01 and ADTRX2 are looking too much complicated for people without radio design experience with a lot of components. This is only partly true at first glance because both SDR transceivers are 90% or more audio and very easy repeatable non critical designs.

Monoband HF SDR Transceiver AVALA-01

30 kHz-35(52)MHz YU1LM/QRP

EXTERNAL LO(local oscillator) CONNECTION

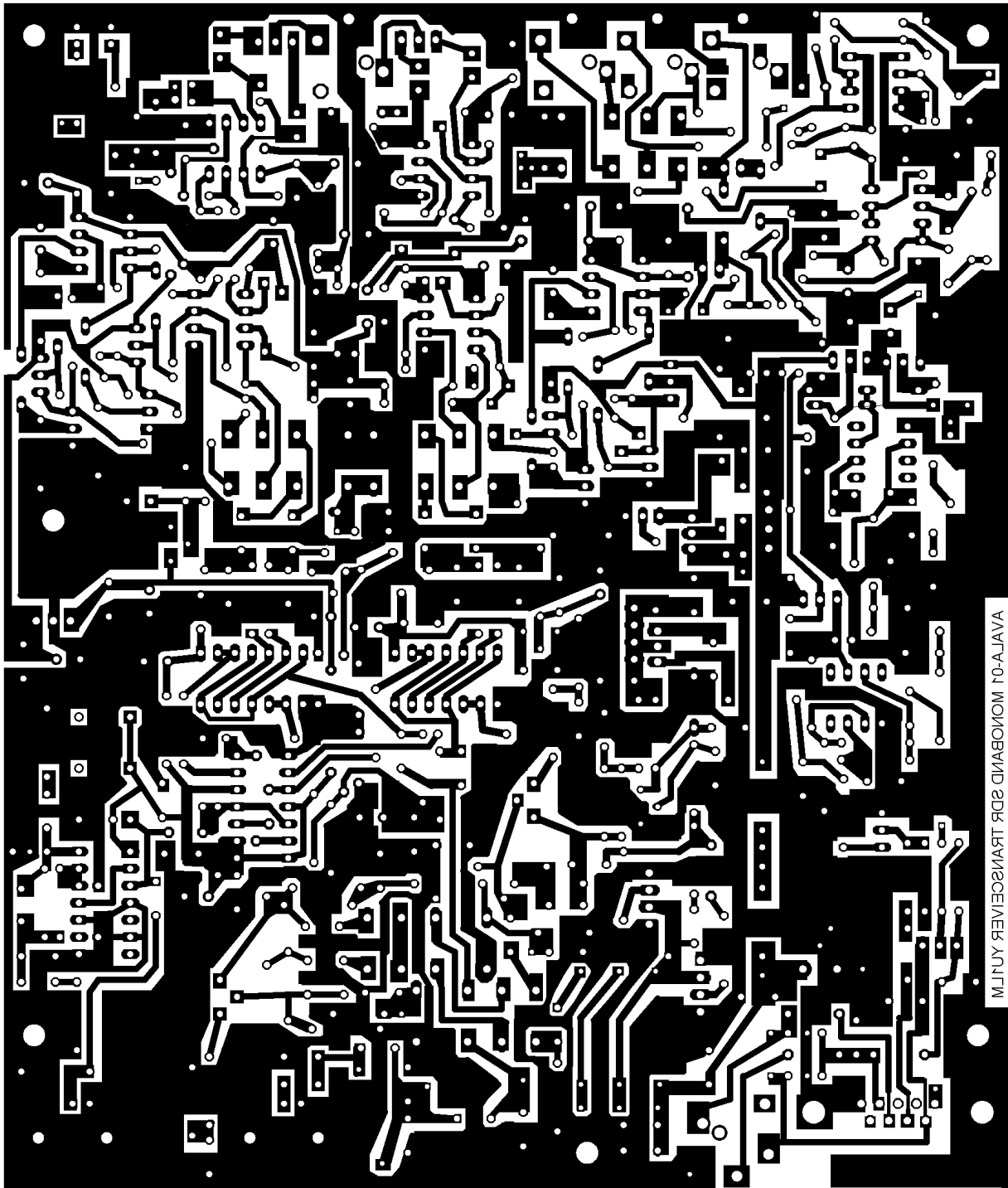




AVALA-01 PC CONTROL + CW MONITOR - YU1LM

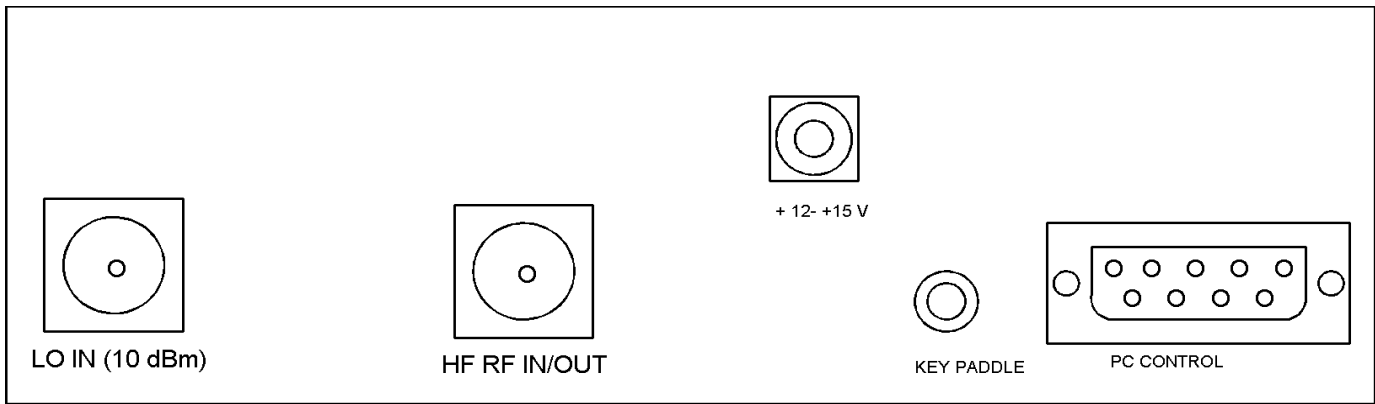
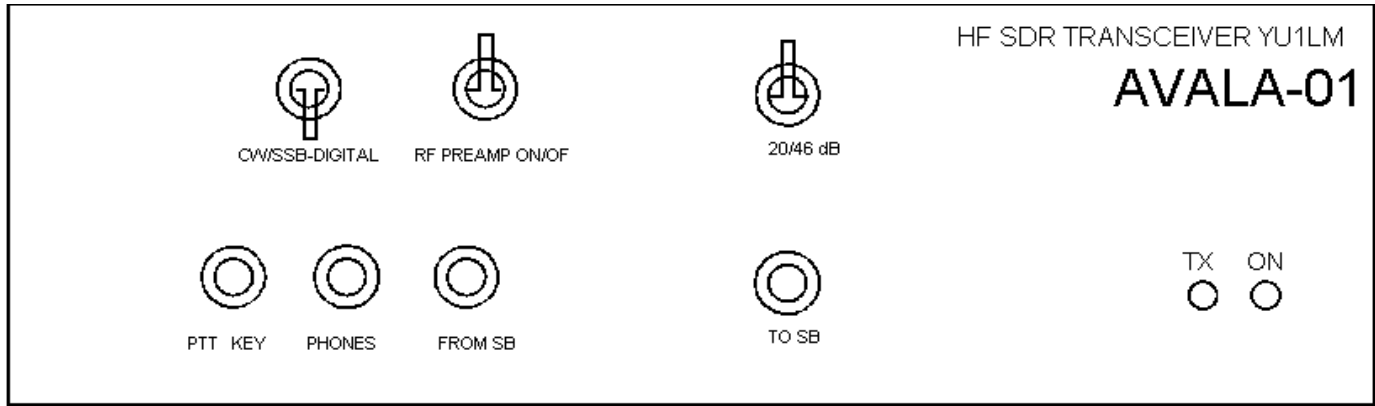
AUDIO CW MONITOR OSCILLATOR
F~ 800 Hz

KEY PADDLE/KEY (WITHOUT MONITOR)/PTT

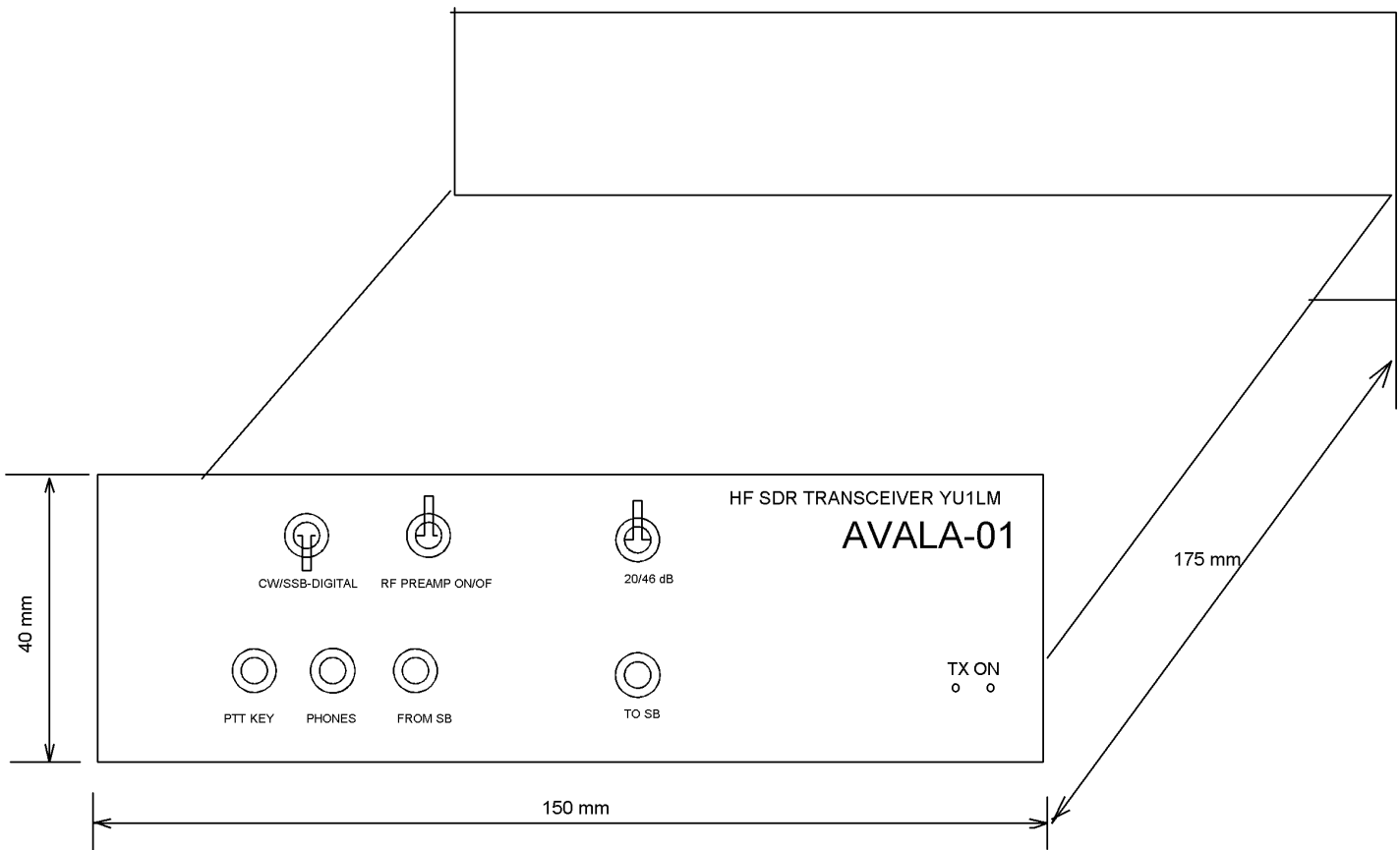


Single side PCB dimensions 175 x 145 mm

I am proposing next AVALA-01 look at drawing down:



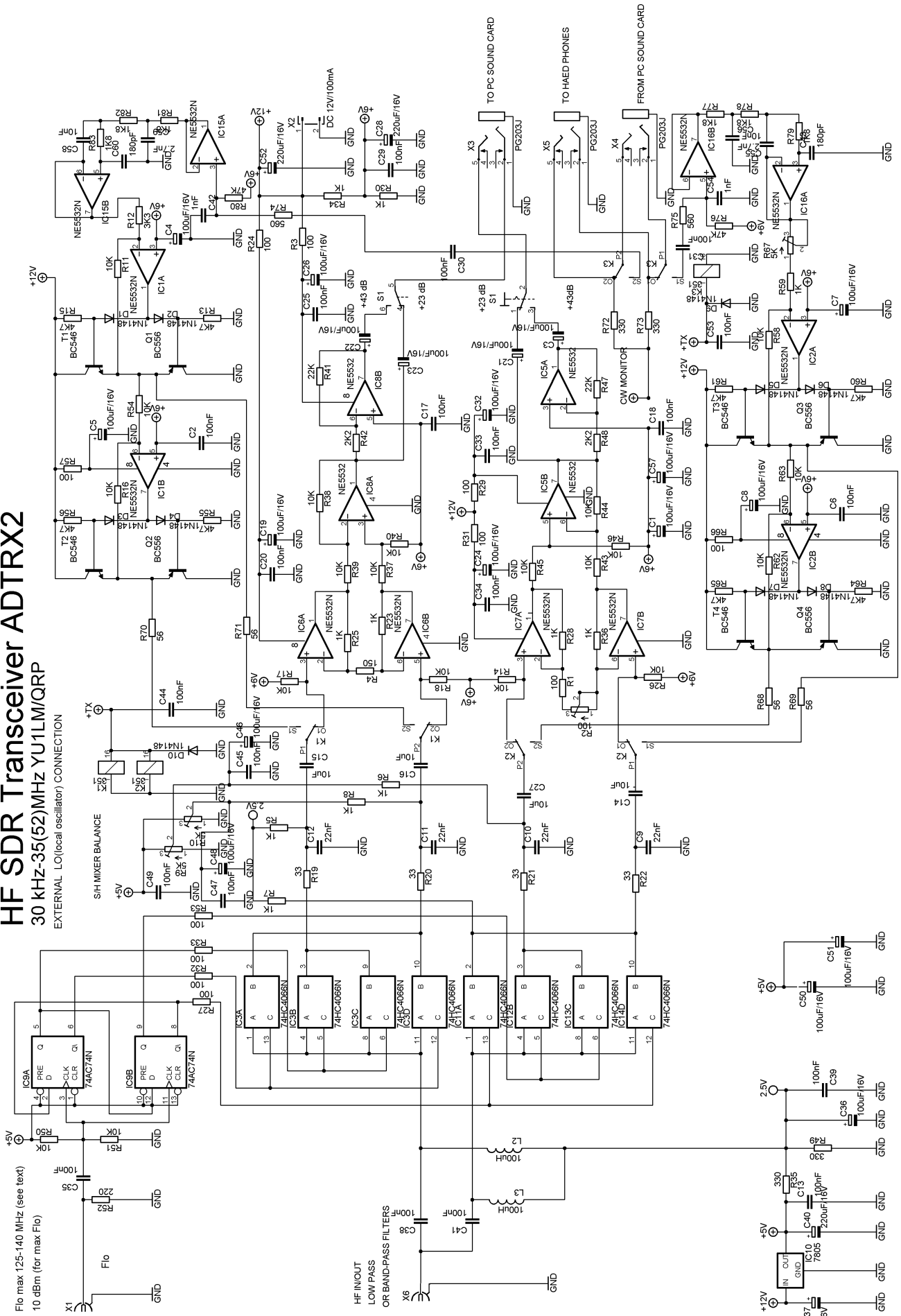
A complete AVALA-01 look is down with PCB front and back panel assembly.



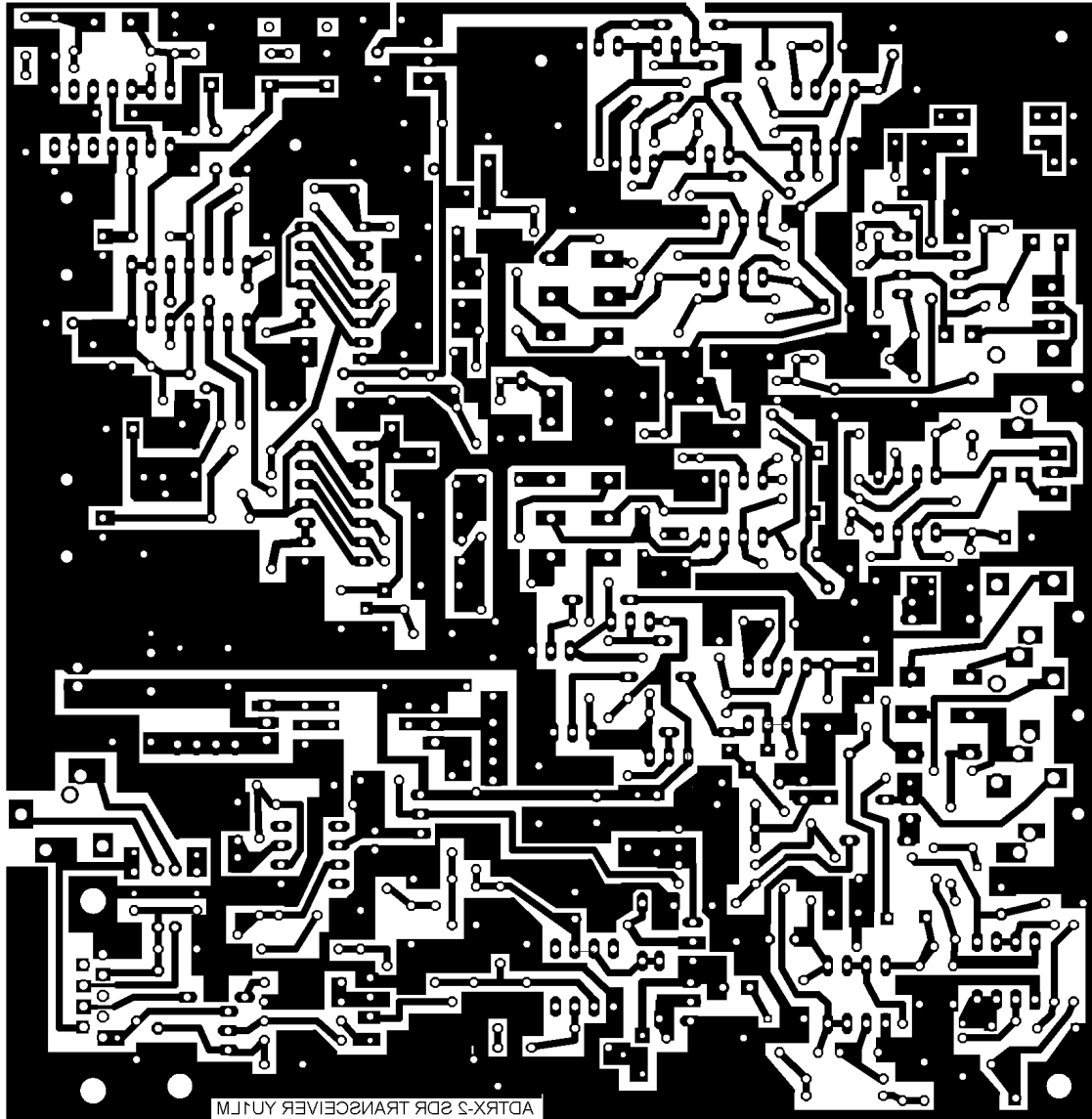
HF SDR Transceiver ADTRX2

30 kHz-35(52)MHz YU1LM/QRP

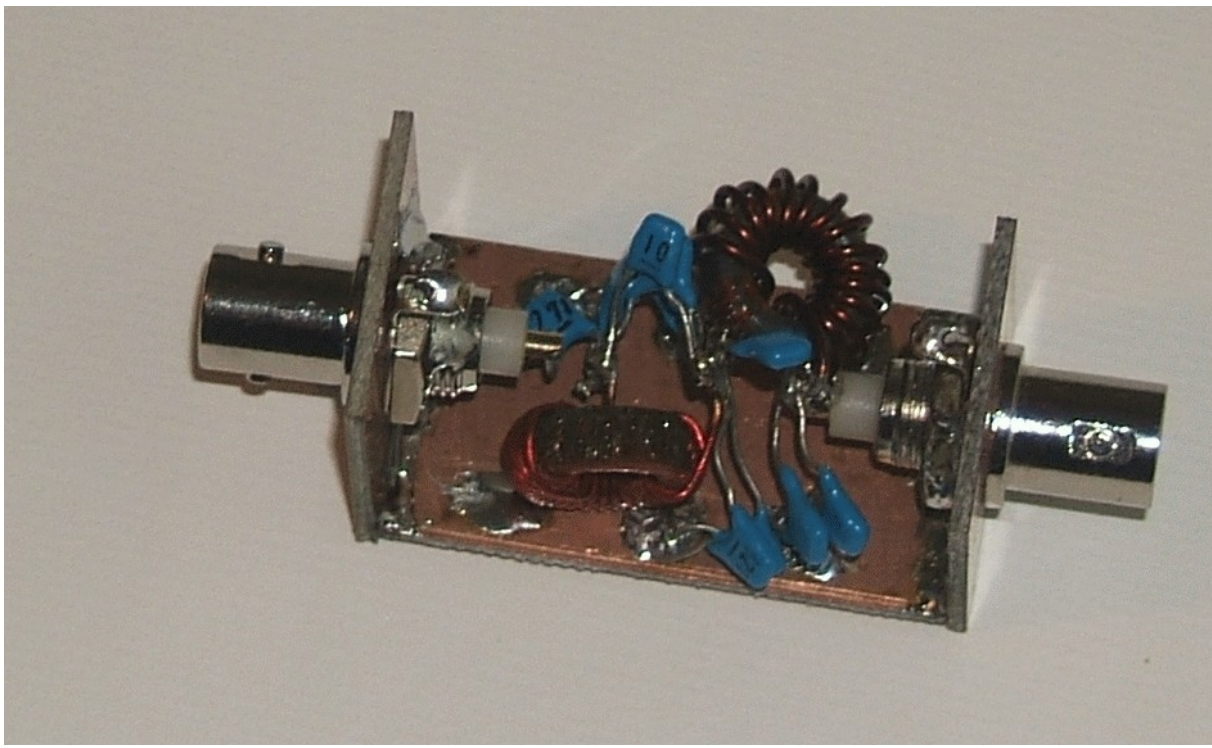
EXTERNAL LO(local oscillator) CONNECTION



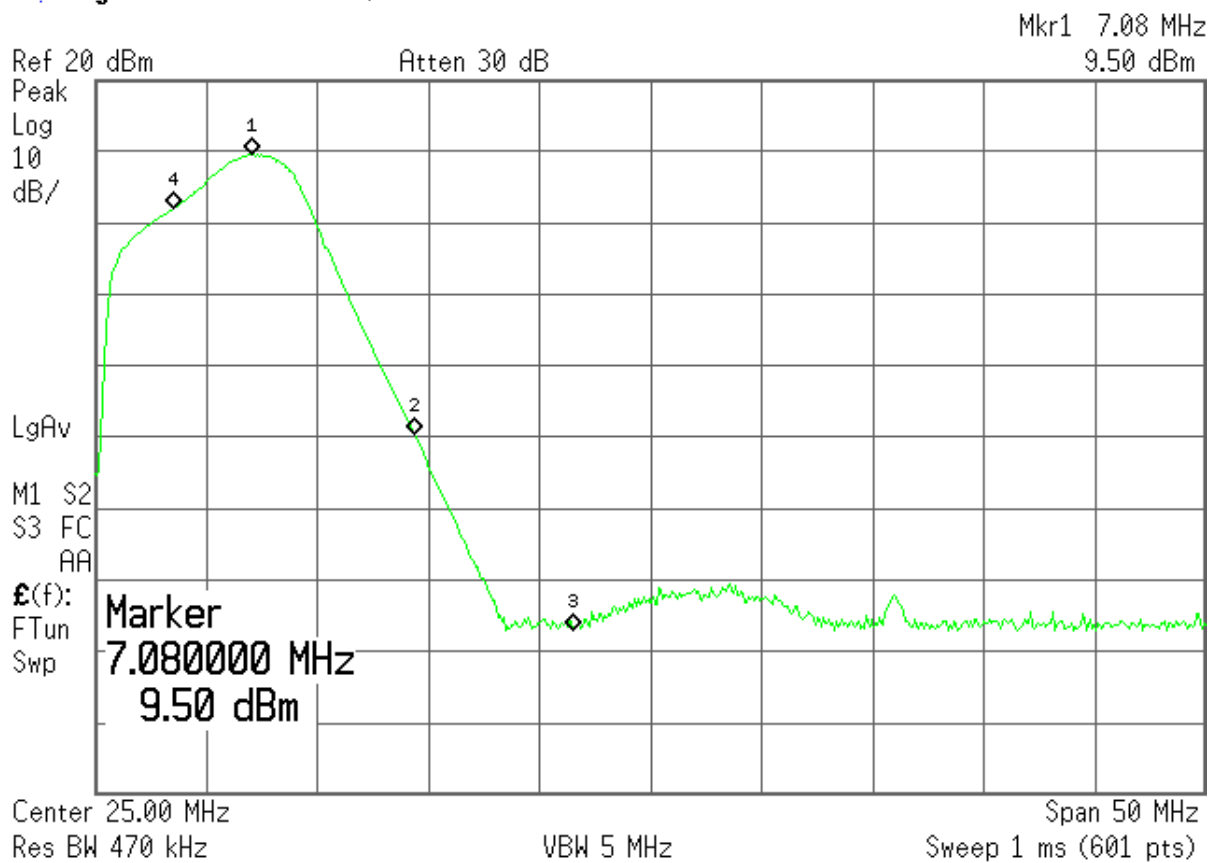
ADTRX-2 Schematics part 1



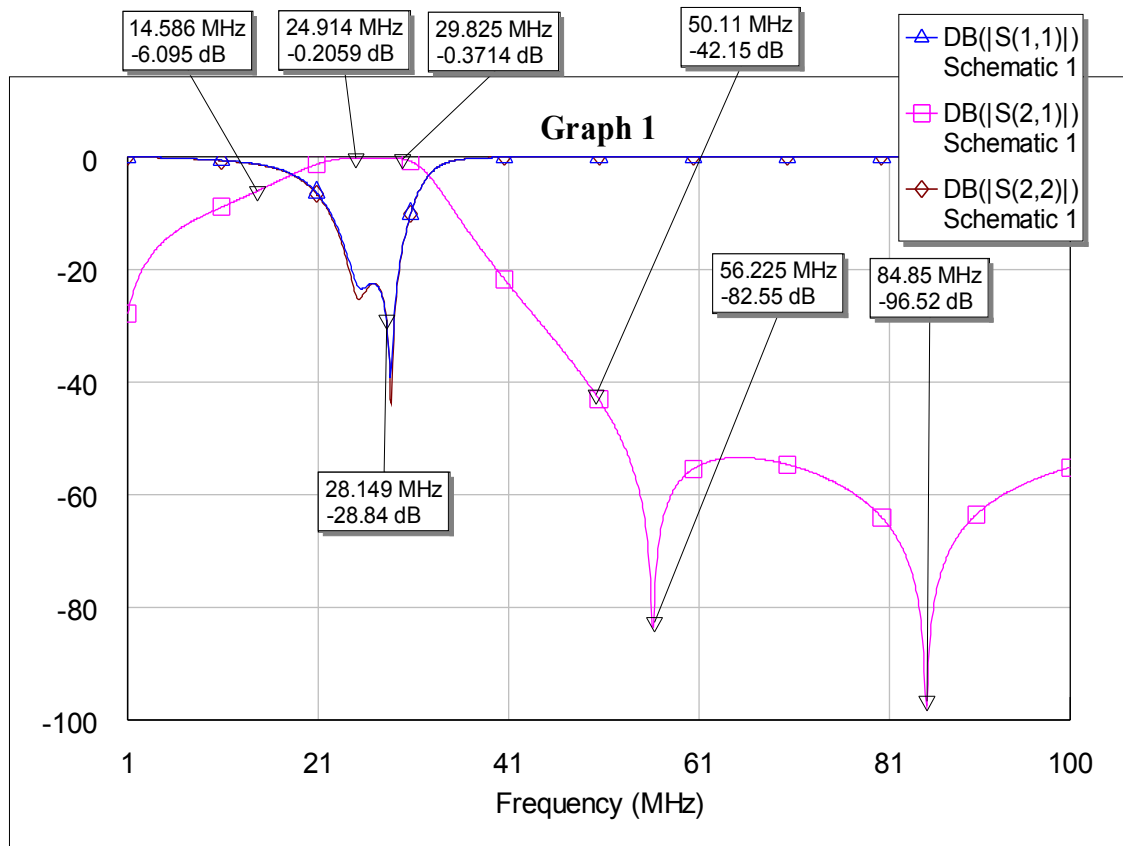
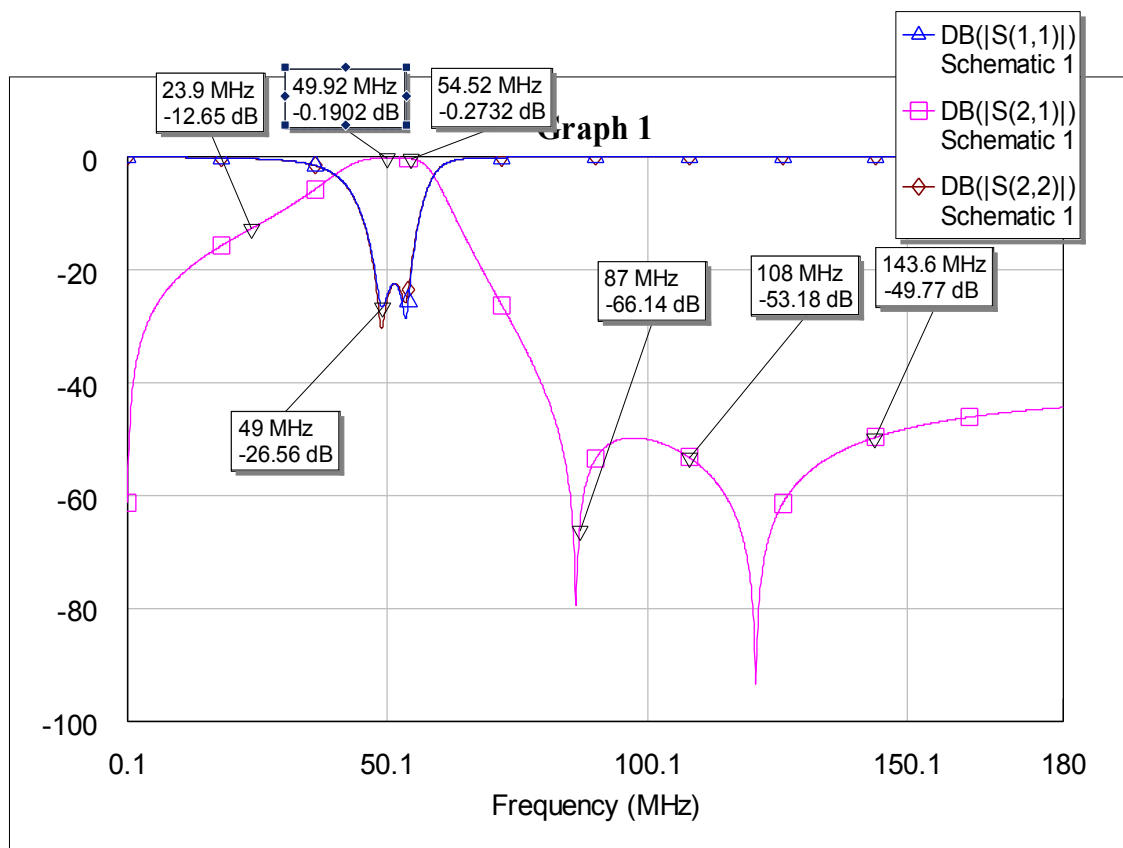
AVALA-01 Transceiver selectivity I made with simple peaked LP (low pass) used in transmission and receiving branches simultaneously with only 2 coils. LP and BP realization is simplified to the end. It is possible also next realization in SDR transceiver for all HF bands. We can add only LP to 30 MHz (50 MHz) or short LP/BP on AVALA board and then add individual band LP/BP-s realized on separate board (see picture BP/LP realized for 7 MHz and amplitude transfer characteristic down) or build new board with DDS LO generator for example AD9951....and filter control. This design is in the preparation, complete HF + 6m multi-band transceiver AVALA-02 with complete PC control.

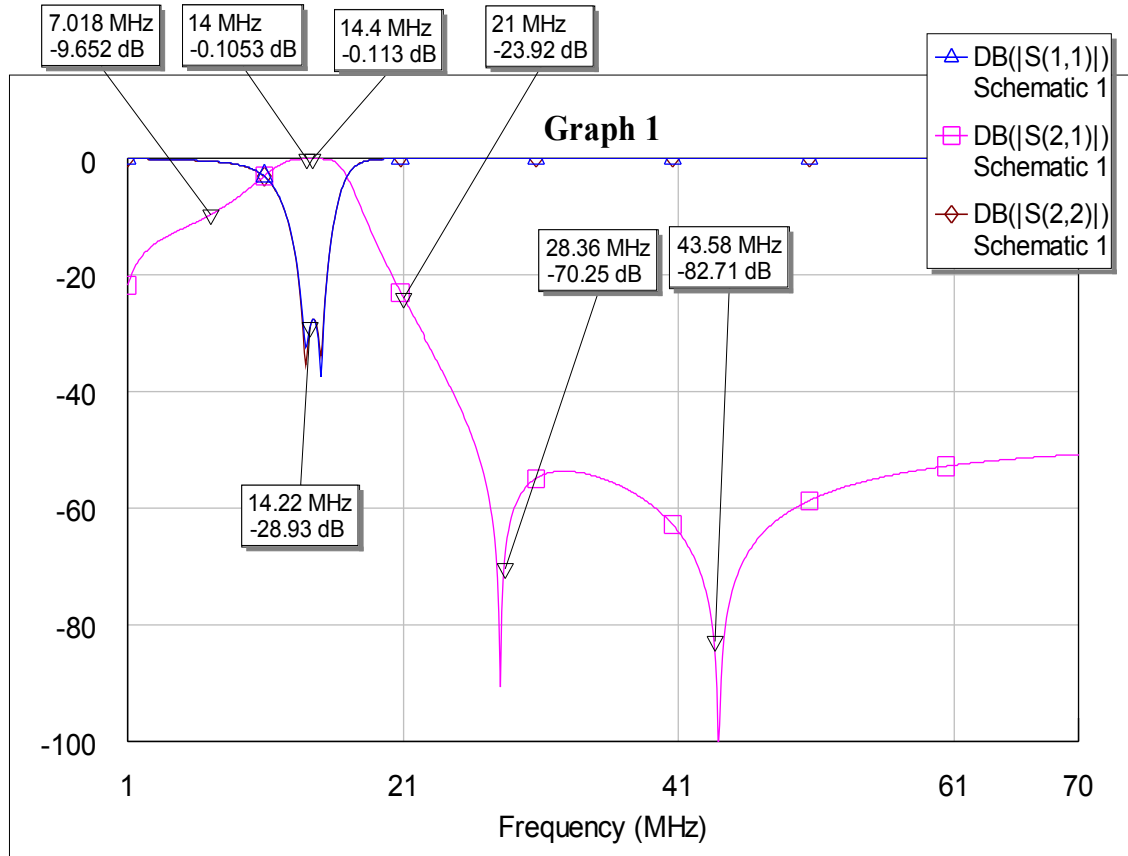
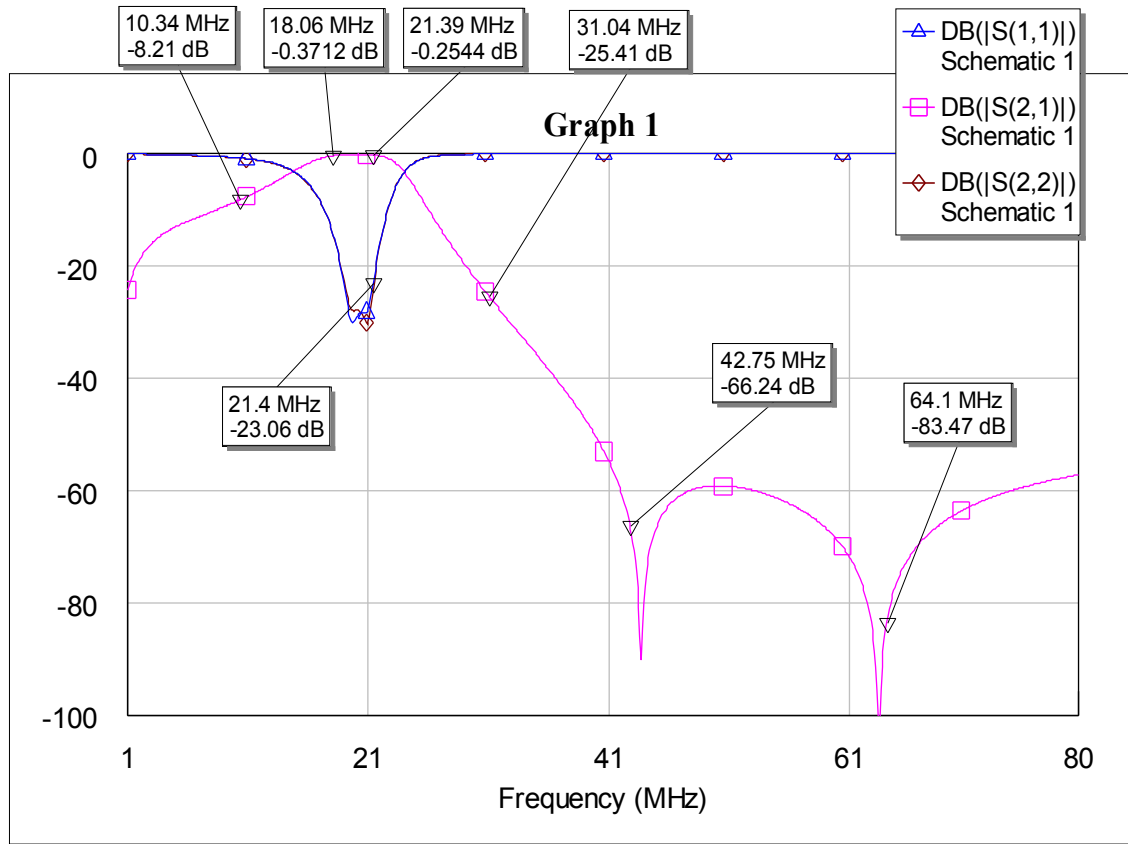


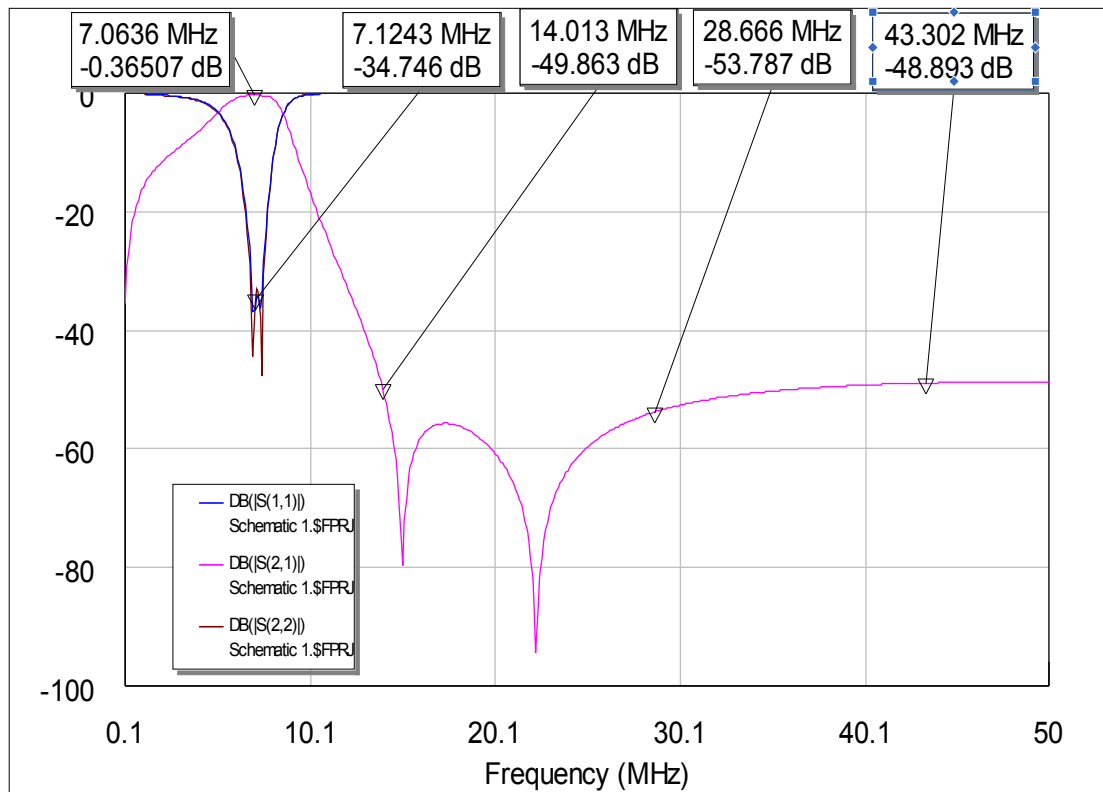
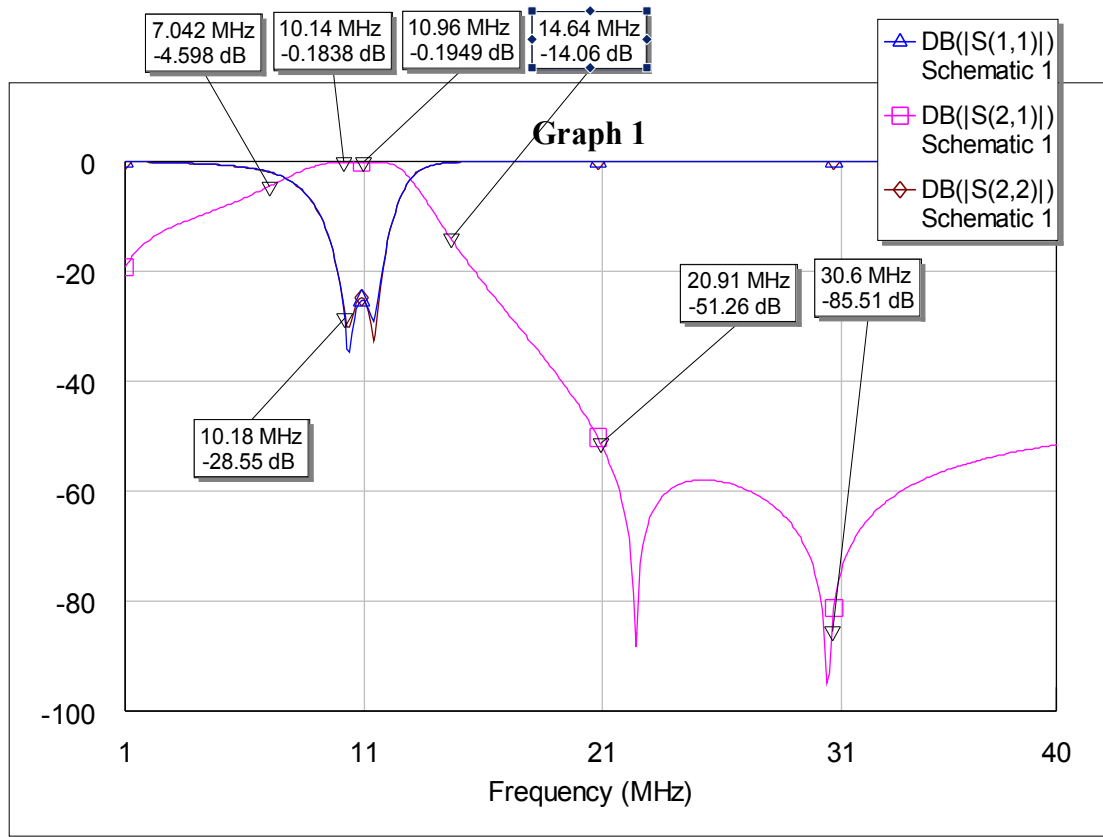
* Agilent 18:09:39 Jul 26, 2007

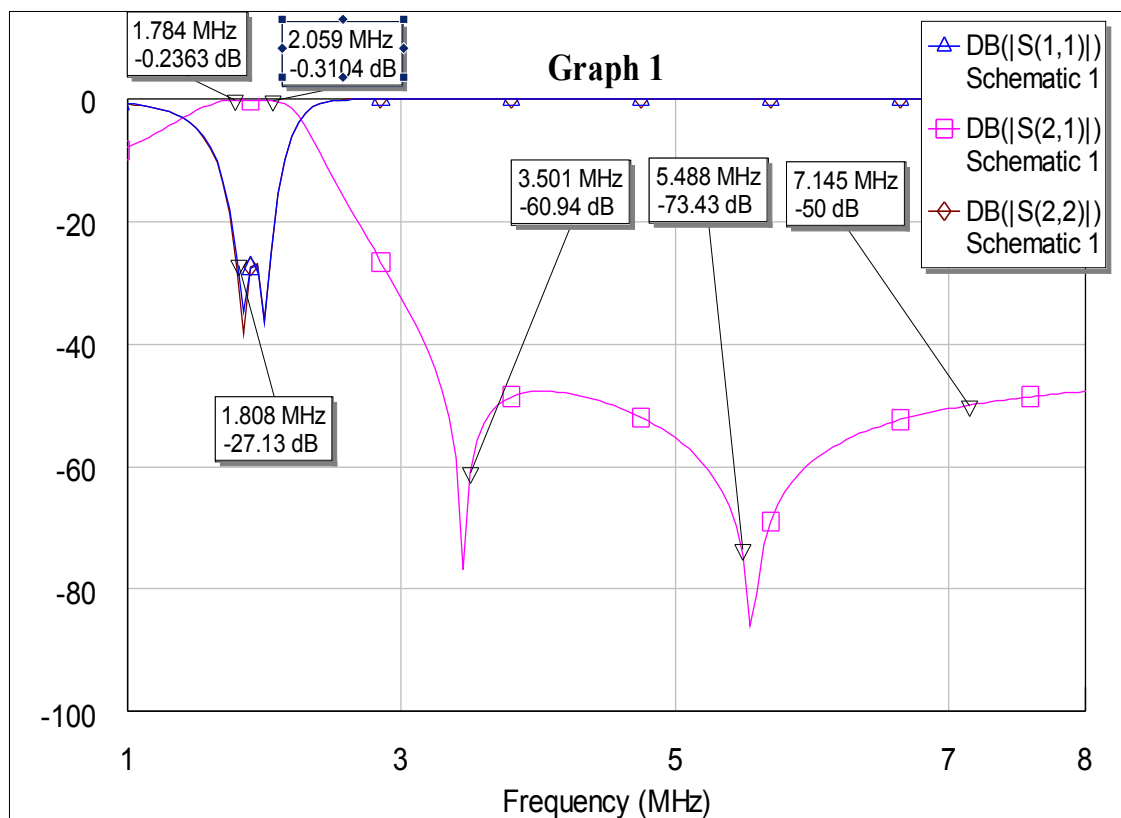
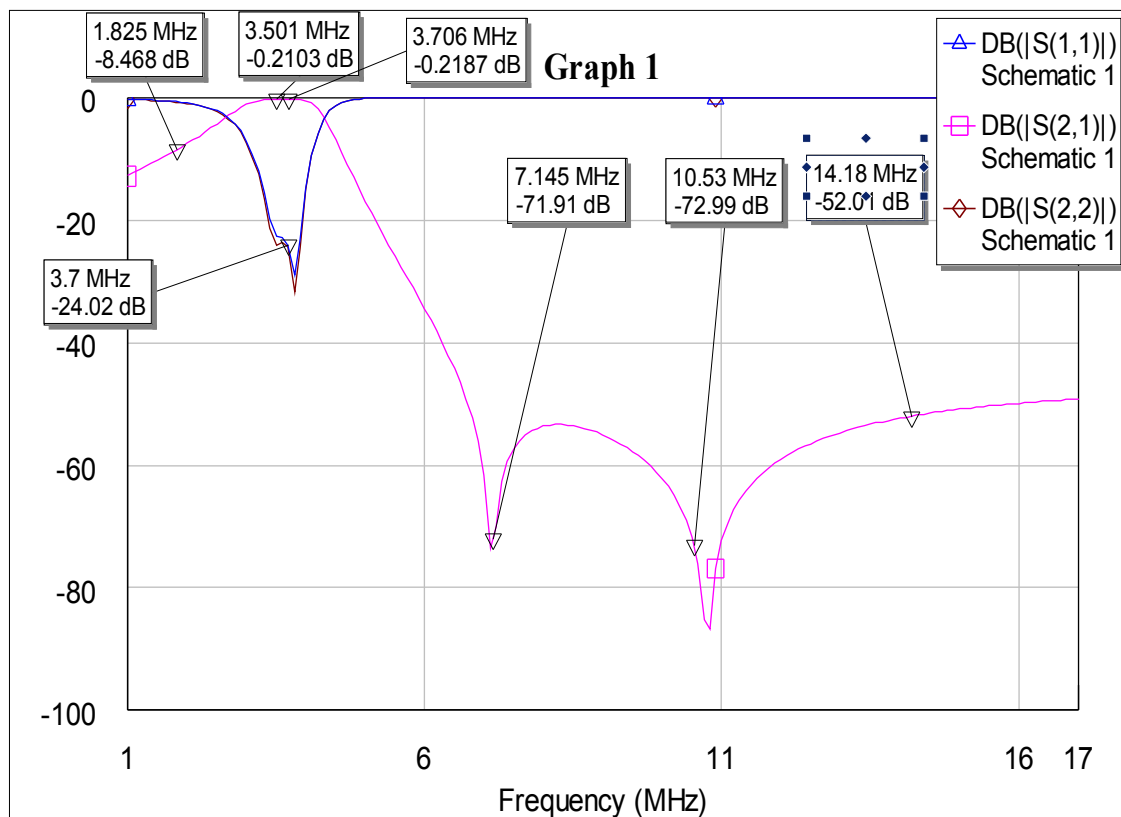


Pictures above are example of the BP/LP filter for 7 MHz which is similar to the proposed in article. The transfer characteristic I obtained at AS screen with function max hold and swept generator with output power +10dBm.

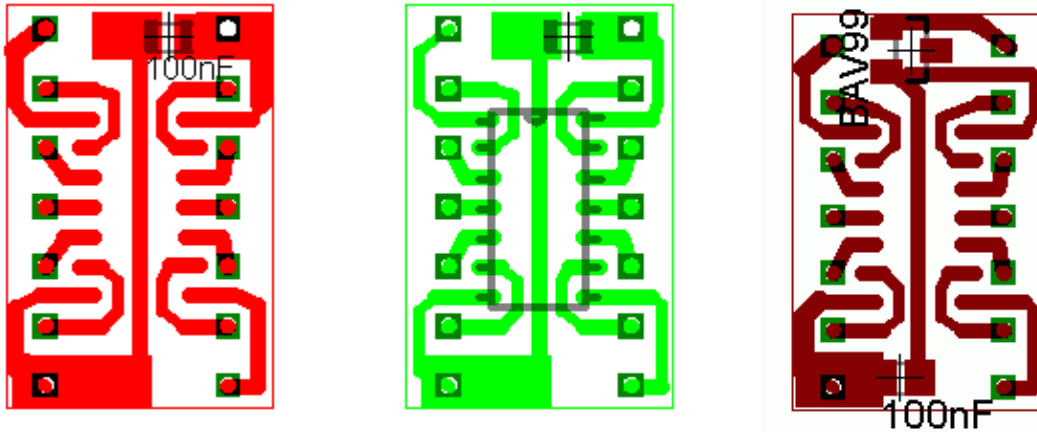








Adapter PCBs will enable operation at 50 MHz such I do in DR2A+ and DR2A++ receivers. Solder with resistor leads through holes PCB to the DR2A++ PCB bottom side first. Adapter PCBs are at top side. After SMT adapter was soldered first than solder SMT chip 74LVC4066 take care Vccmax = + 5V!!!!!!



Single side SMT adapter PCBs (for 74LVC4066 and 74LVC74 right) top view dimensions are 21 x 11.5 mm

SMT adapter single side PCB size is 11.4 x 20.7 mm for 74LVC74 (Vcc max is 3.6 V for Fin max 300 MHz) Vcc max = + 5V with adapter PCB we will enable work up to 52 MHz!!!!!! I didn't made this test I checked combination 74LVC4066 + 74AC74 only and they worked very well to the 35 MHz with 74LVC74 according to the data sheet it will not be problem work to 52 MHz. In case that we use 74LVC4066 change resistors 330ohms at S/H outputs with 82 Ohms. Similar improvements is possible also in all my previously designs with SMT adapter PCBs.

Measuring results which I made with HF S/H SDR transceiver AVALA-01(receiving results are the same for ADTRX-2 except that it hasn't RF preamplifier) are:

1. Receiving range is going from 30 kHz to 35 MHz for DIL ICs version .With built in last modern technology like 74LVC74 and 74LVC4066 and external LO to 52 MHz.
2. IIP3 32-35dBm and it depends from setting and used programs. I changed RX amplification distribution. For first stage I increased gain to the 26 dB and decrease gain to 20 dB for the second stage (all measurements done with 24 bit sound card).
3. MDS -116 to -122dBm also with 24 bit external USB SB card Audigy NX2 with RF preamplifier on -132 to -134 dBm.
4. Image rejection is from 35 -65 dB with hardware realization only
5. Sensitivity 0.15-0.2uV for 10 dB S/N ratio, max S/N ratio I measured was 72dB.
6. SFDR (Spurious free dynamic range) is 93-94 dB, this results are with signals spaced 5 kHz and more. Results are not changing very much if we spaced two signals to classical 20 kHz or more (with new modern SMT ICs 74LVC4066 SFRD is 95- 97dB).
7. 1 dB compression point is + 5 dBm!!!
8. Pout between 3-5W (2W 50MHz) with single FET amplifier .for ADTRX2 output power is +10 dBm (I made one QSO with this power with LY station HI!)
9. Carrier suppression is -60 dBc(1.8 MHz),-56 dBc(3.5 MHz),-52dBc(7MHz),-48dBc(14MHz) and -36dBc(28MHz) all results were achieved without built in components for additional carrier suppression or software help.

10. Image rejection -55 dBc at 1.8 MHz to -40dBc at 28 MHz.

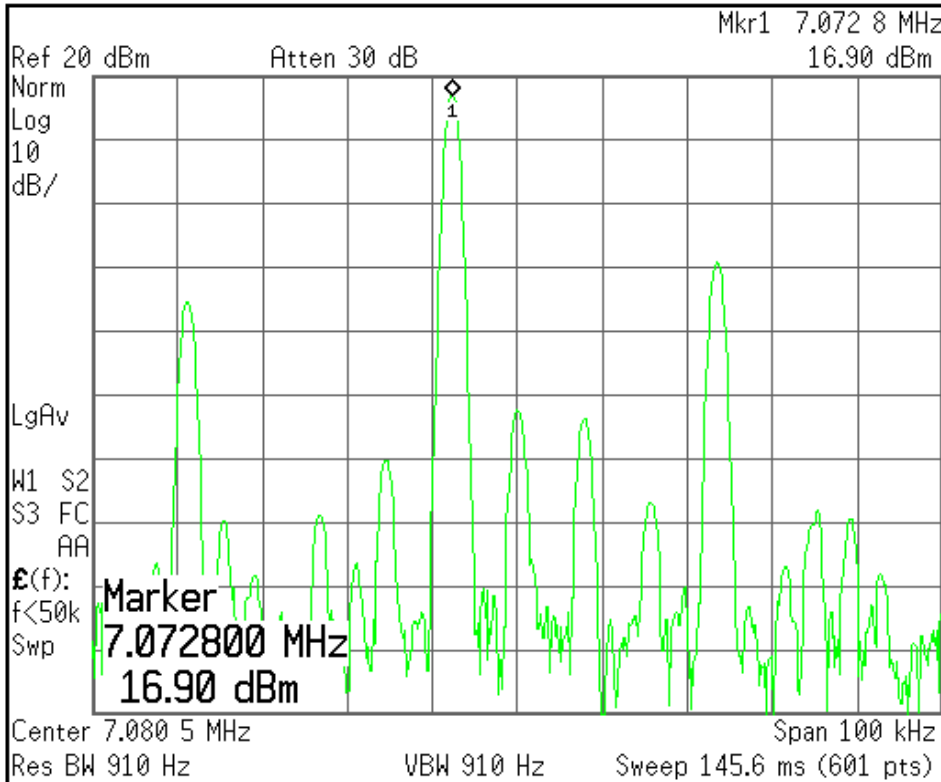
Some excellent performances aren't without other side:

1. First and very big disadvantage is 4 times higher LO. For 52 MHz maximum input frequency LO frequency is 208 MHz.
2. Image rejection is changing through receiving bands and results are done for frequencies 12 kHz from central receiving frequency. There is also degradation in image rejection as frequencies are increasing.

For external LO it is necessary input level to be around 1 Vp-p min for safe operation (for lower LO drive operations are not sure especially for higher LO frequencies)!!! Simple test for 74HC4066(74LVC4066) correct operation is when we measure with DMM (digital multi meter) Vcc/2 or 2.5 V +/-0.5 V at control pins 12, 13 and 5, 6 If it isn't true we have a problem with input LO level or input ICs 74AC74 or 74HC4066 (74LVC4066).

AVALA-01 and ADTRX2 adjustments are simple and done in few steps:

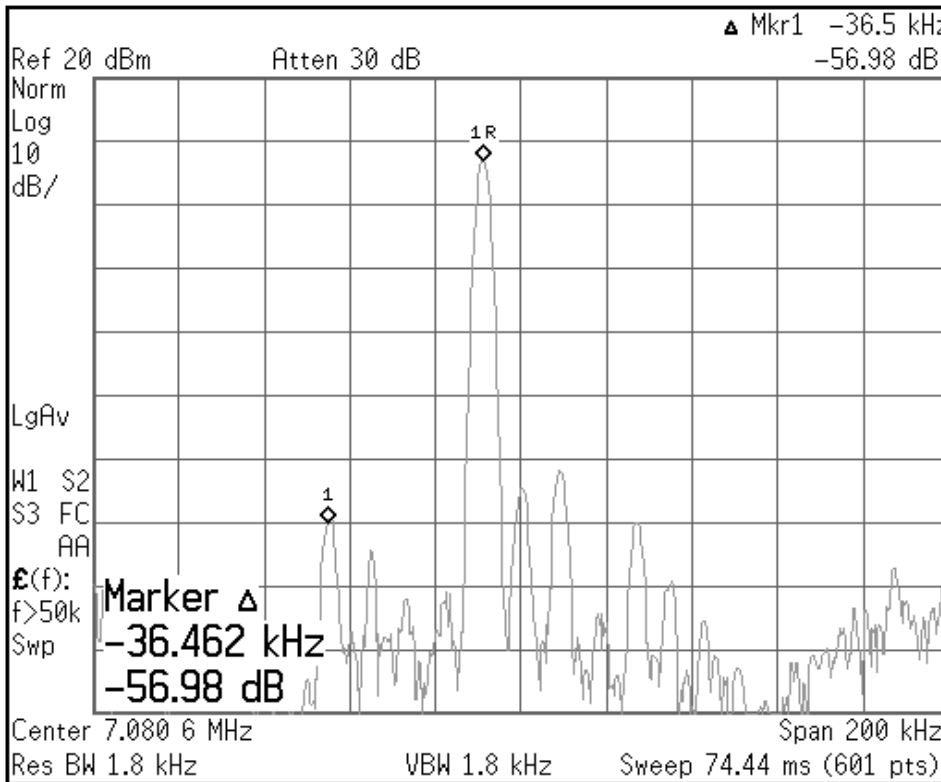
1. RX- Adjust with universal instruments DMM (digital multi meter) that is resistance in feedback RX OP AMP NE5532 potentiometer $56 + 100 = 150$ Ohms
2. RX- Find some strong signal in the air 12 kHz away from zero or connect signal from signal generator to the input of DR2A++ and with 100(500)Ohm potentiometer adjust the minimum unwanted image signal in some SDR program. Additional image rejection adjusts in SDR programs if this possibility exists function such as skew in Alberto I2PHD programs.
3. TX- Connect key at front panel and adjust with 5K pot CW monitor level in headphones.
4. TX- Connect output from SB card at start test tone 12 kHz and then adjust with 5K pot that both I/Q branches are the same. The easy way is to not connect output relay to the +TX voltage!!!. In this case AVALA-01 and ADTRX1 are working at the same way. Of course it is necessary to adjust in software that SDR transceiver is going to transmission (with PTT or KEY control). It is possible to connect output from AVALA-01 or ADTRX2 to some RX (Take care to not connect output to RX when is AVALA-01 TX (power amplifier) with RF power because test RX will burn out!!) with some attenuator 20 dB and more and then monitoring signals at carrier frequency and image frequency adjust their minimum. Also this is way how to adjust output/input BP/LP to the maximum at carrier frequency and their minimum IL. Of course the best way is to use SA(spectrum analyzer) and NA(network analyzer) for these adjustments but this way is not common for the most homebrew. Also adjust output level from SB card for maximum linearity monitoring frequencies of carrier relative to central or zero frequency (if it is 12 KHz then check +/-24,+/-36,+/-48,+/- 60 kHz) . See how spectrum can be if it isn't transceiver adjust well(at first sight it looks OK because image is reject very much but high order nonlinearity are very high!) Please see how some spectrum from AVALA-01 or ADTRX2 look likes down at photos.
5. TX- Next step is to connect power supply from output relay and adjust quiescent current without signals from SB card . I find that best results are for FET IRF510 ~500mA. After this adjustment connect antenna or dummy load(or high power attenuator) to the AVALA-01 output and if it all OK observing current connect output from SB card. If it all OK transceiver is ready for SDR communications all types. If you have instrumentation observe transmitted spectrum to do some fine correction if it necessary or listen on control RX with separate antenna how spectrum looks like measuring signals on "S" meter.



Peak Search
Next Peak
Next Pk Right
Next Pk Left
Min Search
Pk-Pk Search
Mkr → CF
More 1 of 2

File Operation Status, A:\SCREN299.GIF file saved

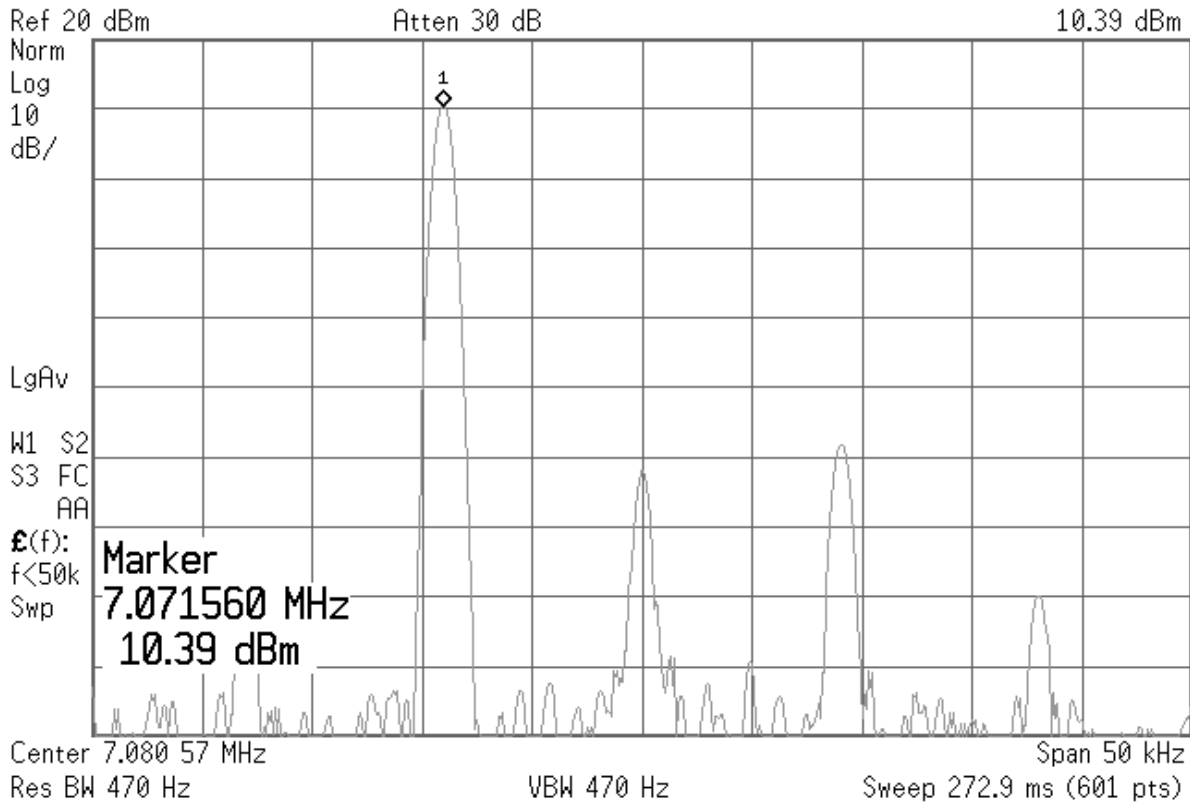
AVALA-01 Pout 6W case driver overload with not adequate quiescent current for FET!



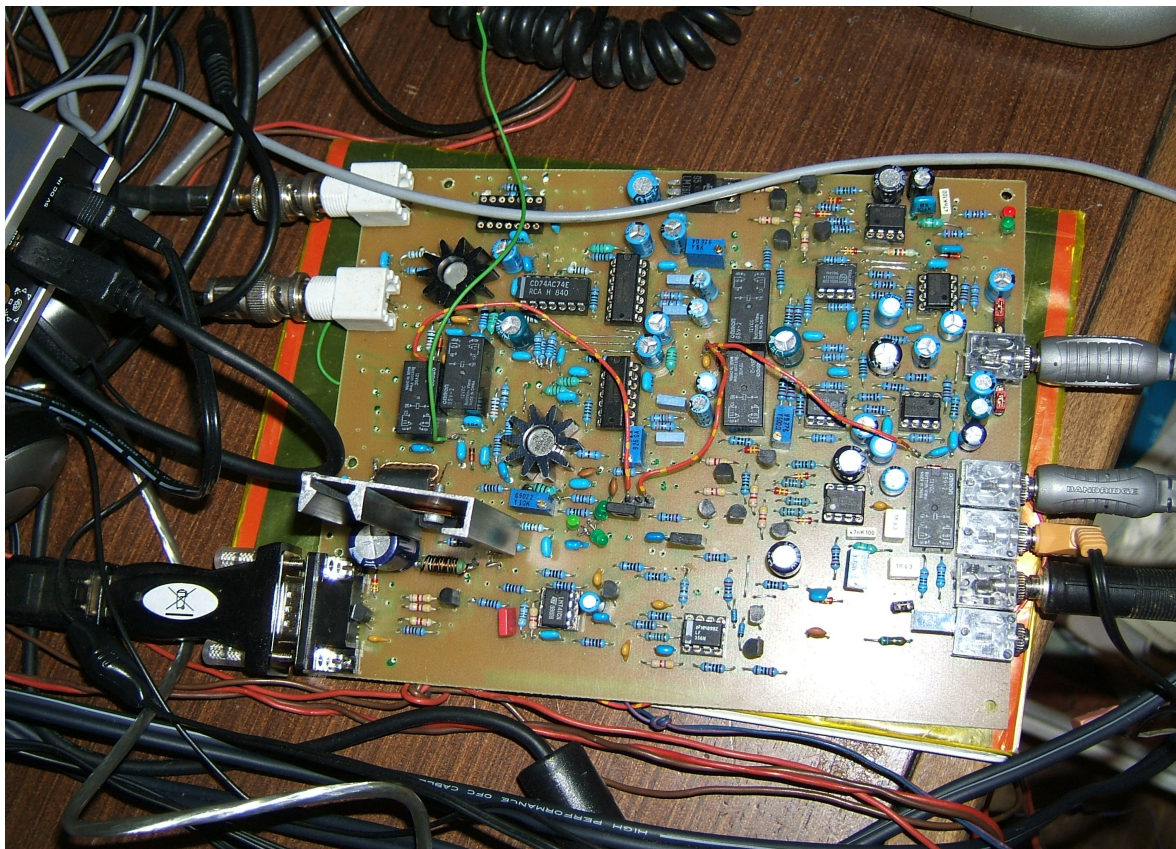
Marker
Select Marker 1 2 3 4
Normal
Delta
Delta Pair (Tracking Ref) Ref ▲
Span Pair Span Center
Off
More 1 of 2

File Operation Status, A:\SCREN314.GIF file saved

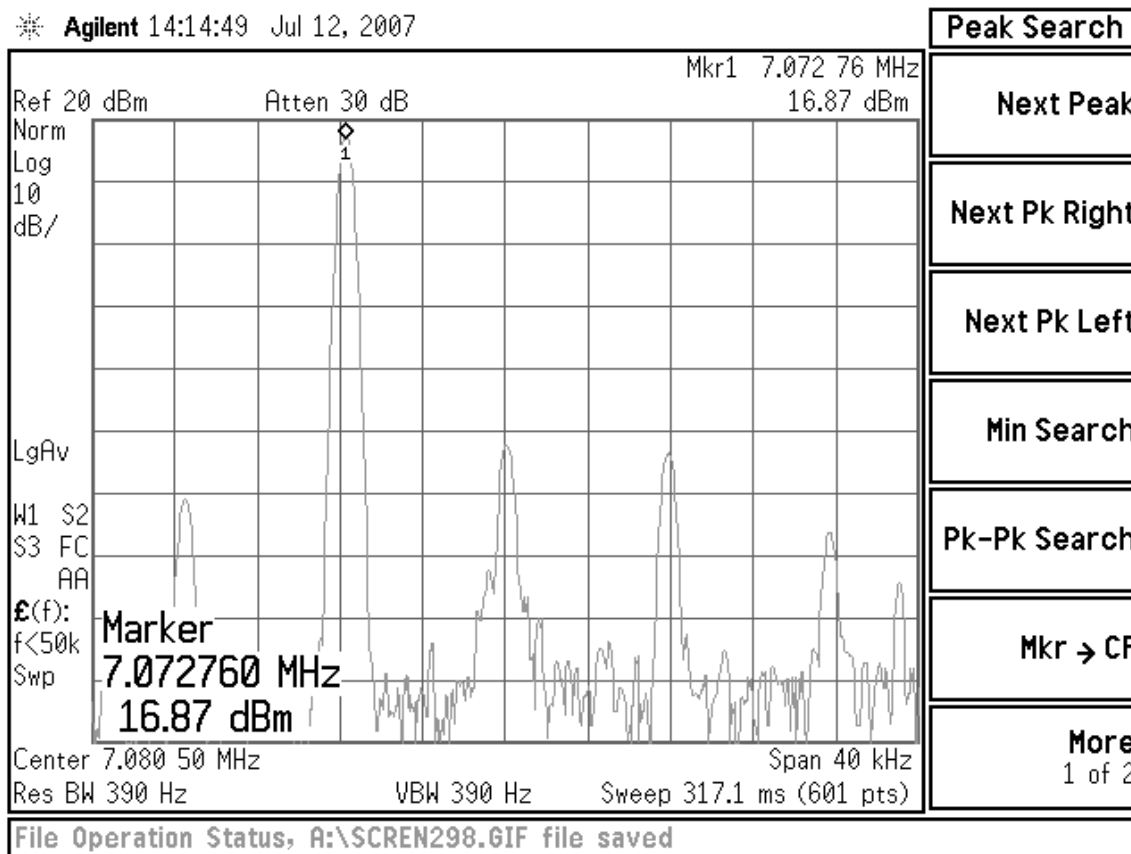
ADTRX2 output spectrum wide Pout=8 dBm (see wideband noise at +100kHz reason why I added input AF LP)



ADTRX2 output spectrum Pout=10 dBm narrow



First AVALA-01 SDR transceiver prototype built by author Tasa YU1LM/QRP without input AF LP



AVALA-01 Pout=6W adjusted correctly (ATT attenuation is 20.9 dB)

My practical experience with AVALA-01 at bands in SDR transmission is next. I made near 500 QSOs on all bands from 1.8MHz to 14 MHz. Near 400 QSOs CW , 60 QSOs in digital modes and 30 QSOs SSB. I took part in WPX CW contest as single band QRP 7 MHz category. Final score 255 QSOs for near 16 hours operation with my multiband 84m horizontal delta loop. I worked all continents except VK/ZL. Receiving with AVALA-01 RX was really amazing like operation at VHF/UHF bands no any evidence of overload clear and crispy sound especially in Alberto's WINRAD because of that I with great impatience expecting transmission software from Alberto I2PHD promised long time ago. Most number of QSOs I made with Duncan's M0KKGK software. It is very good software easy way for operation with benefits of use only one SB card especially in connection with my favourite software MULTIPSK for digital modes from Patric's F6CTE.

Contest SDR operation was very extraordinary experience for me. I used Tom's N1MM software for contesting and Duncan's M0KKGK for SDR operation. PC screen was splitted at 2 parts top for M0KKGK and lower for N1MM. CW control was done with 2 USB-Serial adapters one for SDR RX/TX and second for keying. PC was Pentium 4 2.4 GHz and processing delay was small enough that I can pass in PILE-UPS even with keying speed over 40word/pm. I am QRP operator and I am spending most of my contesting time in searching correspondents SDR gave me quite new benefits that I can very easily find stations and monitoring what is happening at the band. I saw that is possible make virtual connection between PowerSDR software and N1MM and than operation will be good enough even for big PILE-Ups.

Now I am very close to my start goal design and realization competition grade HF SDR transceiver. With addition new board with all band BP/LP and LO generator with DDS ICs AD9951 or better AD9912 PC controlled it will be completely new transceiver name AVALA-02. I hope that I shall be close to target as soon as possible after I find AD9912.

I wish you successful AVALA-01 and ADTRX2 realization and I apologize for some possible mistakes. I made great effort to make SDR projects and share them with all who are interesting for. Anyway send me your comments positive or negative, results or photos of your realization please.

VY 73/72 and GL in SDR homebrew Tasa YU1LM/QRP

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