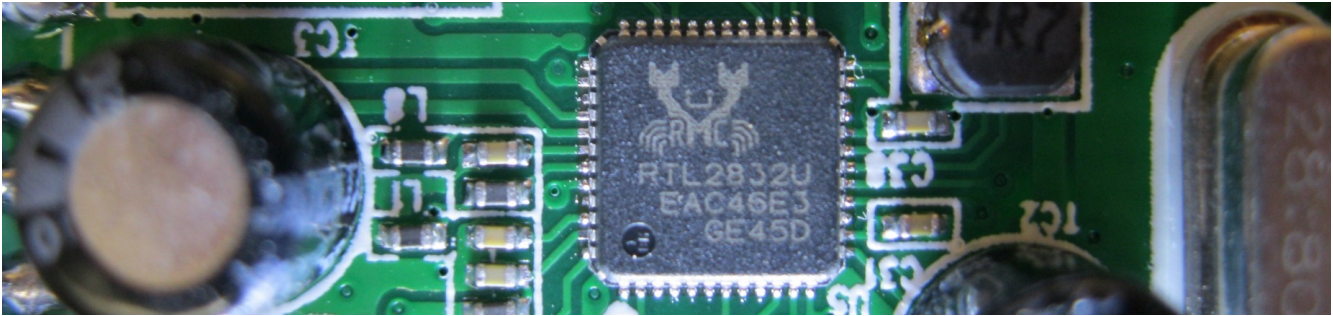# Realtek RTL2832U
The mystery chip at the heart of RTL-SDR.
VERSION 1 ©2015

Corrections are welcome.

1. INTRODUCTION

The Realtek RTL2832U is a 6 mm square chip (QFN) with 12 pins per side. It uses 3.3 Volts and a 28.8 MHz crystal. The chip's datasheet comes with a non-disclosure agreement. The IC is a DVB-T COFDM Demodulator. DVB-T stands for *Digital Video Broadcasting: Terrestrial* and COFDM stands for *Coded Orthogonal Frequency-Division Multiplexing*. The "U" in the name stands for the USB (2.0) interface. USB uses 4 pins: +Voltage, D-, D+, and ground. A USB extension cord is recommended with RTL-SDR to keep the radio away from computer generated noise. The RTL2832U contains eight general purpose input/output ports and an infrared remote control port.

2. TUNERS

The RTL2832U supports tuners at IF, low-IF, and zero-IF (direct conversion). The most common tuner is the Rafael Micro R820T. This chip has an advantage over the Elonics E4000 in that it only uses two of the RTL2832U's four I/Q pins. The unused pins, if not grounded, can be used as clean inputs for direct sampling purposes. The unused pins are the Q+ and Q- branches.

3. RTL_TEST

In Linux, using the terminal, "rtl_test" can be used to test the RTL2832U (Ctrl-Z exits). Program switches include: -s *sample rate* (the default is 2,048,000 Hz), -d *device index*, -t *Elonics E4000 tuner*, -p *ppm error measurement*, -b *output block size*, and -S *force synchronous output*.

4. DATA THROUGHPUT

A high-end sound card will push 32-bits at 192-kHz, a data throughput of 6.144 Mbps. The RTL2832U has only an 8-bit ADC but can run at 3.2 MS/s (million samples per second, 3200-kHz). This calculates out to a throughput of 25.600 Mbps or four times that of a good sound card. The RTL2832U was made to handle compressed MGEG2 and MPEG4 (H.264) transport streams; including video, audio, and data. Modulation schemes include: 4QAM (QPSK), 16QAM, or 64QAM. In 2k mode (1705 carriers), the carrier spacing is 4464 Hz. In 8k mode (6817 carriers), the carrier spacing is 2232 Hz. Under both modes the sampling rate is 18.284544 MHz and the final LO frequency is a fourth of that or 4.571136 Mhz (low-IF). Common bandwidths are 6, 7, or 8 MHz.

5. IMPORTANT PINOUTS

The important RTL2832U pinouts are as follows: *pins 1/2* In-phase Input pos/neg, *pins 4/5* Quadrature Input pos/neg, *pins 11/12* 28.800 MHz Crystal Oscillator, *pin 13* Tuner AGC, *pins 16/17* SCL/SDA Tuner Serial clock/data, *pins 18/19* SCL/SDA 2k (256 byte) EEPROM Serial clock/data S24CS0, *pins 25/26* LDO 3.3V AMS1117, *pin 38* Infrared Port, and *pins 40/41* USB Data pos/neg.

6. INPUT IMPEDANCE

The input impedance of the I and Q lines of the RTL2832U is "unknown". However, much is known about the Elonics E4000 chip. It is a "Multi-standard CMOS Terrestrial RF Tuner" in a 5 mm square package (QFN) that has 8 pins per side. It was designed to interface directly to a digital demodulator. The E4000's analog IF outputs; specifically *pin 20* (I+, IVOUTP), *pin 19* (I-, IVOUTN), *pin 18* (Q+, QVOUTP), and *pin 17* (Q-, QVOUTN) are connected, via a capacitor, directly to pins on the RTL2832U. And these I/Q baseband outputs can have a differential peak-to-peak output voltage of 1000 mV. Meaning, the RTL2832U can handle +4 dBm. The E4000 outputs also see an output load of 15k-ohms and 10 pF. Also telling, the outputs' single ended output impedance is 250-ohms (R$_{OUT}$). A space-wave has an impedance of 377-ohms. Therefore, there may be no significant impedance mismatch between the RTL2832U's I/Q pins and a random wire antenna.

7. ELONICS E4000

The E4000's has a 4.5 dB (or better) noise figure and a 50-ohm RF input. Total gain is ~99 dB, which includes: 30 dB LNA gain, 12 dB mixer gain, and 57 dB IF gain. There are six stages of IF gain, each with a maximum, digitally-programmable gain of: 6 dB, 9 dB, 9 dB, 2 dB, 15 dB, and 15 dB, respectively. The E4000 can handle 2000 mV peak-to-peak or +10 dBm. IIP3 is +5 dBm. It is important to realize that bypassing the E4000 or R820T also bypasses a huge amount of gain. Like radios of old, without RF amplification, use a long wire (SW), large ferrite (MW), or box loop (MW).

8. RTL2832U ARCHITECTURE: DIRECT SAMPLING

The heart of the RTL2832U is its ADC (Analog-to-Digital Converter) and DSP (Digital Signal Processor). It performs Digital Down-Conversion DDC (IF to baseband) via I/Q mixers (phase is 90 degrees apart), digital low-pass filtering, I/Q resamping, and sends 8-bit I/Q data via the USB port.

9. RTL2832U ARCHITECTURE: COFDM

Unused by RTL-SDR is the Fast Fourier Transform FFT unit. This converts time-domain information into frequency-domain information. Time-domain is when the y-axis is amplitude and the x-axis is time. Frequency-domain is when the y-axis is amplitude and the x-axis is frequency. I wrote a FFT algorithm for the PhilSCAN programs. The output seen on programs like GQRX, SDR#, and SDR Touch is frequency-domain information. Under direct sampling gnuradio does the FFT.

The RTL2832U is a COFDM demodulator, that does things like: symbol synchronization, fine frequency adjustment, phase rotation, channel estimation and correction, inner and outer deinterleaving, Viterbi decoding, RS decoding, forward error correction, adjacent and co-channel interference rejection, pre- and post- and long-echo channel reception, impulse noise cancellation, automatic carrier recovery, channel equalization, channel state information, guard period removal, pilot and TPS decoding, sample rate correction, sample rate interpolation and decimation, AGC delay, measurement of radio frequency levels, SNR estimation, control of the tuner's AGC, MPEG proportional integral derivative filtering, etc. The chip can automatically detect modulation parameters (ex. transmission mode, code rate, guard interval) via patent-pending algorithms.

10. POCKET RADIO HF SDR

See Pocket Radio HF SDR for details on how to receive MW and SW using no up-converter (~$43), no fancy metal case (~$24), no 4:1 balun (~$11), and no cables (~$10). DC to 1.7GHz coverage opens up a world of sub-$20 DX, including: MW, SW, FM, CB, HAM, CORDLESS, RC, NOAA WEATHER, TV, MILITARY, AIR, SHIP, RAIL, TRUNKING SYSTEMS, GPS, SATELLITE, and more.

just_rtfm@<NOSPAM>yahoo.com
Dr. Phil's Receiver Designs