

HAM Sample and Hold SDR (Software Defined Radio) Receiver for SSB ,CW ,AM ,FM, DRM..On HF (30 kHz to 70 MHz) in Connection With PC Sound Card– Make it Simple as Possible with Outstanding Performances –Part 1

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I touch my dream. Probably you are asking what I am talking about. I am HAM for more than a 35 years and professional RF designer near 25 years. My dream, for the all this years was to make receiver and later transmitter design for HF to 50-70 MHz simple as possible without any real RF parts few coils Xtal filters...Of course all with very good specifications high IIP3 and very big SFDR . With great technology progress and PC powers this dream is near to be finally realized. Did you ever build HF receiver 30 kHz to 70 MHz without any coil and that it work exceptionally? You are thinking that isn't possible probably but answer is that it is possible and answer is here in the articles This project is part of my try to made SDR transceiver for HF HAM bands in connection with PC sound card and PC DSP processing .Everyone who try to make DC (direct conversion) receiver knows how hard it is to build receiver with good opposite side band rejection or very sharp clear sound and changeable sharp bandwidth filter. Try this in field of mathematical calculation you will realize that is everything much easier but you have to be educated with much sophisticate knowledge to do it. This is series of three parts, three articles are:

Parts 1 very simple receiver DR1 without image rejection receiver very simple but good start with the SDR receiving. This receiver was discovery for me and I spent a lot of time in testing and listening with it in different circumstances. It can be realized for the very short time for the one afternoon and it is very cheep. Present of image are not a big disadvantage like in DC direct conversion receivers but something about that later. This receiver can be used as a second or first IF in receivers after crystal filters which very easy reject unwanted image also. As demodulator it is far superior to the all other types common used demodulators in practice. I never didn't measure S/N ration in HF CW receiver 80 dB before it. DR2 is also very simple and very good I/Q HF receiver frequency are limited to the 30 - 35 MHz with built in components.

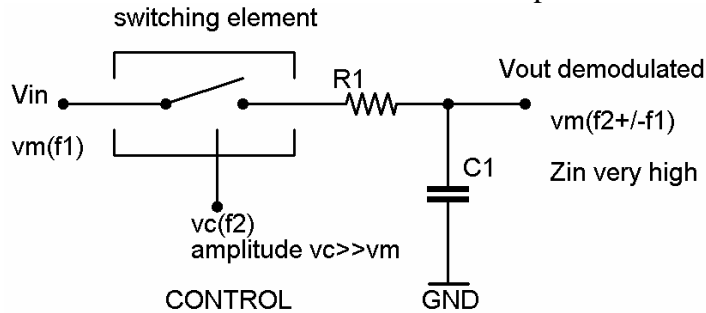
Part2 DT1 DSB modulator for frequency from 30 kHz-70MHz with very good linearity and DT2 SSB/CW or any other modulation SDR HF low power transmitter which can be generate with I/Q signals.

Part 3 SDR HF receivers DR1A (Advanced) similar to the DR1 but with improved specifications the same situation is with DR2A improved DR2

DR1 is one of version receivers which I tested first and a lot of time and which working really good or I can say better fantastic. I shall describe practically realized

receiver with fixed oscillator in reason of simplicity but it is very easy keep on receive all other HF frequency with adding VFO (for example based on DDS chips like AD 9850, AD9851, AD9854... or some other local oscillator) You can find a lot of solution on INTERNET for the VFO (at the end is a big list sites for this subject reference 4). This project is similar in some aspects to the Gerald AC5OG SDR1000 design but it is a much simpler... I suggest all who want to understand better SDR radio subject to read excellent articles from Gerald AC5OG (reference 2) and well known VHF/UHF designer Leif SM5BSZ (reference 3).

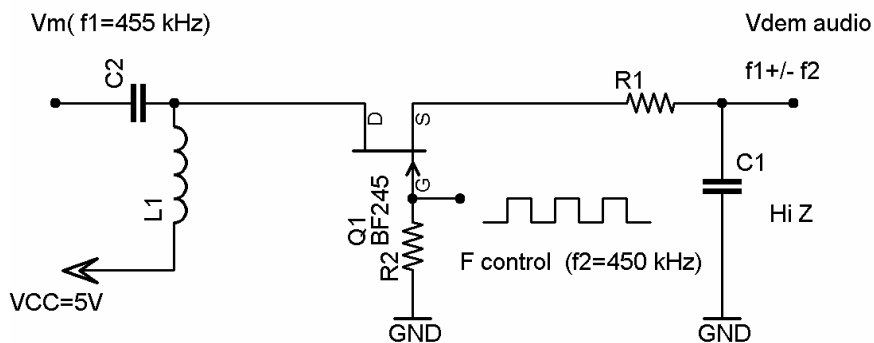
Let's start from the beginning. In the late 80's I have professional task to design detector for the some linear modulations with extremely small DC offset. All my trays were unsuccessful until I didn't use sample and hold detector see below which is really



SAMPLE AND HOLD DEMODULATOR

very simple.

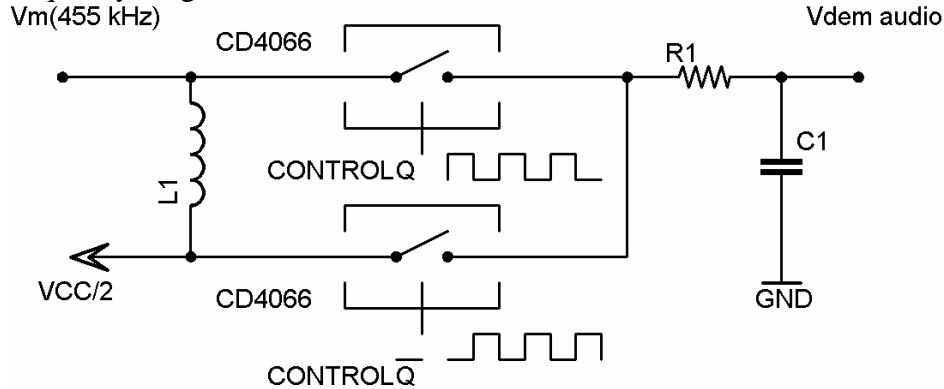
I try to make it at last IF of 1 MHz but FET which I used U310..... didn't work well I try some other DG... switchers and at the last I tried CD 4066.



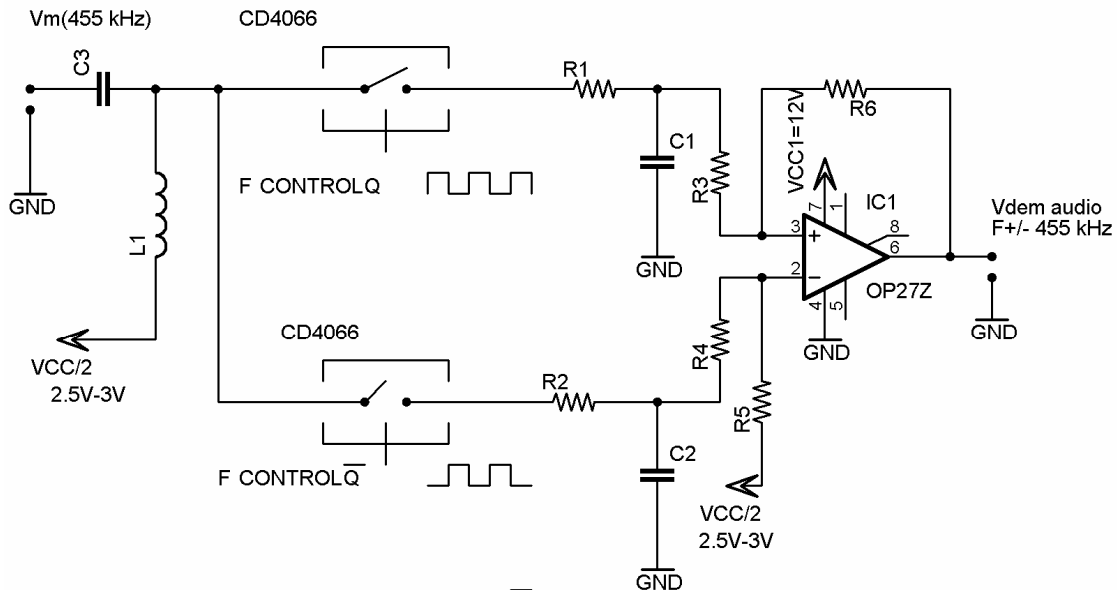
Sample and hold demodulator realised with JFET

Final solution was with CD4066 which worked at new IF 300 kHz and enabled me extremely linear work in connection with AD converter. Sampling capacitors with resistance of switch worked as LP (low pass) filter and it was really easy to make anti aliasing filter before AD. Also FET was working well at this frequency. As HF HAM I tried to use this for amateur purpose but it worked very badly when I passed over 1-2 MHz. When Dr Ulrich Rohde published article reference 5 I remembered my previously work and tried solution but I made change which is the base of the mine later design. At that time YU land was under embargo and I tried solution with CD4066 which was

available in that moment. IC CD4066 except good work has still limits with useful frequency range.



Simplified demodulator U.Rhode from reference 5



BEST WAY TO OBTAIN Q AND Q̄ IS TO DIVIDE F CONTROL BY D FLIP FLOP
F CONTROL HAVE TO BE 2*F AT THE INPUT OF D FLIP-FLOP

DEMODULATOR CIRCUITS MODIFICATION FROM REFERENCE 5 BY YU1LM

When I read in reference (6) article of use 74HC4066 as HF mixer I was delighted. I tried mixer in DC (Direct conversion) receiver but as it was done in original article. At that time I had professional task to design DC receiver with very big DR (dynamic range) and I was designed better post detector amplifier then it was in the R2 famous design from KK7B. Now I mixed this two design and I made DC receiver which is working really good I shall publish this design latter if it interesting for builders.

I like contests and competition very much and I took part in many of them. I am really QRP op you can see my call in many contests and score lists I am using big multiband horizontal loops 84m and 168m. Signals from loop are really test for the receivers big challenge with a lot of signals from wanted and unwanted frequencies. I am using ICOM 725 readjust for the QRP work and it has an improved RX performances as

it is described in the QST and some additional mine improvements. I decided that for new homebrew receiver use 74HC4066 because it was much easy to obtain than FST... chips and I had a lot of normal classical size components (not SMT). I designed RF front end according to the W.Sabin ideas published first in Book Single-Sideband Systems & Circuits page 96-103 after that published in RadCom .Very similar is realization from Oleg Skidan UR3 IQO in his famous T03DSP transceiver reference 1. It is front end with 74HC4066 mixer without RF amplification before roofing filter. I tested front end and it works very well from very low frequency to the 70MHz where IL (Insertion Loss) grove up from 5.5-6 db to 7 dB. IIP3 was around 30-35 dBm what is really good results for this cheep and easy obtainable component. After roofing filter I inserted IF amplifier with very big DR (dynamic range) and gain of 22 dB and AGC circuit with PIN diodes which after new crystal filter feed demodulator. I tried few solution for demodulator as it is in original AC5OG papers but with 74HC4052 which is also 1-4 multiplexer and it is also recommended from Leif SM5BSZ. I was disappointed with results because useful bandwidth going up to the 10 MHz. It works in receiver as IF 9 MHz demodulator circuits but I wasn't satisfied with it to the end. I tested SDR receiver first time with software from DL6IAK ref 7 and after those with others freeware software. Basic idea for design was to simplify RX hardware design and to make bigger use of PC in receiver realization. I looked once more to the different articles and some my papers and find my solution from 1993 as variation of article 5 and changed CD series with 74HC series 4066 and I was really surprised with this "dead bug" construction can do. To speed up testing I used demodulator as SDR receiver connecting to the antenna for the first moment. I connected my big loop through 7 MHz band pass filter and results from these simple circuits were really unbelievable. Surprisement kept on when I adjust my DDS synthesizers to 3.5 MHz and for the quick test I missed any BP filters. It was during one contest and I couldn't believe. No noticeable IMD (intermediations) or sign of any overload when I back to the 7 MHz with a loot of very strong broadcast stations all without any filters try this test with any other mixer or demodulator.

I easily copied very weak station in presence of strong I used mainly software for SDR receivers from Alberto I2PHD and I tested other freeware software ref 1,2,3,4,5.....thanks boys for your big job and effort to share your work with all others.

I2PHD software enable me great flexibility and I listened a lot of HAM and commercial stations without problems. Also all other freeware software working similar but it is evident difference in results and flexibility. Software made by Vittorio IK2ZCL also gave very good results it enable the most pleasant listening but it take some time to adjust (it is for fixed audio frequency).When next week my neighbor YU1KR start competition with his HP (high power 1KW) station and 3el beams in my direction distance between us is around 350m by air. I noticed first time noticeable IMD harmonically related to the its demodulated audio LF(Low frequency) .Check with oscilloscope gave me evidence that post demodulation low noise amplifier OP027 generate IMD because of low side clipping. Output swing for OP AMP is different with single power supply and it is hard that it arrive to the zero (0)V. Useful output is for this simple schematic 2Vp-p at the output with power supply 5V for digital circuits. If you like more dynamic made change power supply with 6V Voltage regulator and than output swing will be near 3Vp-p 6V speed up dividers and lower ON resistance and it is max for 74AC74. I measured demodulated signal from YU1KR. It was around 0 to -5dBm and

with 20dB amplification from OP it is too much big signal for OP AMP my sound card was Realtek AC97 in my lap-top. Because of that I put 15 dB attenuator between sample and hold detector and antenna. Now it was possible to listened very weak station 3-5 kHz away easy and there wasn't evidence of clipping OP. I compared these results with some other design see presentation renaissance of DC receivers current receiver DR1 is without audio image rejection and it was superior very much too all other very good DC (direct conversions) receivers designs R1 ,R2....etc. There is no sign of gargling sound (not clear sound) hum or microphone tendency characteristic for DC receivers when we have a lot of gain or when we reduce available bandwidth to few hundred Hz or less. Listening with DR1 was really music for my ears. I am using headphone always, with it is much easier to notice all potential problems in receiving chain than with loud speaker. Measured results, mainly done with Alberto I2PHD SDR receiver, are:

1. Receiving range from 30 kHz to 70 MHz (with Q oscillator it is limited to 15 MHz with one xtal Q 14.318 MHz you can receive 7.169 MHz and 3.575MHz ..Oscillator working with C2,3=33pF between 2-20 MHz for other change C2,C3)
2. IIP3 28-33 dBm it depends from setting and used programs (all with 16 bit sound cards). Max measured IIP3 with only 3 dB AF gain is 38 dBm but with reduced sensitivity
3. MDS 102-105 dBm
4. Sensitivity 3-5 uV for 10 dB S/N ratio, max S/N ratio I measured was 80 dB (result hard to obtain with any other only hardware HF receiver). This sensitivity is more than enough for frequency near 20 MHz with adequate antenna system, for higher frequency it is recommend increasing AF gain or putting some RF preamplifier in front of DR1 to lower F (noise figure) of receiver.
5. SFDR (Spurious free dynamic range) is 88-92 dB, this results are with signals spaced 2 kHz and more. Results are not changing very much if we spaced two signals to classical 20 kHz or more. All measurements are done by use HP8662 signal generators and HP 70000 series spectrum analyzer. See same specification for the some very expensive HAM Rig.

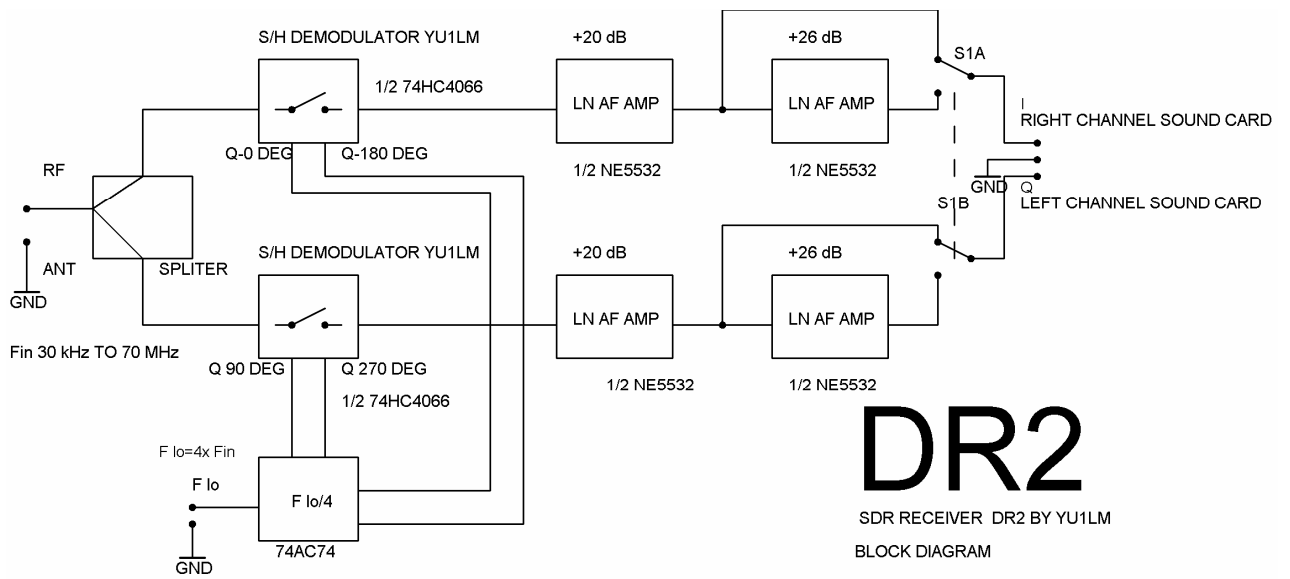
These results are really very good for receiver from only “two or three” parts without any resonant circuits completely audio design HI!!!! Some excellent performances are not without other side.

1. First and very big disadvantage for potential builders are twice (2) higher frequency for LO (local oscillator)
2. Receiver has an audio (IF) image and it is disadvantage in crowded bands but my practical experience with external LO and changing IF in PC sound card talking to me that it can help to minimize problems of unwanted receiving. One little trick for HAM bands is to use LO exactly at the beginning off band 2 x 3500 kHz Out band signals are very often very rarely Listening broadcast station and DRM station was also very good. Image receiving is problem in case two same strength station. I was capable to receive a lot of broadcast stations with only half of meter wire antenna. If you want to receive weak station it is necessary to put preamplifier in front of DR1 for short receiver

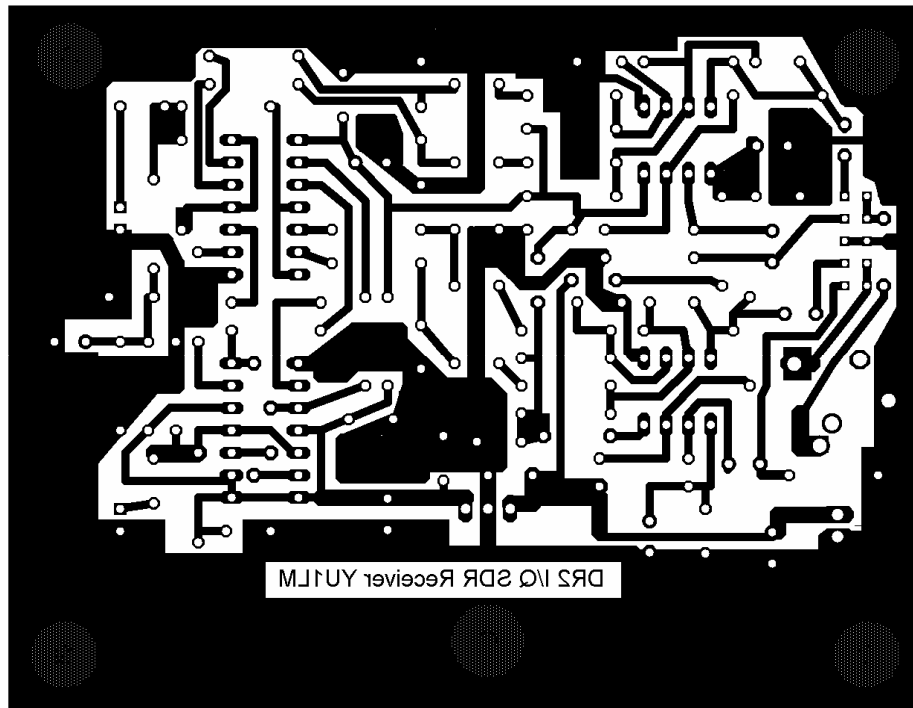
Real advantage of SDR receivers and receiving without audio IF image is possible with second SDR receiver called **DR2**. It is very simple construction but outstanding performances. Specification is similar to DR1:

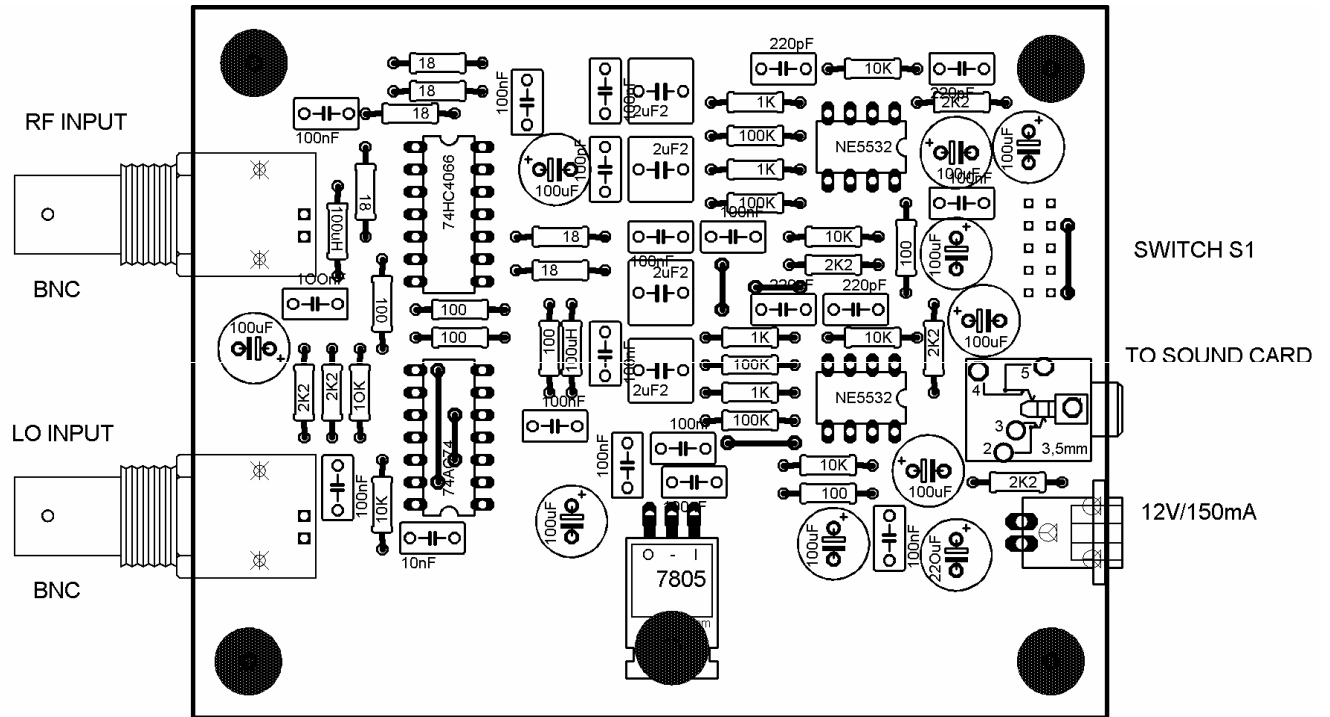
6. Receiving range from 30 kHz to 35 MHz (limited with D Flip Flop 74AC74 $V_{cc}=6V$ max input frequency is around 140 MHz)
7. IIP3 28-32 dBm it depends from setting and used programs (all with 16 bit sound cards). Max measured IIP3 with only 3 dB AF gain is 35 dBm but with reduced sensitivity
8. MDS 101-106 dBm
9. Sensitivity 3-6 μV for 10 dB S/N ratio, max S/N ratio I measured was 77 dB (result hard to obtain with any other only hardware HF receiver). This sensitivity is more than enough for frequencies near 20 MHz with adequate antenna system, for higher frequency it is recommend increasing AF gain or putting some RF preamplifier in front of DR2 to lower F (noise figure) of receiver.
10. SFDR (Spurious free dynamic range) is 88-94dB, this results are with signals spaced 2 kHz and more. Results are not changing very much if we spaced two signals to classical 20 kHz or more. All measurements are done by use HP8662 signal generators and HP 70000 spectrum analyzer. See specification for the some very expensive HAM Rig.
11. Audio image IF rejection depend from software but without any adjustment it is between 35-45 dB and it is not changing through the HF bands. With careful adjustment in software it is possible obtain 50 or more dB.
12. DR2 receiver need external LO (local oscillator) 4 timer higher than receiving frequency.

At the first moment design of DR2 and DR1 receivers are same or very similar as it is done in Gerald AC50G SDR1000. But I shall explain what is main difference according to main point of view is. We are talking about using the same I/Q concept. Sampling idea is the same but sampling time is 50% of pulse duration time in my design not 25% as it is in QSD based on 1 to 4 multiplexer/demultiplexer design. 50 % design enable higher frequency and better balancing. Few weeks ago I saw simulation of QSD that talking that 50% is not an optimum but my experience is quite opposite. Advantage of 50% sampling time will be described in part 2 when I shall explain transmitting part of SDR radio. The biggest disadvantage of QSD design is very bad impedance which QSD demodulator offering to band pass filters. Audio termination is good but RF very bad. Because of that I am using additional R to improve matching. Adding R will increase noise figure for 3-5 dB of receiver but I think that is for HF not important so much, atmosphere noise is much higher even at the 50 MHz. Antenna terminations is changing with frequency change but change is not so big. VSWR is better than 2. DR2 working with 100 Ohm sampling source resistance in ON for 74HC4066 is around 50-70 Ohm... Balancing using D Flip-Flop has very big advantage over all other ideas first reason is simplicity and leak of even harmonics. This is very evident in TR1 DSB modulator realization for HF output spectrum is really very clear. Switching performances as switching capacitors filter are worst than in QSD but still with very high equivalent Q.



Dimensions single side PCB is 105x80 mm





This is the end of article part1, in part3 I shall keep on with improved versions of both receivers. I wish successful DR1 and DR realization and send me your comments please.

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References:

1. Skidan@mail.ints.net T03DSP UR3IQO <http://users.ints.net/skidan/T03DSP>
2. <http://www.nitehawk.com/sm5bsz> Leif LINARD
3. <http://www.flex-radio.com> SDR1000 Gerald AC5OG
4. <http://www.njqrp.org/mbrproj/9850dds.html>

www.analog.com/en/prod/0,,770_843_AD9850,00.html

<http://www.qsl.net/pa3ckr/signalgenerator/>

http://www.k6ese.com/DDS_Project.htm

http://ham.kiev.ua/pic/dds_ham2.html

<http://www.qsl.net/om3cph/dds/rx.html>

<http://www.seboldt.net/k0jd/otheryfo.html>

<http://perso.wanadoo.fr/f6itv/p2063001.htm>

<http://koti.netplaza.fi/~jonverro/ad9854.htm>

<http://www.labyrinth.net.au/~steve/freq/>

<http://members.aol.com/D14JAL/DDS.html>

<http://hem.passagen.se/communication/dds.html>

5. *Recent Advances in Shortwave Receiver Design* Dr. Ulrich Rohde *QST* Nov 1992 page 53
6. *RF Design* 6/1995

Software LINK for SDR radio receiving and transmitting

1. <http://digilander.libero.it/i2phd/> SDRadio software ver 0.95
www.qsl.net/i2phd Alberto I2PHD <http://gpsdo.i2phd.com/>
2. ik2czl@weaksignals.com <ik2czl@weaksignals.com>ik2czl@weaksignals.com
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5. <http://www.nitehawk.com/sm5bsz> Leif LINARD
6. <http://www.flex-radio.com> SDR1000 Gerald AC5OG
7. dl6iak.ba-karlsruhe.de