

Introduction to Software Defined Radio

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What is Software Defined Radio?

Definition

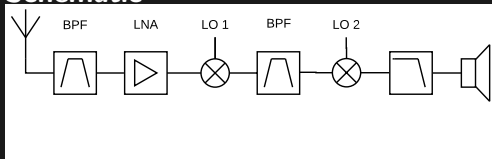
Software-defined radio (SDR) is a radio communication system where components that have been typically implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system.^a

^aSoftware Defined Radio: Architectures, Systems and Functions (Markus Dillinger, Kambiz Madani, Nancy Alonistioti) Page xxxiii (Wiley & Sons, 2003, ISBN 0-470-85164-3)

- 1 Introduction and Background
- 2 Overview of SDR Hardware
- 3 Overview of SDR Software
- 4 Conclusions and Additional Resources

Conventional Receivers

Schematic



- Superheterodyne receiver
- Completely analog design
- High complexity
- High accuracy of components required

Example: FT 817

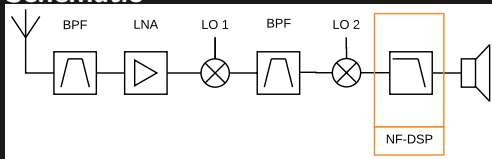


By wildergeek on picasaweb [CC BY-SA 3.0
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Commons

Superheterodyne with DSP

Schematic



- DSP functionality in AF
- High complexity
- High accuracy of components required
- Improved NF quality

Example: IC 7600



Photo by Kjell, SM0FOB, src:

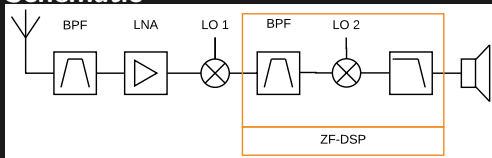
<http://picasaweb.google.com/sm0fob/>

SomeHamRadioActivity#

5342440689000150978

TRX with IF-DSP

Schematic



- Only one mixer/LO
- Reduced number of analog components
- Increased flexibility of filters and processing

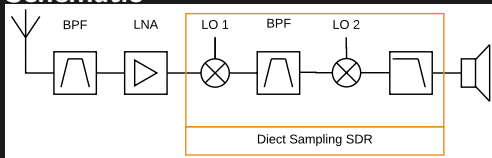
Example: KX3



Photo by JR1CHU, <http://photozou.jp/photo/show/216071/224352880>

Direct Sampling TRX

Schematic



- No mixer/LO required
- Higher bandwidth
- Filter bank required
(due to aliasing)

Example: Hamlab
Image removed due to
unclear copyright

Why is SDR interesting?

- Higher bandwidth for digital applications
→ can monitor one, sometimes multiple bands
- Higher flexibility
→ can work on different modes
- Fast reconfigurability
→ but antenna may not be resonant. . .

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RTL-SDR

Various models

- **Cost:** ~ 10 €
- **Frequency range:**
50 - 1800 MHz
- **Bandwidth:** < 2.4 MHz
- **Resolution:** 7-8 bit
- **Analog filters:** none
- **RX/TX:** RX only

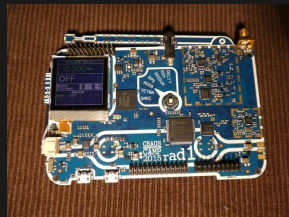


DVB-T USB dongle using the RTL 2832U controller and R820T tuner chip

Medium-level Boards

HackRF One/rad1o

- **Cost:** ~ 300 €
- **Frequency range:**
50 MHz - 6 GHz
- **Bandwidth:** ≤ 20 MSps
- **Resolution:** 8 bit
- **Analog filters:** none
- **RX/TX:** Half duplex



rad1o

High-end Boards

USRP B200/B210

- **Cost:** ~ 700 €
- **Frequency range:**
50 MHz - 6 GHz
- **Bandwidth:** ≤ 56 MSps
- **Resolution:** 12 bit
- **Analog filters:** none
- **RX/TX:** Full duplex



USRP B200

High-end Boards

LimeSDR

- **Cost:** ~ 260 €
- **Frequency range:**
0.1 MHz to 3800 MHz
- **Bandwidth:** 61.44 MHz
- **Resolution:** 12 bit
- **Analog filters:** none
- **RX/TX:** 2RX/TX, full duplex

Image removed due to copyright reasons.

LimeSDR

Image from <https://www.crowdsupply.com/lime-micro/limesdr>

Other Boards

FlexRadio/ApacheLabs

for the ham radio operator

- **Cost:** > 1000 €
- **Frequency range:**
30 kHz - 54 MHz
- **Bandwidth:** ≤ 96 kHz/
7 MHz
- **Resolution:** 16 bit
- **Analog filters:** Available
- **TX Power:** ≤ 100 W

USRP Networked Series

for research and development

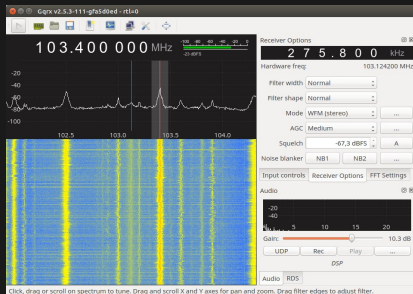
- **Cost:** > 1500 €
- **Frequency range:**
DC - 6 GHz
- **Bandwidth:** ≥ 100 MHz
- **Resolution:** 16 bit
- **Analog filters:** none
- **RX/TX:** Full duplex

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HSDR/SDR#/GQRX

General "software radios"

- Similar functionality to hardware radio
- Common demodulators included
- Can be "wired" to other tools (e.g. fldigi) using virtual audio cables/pipes
- Windows:
HSDR/SDR#/Gqrx
- Linux/OSX: GQRX

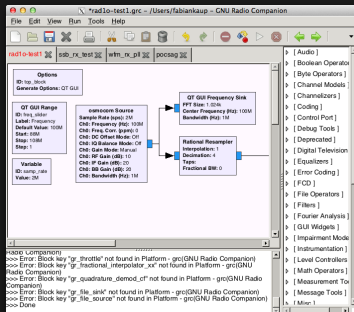


GQRX

gnuradio

Environment to connect functional blocks

- Blocks written in Python
- Well defined interfaces
- GUI: Gnuradio-companion
- GUI applications possible
- Wide variety of functions/ blocks available
- Works on real-time data and recorded samples



Gnuradio-companion

rtl_*

CLI tools compiled for DVB-T
dongles with RTL chip

- **FM radio:** rtl_fm
- **RF power:** rtl_power
- **TCP server:** rtl_tcp
- **433 MHz ISM:** rtl_433
- **ADSB monitoring:**
rtl_adsb, dump1090



```
Applications — fkaup@odroid-server: ~ — ssh — 96x22
Found 1 device(s):
0: Generic, RTL2832U, SN: 7777111153785700

Using device 0: Generic RTL2832U
Found Rafael Micro R828T tuner
Exact sample rate is: 250000.000414 Hz
Sample rate set to 250000.
Bit detection level set to 0.000.
Tuner gain set to Auto.
Reading samples in async mode...
Tuned to 433915098 Hz.
2015-12-21 12:28:52 AlectoV1 Sensor 102 Channel 1: Temperature 11.1 C: Humidity 72 %: Battery OK
2015-12-21 12:28:56 LaCrosse TX Sensor 0f: Temperature 11.2 C / 52.2 F
2015-12-21 12:29:23 AlectoV1 Sensor 102 Channel 1: Temperature 11.1 C: Humidity 72 %: Battery OK
2015-12-21 12:29:25 GT-WT-02 Sensor 57: battery OK, channel 1, button 0, temperature 10.9 C / 51
.6 F, humidity 77%
2015-12-21 12:29:34 AlectoV1 Sensor 102 Channel 1: Temperature 11.1 C: Humidity 72 %: Battery OK
2015-12-21 12:29:38 LaCrosse TX Sensor 0f: Temperature 11.2 C / 52.2 F
2015-12-21 12:30:15 GT-WT-02 Sensor 57: battery OK, channel 1, button 0, temperature 10.9 C / 51
.6 F, humidity 77%
[0] @bash: ~[rtl_433]* *odroid-server* 12:30 21-Dec-15
```

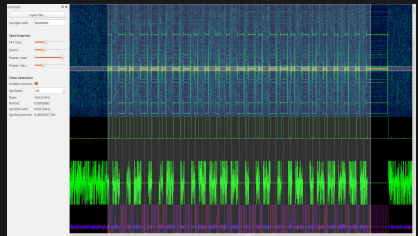
Weather monitoring using rtl_433

inspectrum

”tool for analysing captured signals, [...] from software-defined radio receivers.”¹⁾

- Works on recorded data
- Time and frequency domain analysis
- Tools to simplify sample identification
- Sampling of data
- Export of sampled data

¹⁾ <https://github.com/miek/inspectrum>



Screenshot of inspectrum

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Conclusions

- Lots of projects under heavy development
- Hardware about to get affordable
- Combination of hardware and software engineering
- Unprecedented flexibility

Additional Resources

Tutorial:

- SDR tutorial: <https://greatscottgadgets.com/sdr/>
- Recordings from the Software-defined Radio Academy:
<https://www.youtube.com/channel/UC1GAlgAqrkjeeLmIkCB8pgQ>

Hardware:

- RTL-SDR: <http://rtlsdr.org/>
- rad1o: <http://radio.de/>
- HackRF One: <https://greatscottgadgets.com/hackrf/>
- USRP B200/B210: <http://www.ettus.com/product/details/UB200-KIT>

Projects:

- RTL-SDR: <http://www.rtl-sdr.com/>
- Gnuradio: <http://gnuradio.org/>
- Inspectrum: <https://github.com/miek/inspectrum>
- ...and many more

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