

SDR – Software Defined Radio

Ken Dorsey

KA8OAD

SDR – What is it?

- Simply put Software Defined Radio, also known as Software Radio or SDR is defined as “A radio in which some or all of the physical layer functions are software defined”
- Components that were once typically implemented in hardware (i.e. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented in software
- While the concept of SDR is not new, the rapid growth in the capabilities of digital electronics have given rise to and made practical many processes which used to be only theoretically possible.

Classic radio vs SDR a comparison

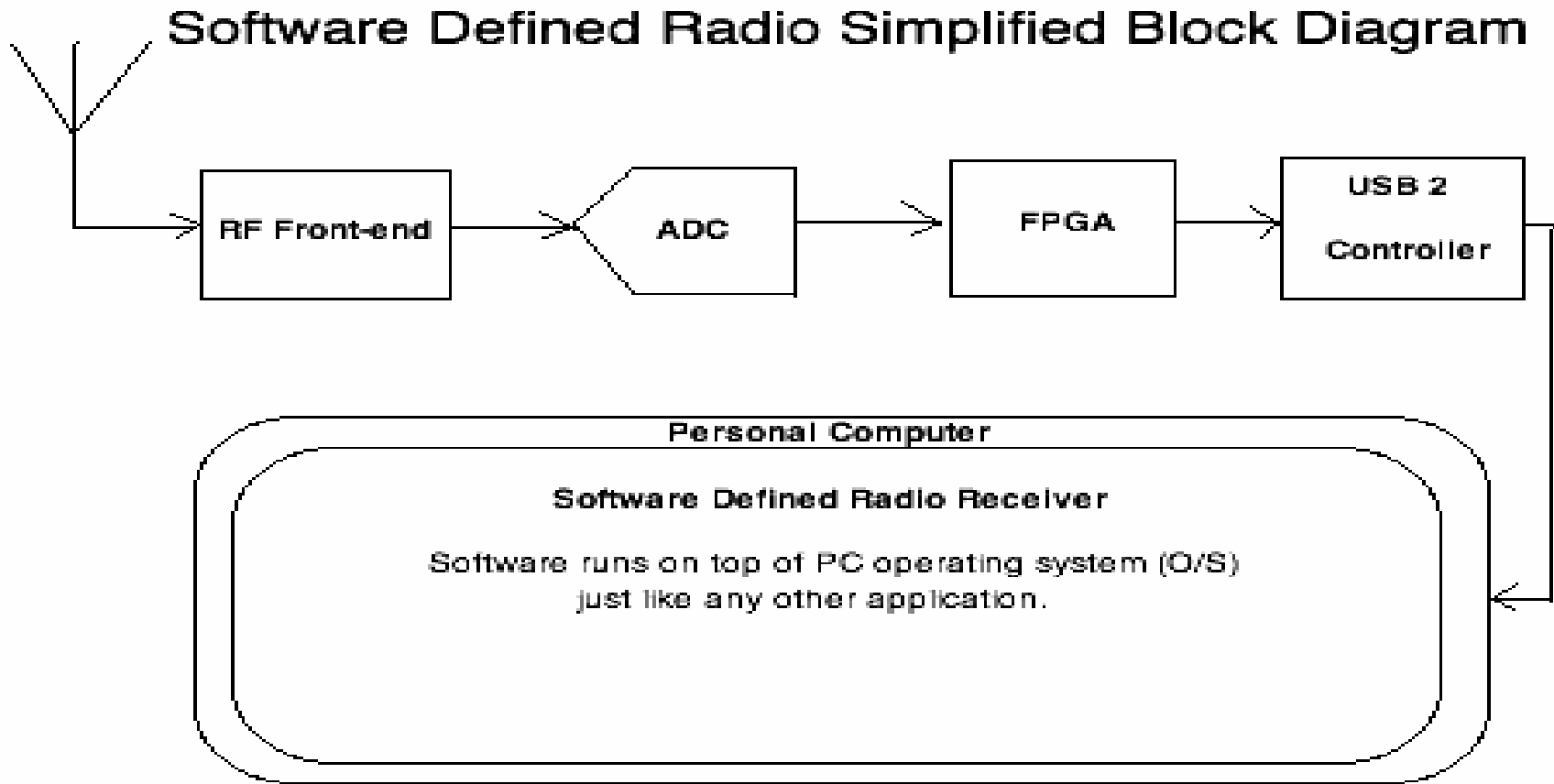
Classic Radio

- A traditional piece of hardware we are all familiar with
- Uses a hardware based receiver and demodulator
- Uses analog filtering with fixed filters for the required application
- Recovers either an analog signal or digitizes demodulated bits

SDR Radio

- Uses a more, or less, classic radio front end / tuner to down-convert either to IF or to baseband - USRP (Universal Software Radio Peripheral)
- Uses a high-speed ADC to digitize the IF or baseband signal
- Uses digital signal processing for filtering, equalization, demodulation and decoding

A basic SDR system may consist of a personal computer equipped with some form of A/D converter preceded by some type of RF front end.



Advantages of SDR radio

- Much more flexible as they are “software defined”
- As long as the tuner frequency, ADC sampling rate and computing power are sufficient **ANY** receiver can be implemented in pure software, without hardware changes
- Decoders can be designed in software with the ability to handle both audio and digital modes

Hardware and OS Requirements

- Personal Computer
 - Multi-core CPU's are highly recommended
 - Select a CPU with a large L2 or L3 cache
 - Some examples are
 - Core i3 or i5 processors
 - Quad core processors
 - Intel Core 2 Duo
 - AMD Phenom II
 - At least 4 GB of ram
 - USB 2.0 Required
 - Windows XP or higher (32-bit or 64-Bit OS) or Linux

- Amateur Radio Transceivers

- FlexRadio Systems (www.flex-radio.com) \$650 and up

- FLEX-1500

- 0.01 – 54 Mhz RX, 160 – 6m TX, 5W

- FLEX-3000

- 0.01 – 65 Mhz RX, 160 – 6m TX, 100W MARS/CAP

- FLEX-5000

- 0.01 – 65 Mhz RX, 160 – 6m TX, 100W MARS/CAP

- SoftRock (www.wb5rvz.com) (fivedash.com) \$89/band

- RXTX Ensemble (kit) 1W

- 160m

- 80m/40m

- 40m/30m/20m

- 30m/20m/17m

- 15m/12m/10m

- General Coverage Receivers (Amateur and Commercial use)
 - Cross Country Wireless (www.crosscountrywireless.net) \$266
 - .85 – 40 Mhz
 - RFSPACE (www.rfspace.com) from \$525
 - .05 – 30 Mhz
 - Microtelecom (microtelecom.it) \$1199
 - .1 – 30 Mhz
 - WinRadio (www.winradio.com) from \$749.95
 - .9 – 1800 Mhz
 - Software Radio Laboratory (www.srl-llc.com) \$899.99
 - .1 – 62.5 Mhz
 - FUNcube Dongle (www.funcubedongle.com) £124.99 ~ US\$201
 - .15 – 1900 Mhz (gap from 240 – 420 Mhz)

And many more...

Software

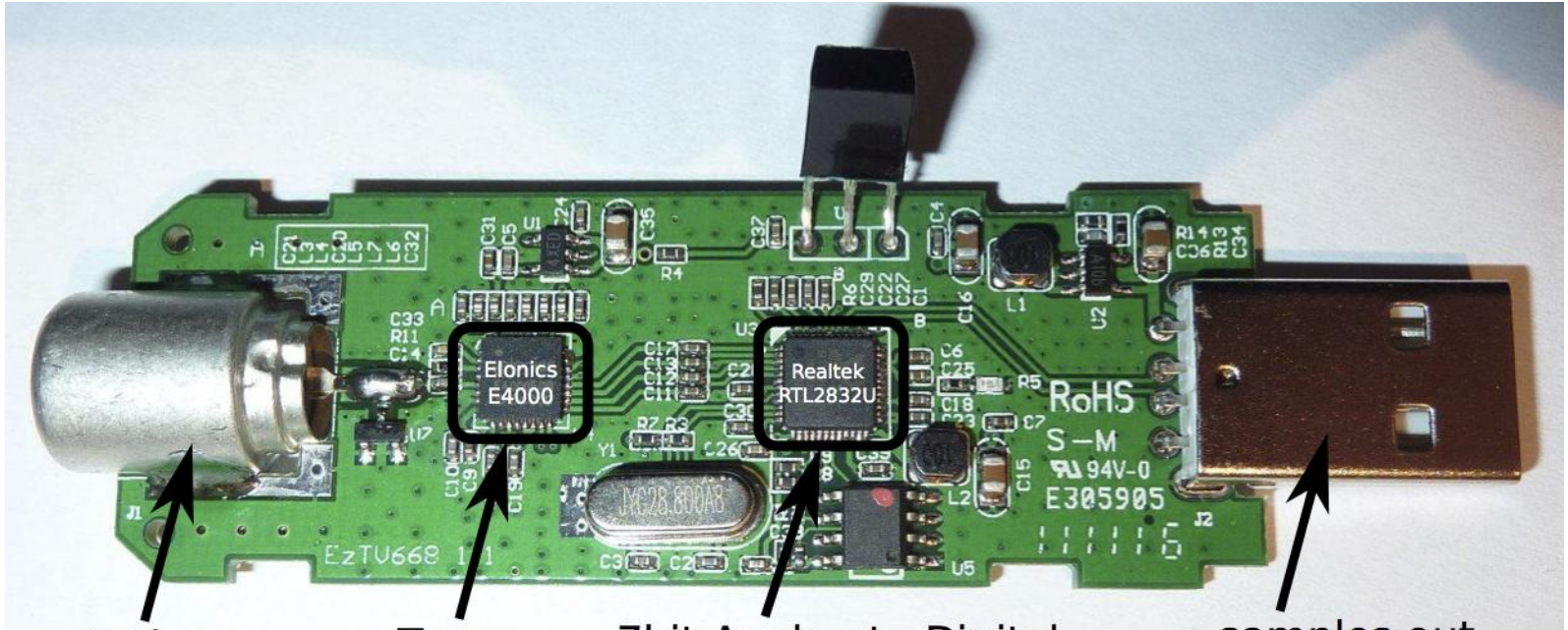
- Like the receivers there are several options to choose from, these are all **FREEWARE**
 - HDSDR (www.hdsdr.de) Windows
 - Rocky 3.7 (www.dxatlas.com/rocky) Windows
 - PowerSDR (code.google.com/p/powersdr-iq) Windows
 - Winrad (www.winrad.org) Windows
 - GNU Radio (gnuradio.org) Linux
 - SDR Sharp or SDR# (www.sdrsharp.com) Windows/Linux
 - SDR-Radio (sdr-radio.com) Windows
 - GQRX (www.oz9aec.net/index.php/gnu-radio/gqrx-sdr) Linux
 - LinRADIO (www.linradio.com/) Linux

The RTL DVB-T USB Tuner



Realtek RTL2832U based DVB-T Receivers

- More than 20 different devices from various vendors all based on the identical RTL2832 reference design
- Only major difference is the mechanical shape/size and silicon tuner used
- RTL2832U implements an ADC, DVB-T demodulator and a high-speed USB device
- A digitally controlled tuner selects a frequency band around a target center frequency and demodulates it to baseband. The RTL2832U serves as an analog to digital converter that samples the baseband signals and outputs the samples through the USB port. The device uses IQ baseband demodulation and sampling
- Uses I2C controller to control the tuner frontend
- Normal mode of operation includes a full DVB-T receiver inside RTL2832U hardware and only sends MPEG2-TS via USB



RF in

Tuner

7bit Analog to Digital

samples out

SDR Radio on a “budget”

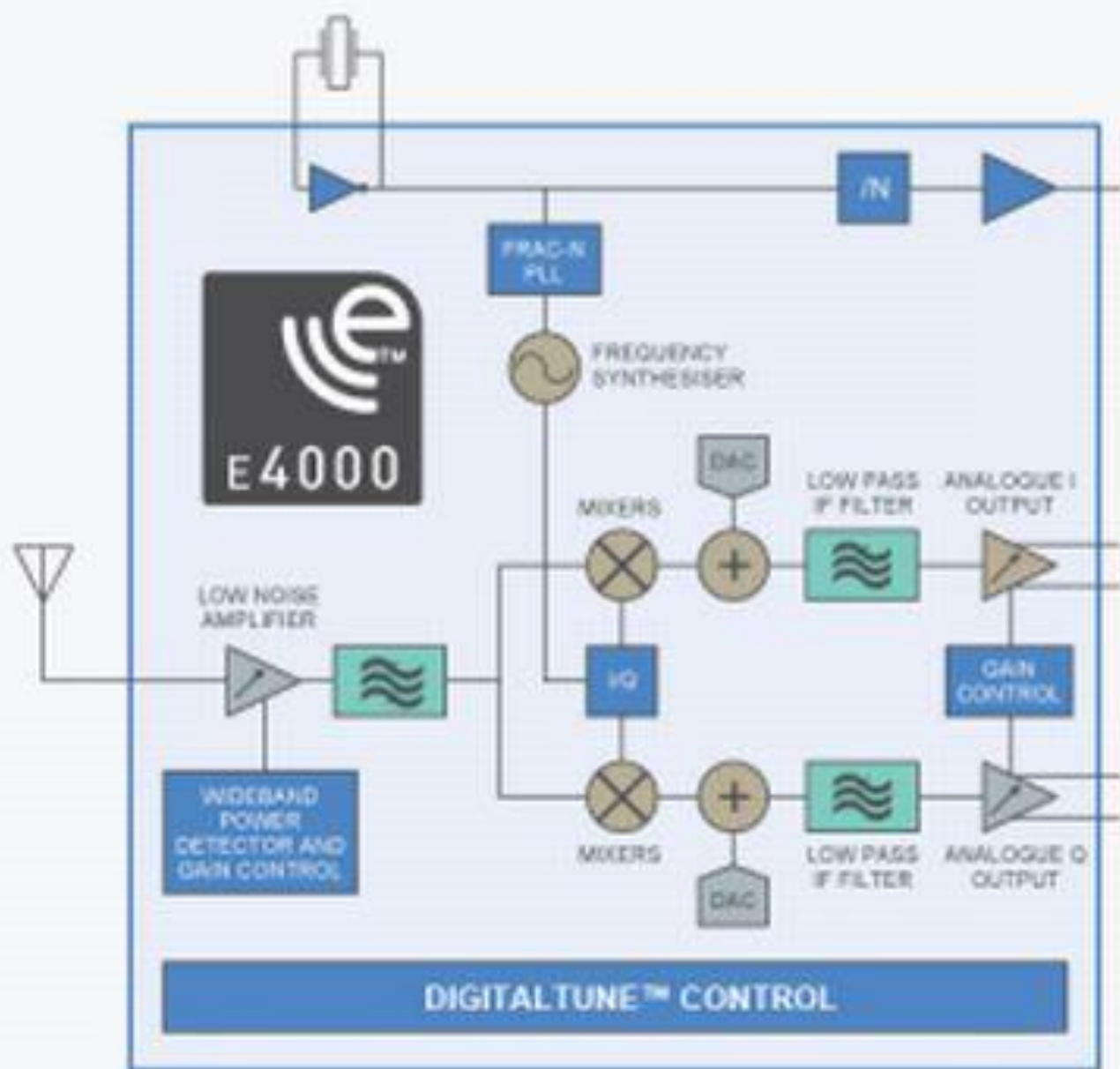
Generally referred to as RTL-SDR

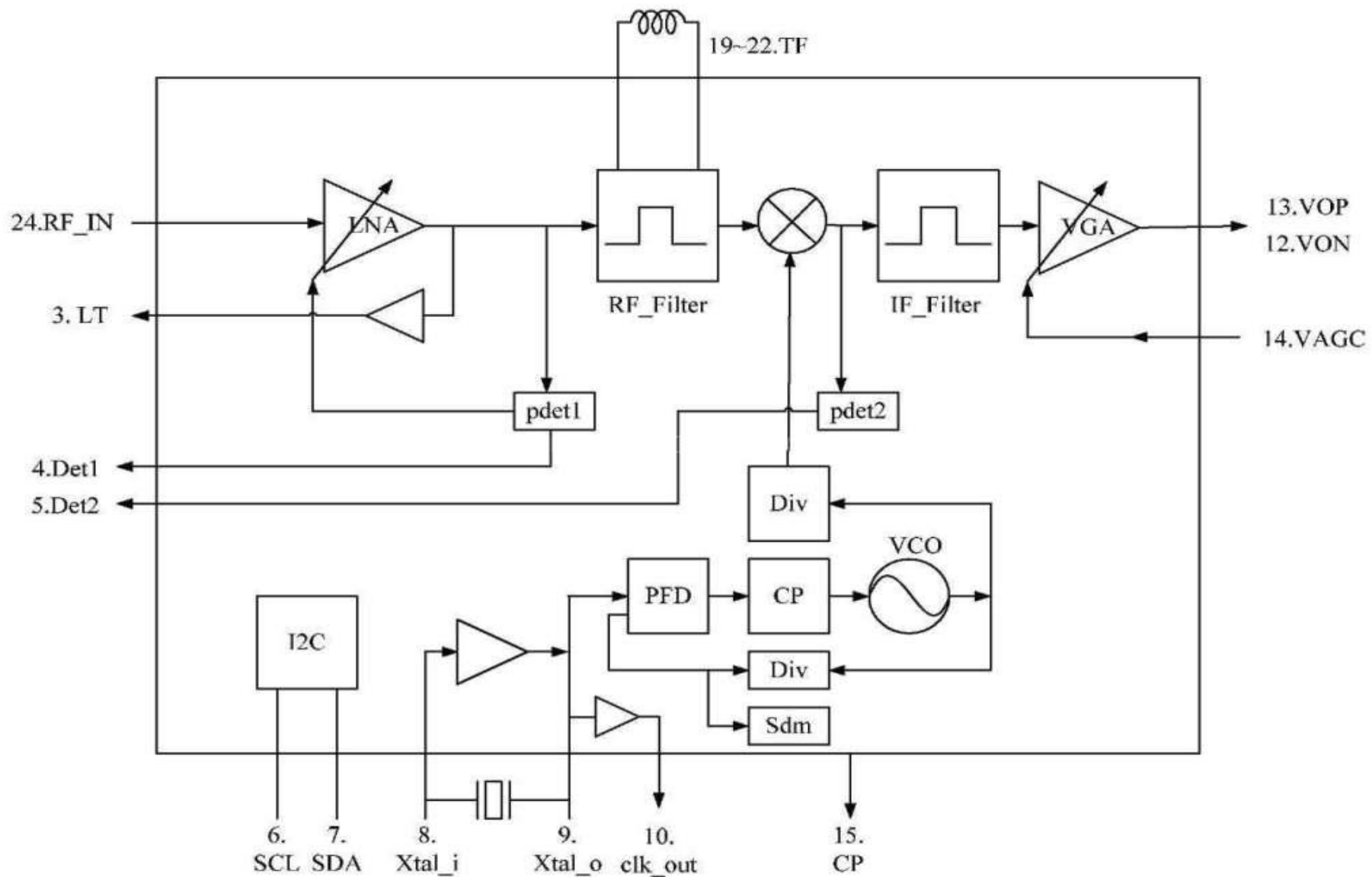
So what is RTL-SDR ?

An observant V4L/DVB Linux kernel driver developer (Antti Palosaari) working with the Realtek DVB-T USB receiver discovered that the Realtek digital chip (RTL2832U) had some undocumented commands/registers by which it can be placed into a mode where it simply forwards the unprocessed raw baseband samples via high-speed USB into the PC enabling it to become an SDR. So, with some “creative” software re-purposing, it is possible to turn a consumer-grade DVB-T USB TV receiver into a fully operational software defined radio.

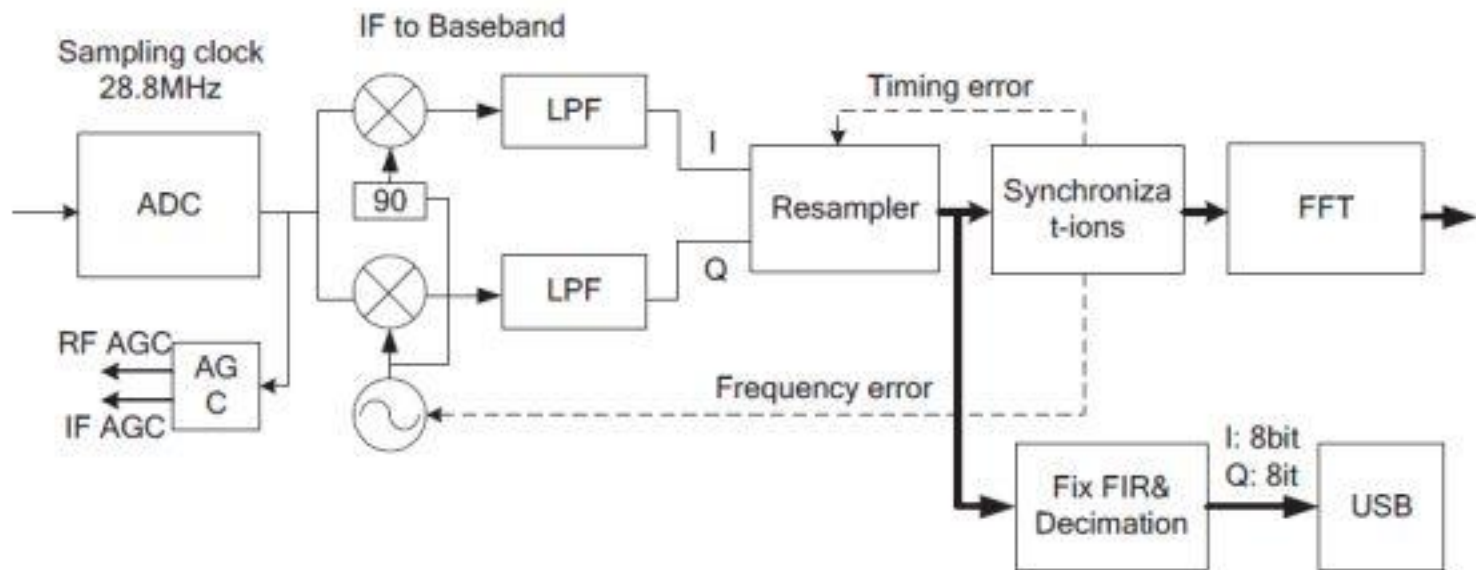
At a street price of about \$20 this is undoubtedly the most capable low-cost SDR hardware available.

- RTL DVB-T USB Tuner – what do I need to look for?
 - The tuner must use the Realtek RTL2832U chipset
 - There are three tuner IC's used by most manufacturers
 - the Elonics E4000
 - 52 Mhz – 2200 Mhz (gap from 1100 to 1250 Mhz)
 - the Rafael Micro R820T
 - 24 Mhz – 1766 Mhz
 - the **Fitipower FC0013**
 - 50 Mhz – 1700 Mhz





Simplified block diagram of the R820T tuner



RTL2832U Block Diagram

Is it possible to receive HF?

- Yes, by adding an upconverter (MF, HF) you can add the ability to receive 0.5 Mhz to 50 Mhz (100.5 Mhz – 150 Mhz)
 - The upconverter (Ham It Up) is sold by NooElec (www.nooelec.com)



Some of the things you can receive

- AM
- WFM
- NFM
- CW
- SSB
- WFAX
- SSTV/FSTV
- PACKET
- D-STAR
- ACARS (Aircraft Communications Addressing and Reporting System)
- ADS-B (Automatic Dependent Surveillance Broadcast – Aircraft)
- GMR
- TETRA
- APCO25 (P25)
- SATELLITE
- RTTY
- AIS (Automatic Identification System - Maritime)
- DAB (Digital Audio Broadcasting)

Any mode, anywhere

The Final Cost – multiple sources

From NooElec:

Ham It Up	\$42.95
TV301U DVB-T USB Stick (E4000 tuner)	\$37.95
Male IEC 169-2 (PAL) to Female BNC	\$2.99

From Amazon:

RF Coaxial Cable SMA male to BNC Male	\$5.50
Micro-USB Home Charger	\$4.47
SMA male to SO-239	\$7.00
Shipping (approximately)	\$3.95

Total	<hr/> \$104.81
-------	----------------

(Optional TV28T v2 DVB-T USB - R820T tuner)	\$17.95
---	---------

The Final Cost – Amazon only

From Amazon:

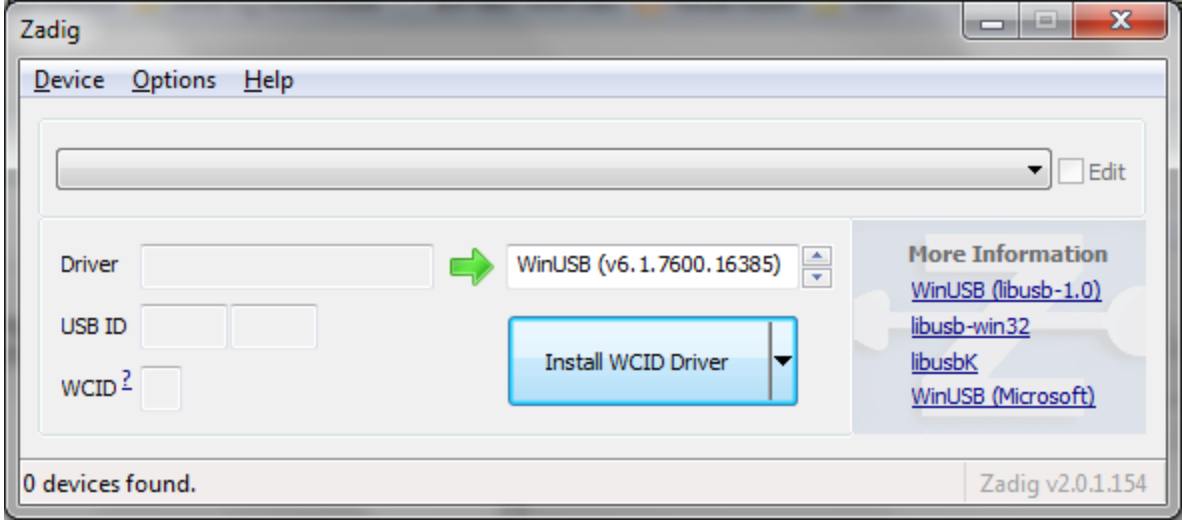
Ham It Up	\$52.95
TV301U DVB-T USB Stick (E4000 tuner)	\$42.95
Male IEC 169-2 (PAL) to Female BNC	\$4.95
RF Coaxial Cable SMA male to BNC Male	\$5.50
Micro-USB Home Charger	\$4.47
SMA male to SO-239	\$7.00
Shipping (approximately)	\$3.95
	<hr/>
Total	\$121.77

(Optional TV28T v2 DVB-T USB Stick - R820T tuner) \$19.95

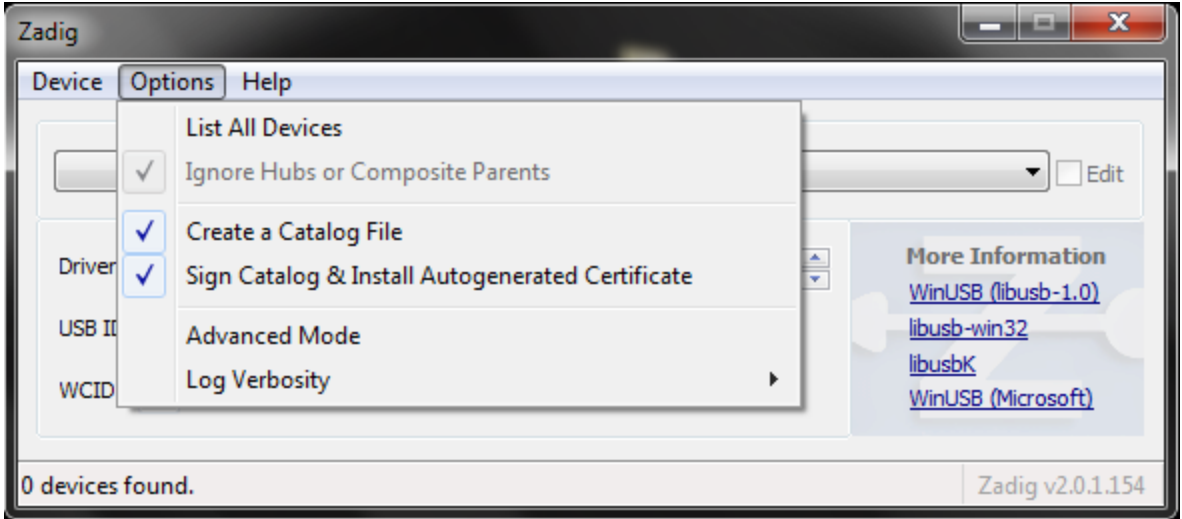
Software required and installation procedure

1. Install the latest USRP driver (Zadig) for the DVT-B USB stick (DO NOT install drivers from the disk if one comes with the device)
NOTE: The driver is port specific, if you move the RTL2832U from a previously installed USB port to a different USB port you will need to re-install the driver for that port.
sourceforge.net/projects/libwudi/files/zadig/
 - a. Download the latest driver package (zadig_v2.0.1.160.7z as of this writing). You will also need to download and install 7Zip software to extract Zadig if you do not already have it installed.
www.7-zip.org/
 - b. Extract the Zadig driver package to a folder.
 - c. Insert your RTL2832U stick into an available USB port.
 - d. Your device should be detected by Windows and Windows will attempt to install drivers for the device, you can cancel the installation procedure but its not necessary to do so as the drivers will be over-written during the install procedure.
 - e. Install the Zadig drivers for your RTL2832U stick using the following procedure:

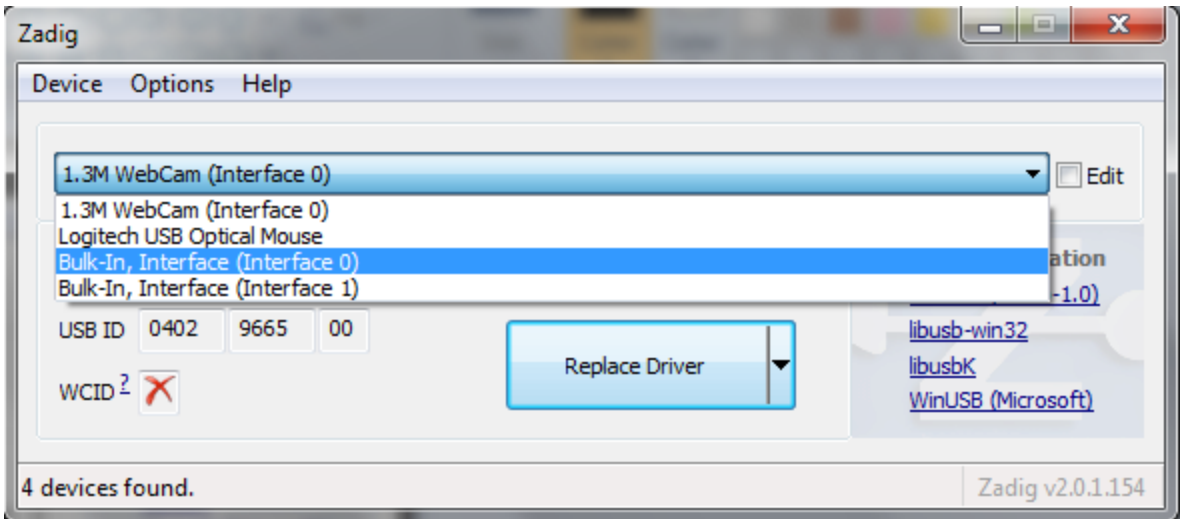
I. Run the Zadig.exe file and you should see the following:



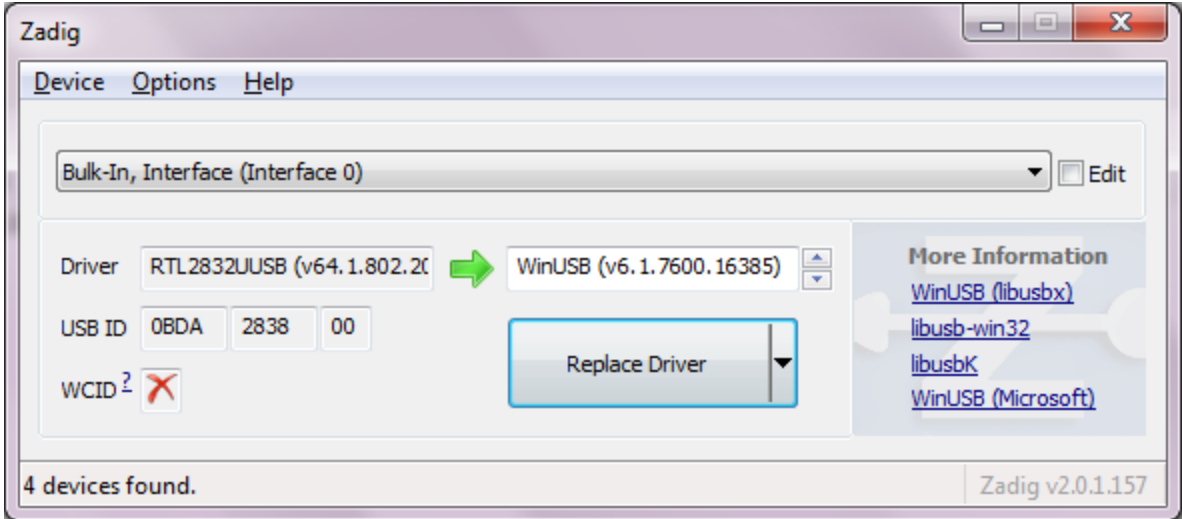
II. Click on "Options" and select "List All Devices"



III. Choose the device that has “Bulk-In, Interface (Interface 0)”:



IV. In the box to the right of the green arrow make sure “WinUSB” is selected

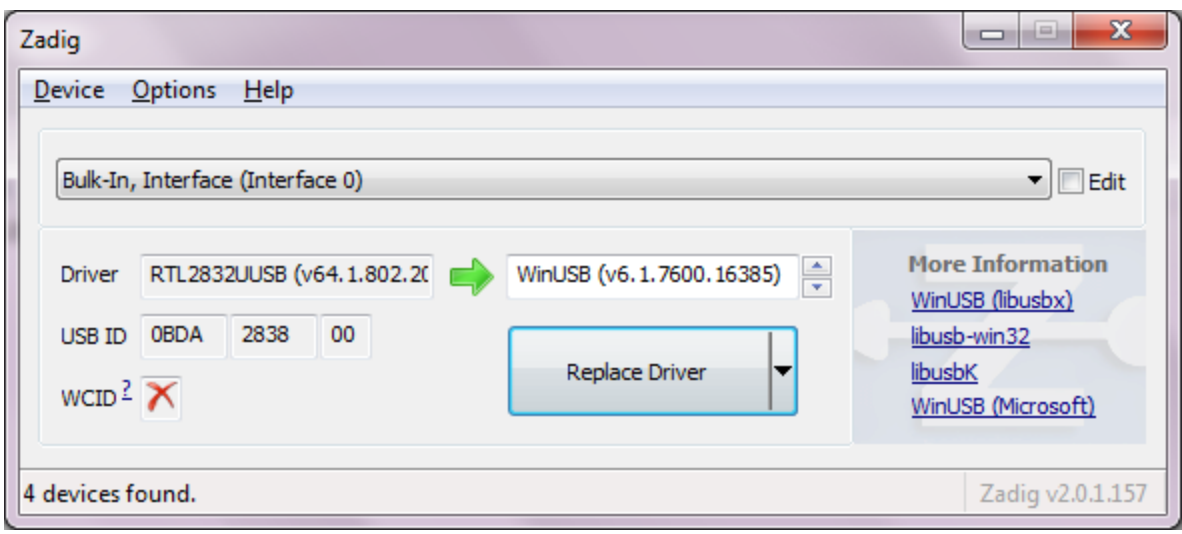


V. Check that the VID and PID (USB ID) are correct for your device:

Most popular:

VID	PID	Tuner	Device Name
0x0bda	0x2832	all of them	Generic RTL2832U (e.g. hama nano)
0x0bda	0x2838	E4000	ezcap USB 2.0 DVB-T/DAB/FM dongle
0x0ccd	0x00d3	E4000	Terratec Cinergy T Stick RC (Rev.3)
0x0ccd	0x00e0	E4000	Terratec NOXON DAB/DAB+ USB dongle (rev 2)
0x185b	0x0620	E4000	Compro Videomate U620F
0x185b	0x0650	E4000	Compro Videomate U650F

IV. Click the “Replace Driver” button to install the new (Zadig) driver



2. Download the ExtIO_USRP plugin (.dll's) for the SDR software you wish to use (allows one to use USRP as the baseband input):

For HDSDR

www.hdsdr.de

For SDR#:

sdrsharp.com/index.php/downloads (SDR# RTLSDR Plugin)

For SDR Radio:

www.aa5sh.com/?page_id=65 (SDR-RADIO.com.RTLUSB.zip)

Unzip the file or files into their separate folders.

In addition:

For all software (it has a test program included to test your dongle installation):

sdr.osmocom.org/trac/attachment/wiki/rtl-sdr/RelWithDebInfo.zip

Unzip this file into its own folder (default: rtl-sdr-release)

Open a command prompt window (start -> run -> cmd)

Change the directory to the rtl-sdr-release/x32 folder

(cd c:\xx\xx\rtl-sdr-release)

At the command prompt type: rtl_test -t

This program will test your RTL hardware and driver installation and will return values for some of the various operating modes of the device, if you don't see this information you will need to check to be sure that the Zadig drivers were properly installed.

3. Install the SDR software you wish to use. I recommend either HDSDR, SDR# or SDR-Radio.

For HDSDR:

www.hdsdr.de/ (Version 2.51 or the newest)

For SDR#:

sdrsharp.com/index.php/downloads (SDR# Stable)

For SDR-Radio:

v2.sdr-radio.com/Previews.aspx (Preview 5 – build 1273)

Installing SDR-Radio:

1. Install the SDR-Radio software
2. Extract the .dll files (SDR-RADIO.com.RTLUSB.zip)
3. Open the folder that you just extracted, SDR-RADIO.com.RTLUSB, there will be two folders, 32bit and 64bit
4. Open the folder that matches your Windows version (32bit or 64bit) and copy the three .dll files contained in that folder to the SDR-RADIO-PRO.com folder, usually found in the “Program Files” folder
5. Run the SDR-Radio software
6. Click on the “Radio” button near the top of the console.
7. Add a radio definition, be sure to change the radio type in the drop down menu to RTL SDR (USB).
8. Click the “Search” button and if everything is installed correctly SDR_Radio will find the RTL2832U.
9. Click “OK” and your stick should show up in the radio definitions box.
10. Highlight the RTL2832U device in the radio definitions list and click start.
11. SDR-Radio should now be running using the RTL2832U stick.

- Ham Radio Science
www.hamradioscience.com
- RTL-SDR and GNU Radio
www.superkuh.com/rtlsdr.html
- AB9IL.net
www.ab9il.net/software-defined-radio/rtl2832-sdr.html
- ARRL
www.arrl.org/software-defined-radio
- Wikipedia
en.wikipedia.org/wiki/Software_defined_radio
- osmocomSDR
sdr.osmocom.org/trac/wiki/rtl-sdr
- rtlsdr.org
www.rtlsdr.org
- Complete step-by-step installation instructions for Linux (Ubuntu)
vereniging.opensource.nl/wiki/index.php/Software-Defined_Radio_on_Ubuntu
- Many YouTube videos – search for RTL SDR, RTL-SDR or RTLSDR