VersaRef
Reference Clock Generator

- 0.01Hz to 200MHz
- Internal 10MHz Oven Osc
- GPS Lockable
- 8-19 VDC Power
- 3.3V Square wave output
Memory = [01]
145.123,456 MHz
Pros

• Oven Osc stable within a minute
• Frequency Range and Resolution met.
• No Switching power supply noise

Cons

• Crystal Aging very apparent
• Si5338 Spurs could be an issue
• Probably too expensive to produce due to small market.
and now it's time for something completely different
RxPander
VHF/UHF Down Converter

1700MHz

40MHz

5MHz

Moe Wheatley AE4JY
A Little History

- 2010 Howard Long, G6LVB designed a TV Tuner Chip based USB dongle for receiving amateur satellites called FUNcube Dongle.
- 2011 Antti Palosaari managed to get 8 bit I/Q data out of a TV tuner USB Dongle. From that the RTL Dongles were hatched.
- 2012 Osmocom's OsmoSDR and others??
- Youssef Touil author of SDR# and Airspy
The Questions

• The proliferation of cheap USB Dongle TV Tuners sparked an investigation into the “innards” to see if there was anything useful. Tens of thousands of these things have been bought as general purpose SDR's primarily for VHF/UHF reception.

• What kind of performance could be expected?

• Could the chips used in the dongles be purchased by “mortals” and put in a product?
FUNcube Dongle

Mirics MSi001 RF Tuner Chip

~$200  150kHz to 2GHz  190kHz BW
RTL Dongles

~$20  25MHz to 1.7GHz
~2.8MHz BW
What's in an RTL Dongle?

The Dongles contain two main chips.

- An Analog Down Converter chip, usually an R820 or E4000.
- A Realtek RTL2832U DVB-T COFDM Demodulator + USB 2.0 interface.
Limitations of the RTL Dongle

• Frequency controlled by simple crystal with no temperature compensation.
• Frequency PLL step size ~1kHz or so.
• No RF filtering so easily overloaded by just about any strong signal.
• The USB interface limited to 8 bits I/Q so Gain Control is required.
The Interesting Part

• The RTL2832 chip is primarily a DTV demodulator chip so is not much use for general reception except for the raw I/Q mode which has major limitations.

• The Rafael Micro R820 chip is generic and is just a programmable analog RF down converter. It looked like it could be a very useful building block.

• Very limited technical information on this chip so could it be integrated in a custom design?
Down Converter Design Goals

• Improve dynamic performance with some RF Filtering.

• Be able to lock the frequency to a 10MHz GPS reference.

• Have 1 Hz frequency resolution.

• Get maximum IF BW around 8MHz

• Find a source and info for the R820 chip.
Terrestrial DTV TV Silicon tuner

R820T

Features
- Support all digital TV standards: DVB-T, ATSC, DTMB, IRIB and ISDB-T.
- Lowest BOM cost WITHOUT external SAW filters, LNA, balun, LDO, and adjustable parts.
- Low cost Single-In Digital TV Application
- Compliant with EN 300 744, Nordig 2.2, D-BOOK 7.0, ARIB B21, ABNT 15604, ATSC A74 and GB20600-2006
- Compliant with EN-55020, EN55013 and FCC
- Ultra low power consumption < 190mA
- Single power supply with 3.3V
- 2-wired I2C interface
- 24-pin 4x4 QFN lead-free package

Applications
- Terrestrial Digital TV
- Desktop/Laptop PCTV, Mini-card, and USB peripherals
- Set Top Box
- Portable Media Player

Universal DTV

Rafael Micro. Proprietary and Confidential
Quick Reference Data

Typical figures

- Frequency range: 42 to 1002 MHz
- Noise figure: 3.5 dB @ RF_IN
- Phase noise: -98 dBc/Hz @ 10 kHz
- Current consumption: <178 mA @ 3.3V power supply
- Max input power: +10 dBm
- Image rejection: 65 dBc
First Prototype

- The easiest platform for us to work on was the RFSpace NetSDR radio since it already had headers in place for a down converter module.
- A PCB was made and some R820 chips were desoldered from some RTL Dongles and reused.
- In parallel, a request to Rafael Micro was made to see if the chip could be purchased as well as get more detailed technical information.
Good News Bad News

- R820 chips could be purchased for production quantities.
- Data Sheet and Example Driver code required NDA.
- Data Sheet same non-detailed one as bootleg one found on Internet.
- Example driver code had no explanation as to how it worked.
- With modifications to get better frequency resolution, the Driver was ported to NetSDR Micro Controller.
EFF Module Block
(Extended Frequency Function)

40MHz to 1700MHz

30MHz HP Filter

110MHz HP Filter

40MHz Reference Clock

R820

5MHz IF out

I2C Control
EFF Module for NetSDR
But I don't have a NetSDR..

• Now that we knew how to “Drive” the R820 chip, how about a general purpose down converter?
• So the “RxPander” project was launched.
• Basically a stand alone analog down converter taking 40 to 1700MHz down to 5MHz.
• Adds a USB virtual serial port for frequency control and power along with a 10MHz reference input.
RxPander Block Diagram

40MHz to 1700MHz

30MHz HP Filter

110MHz HP Filter

R820

5MHz IF out (Inverted)

5MHz IF out (Inverted)

I2C Control

21.4MHz Variable Reference Clock For 1Hz Frequency Resolution

10MHz Ref In

10MHz TCXO

Analog SW

AD9913 DDS

21.4MHz Xtal Filter

SPI Control

STM32F100 uC

FTDI USB Chip

USB
First Prototype
In a Hammond Enclosure
HF Filter Verification

"Elsie" Simulation

RxPander 30MHz HP Filter

Array Solutions VNA 2180
FM Filter Verification

“Elsie” Simulation

RxPander 30MHz and 110Mhz HP Filters Combined

Array Solutions VNA 2180
PLL Reference Phase Noise Test

Raw AD9913 DDS 21.4MHz Output

DDS 21.4MHz AFTER Crystal filter
Sensitivity Measurements

MDS = -174dBm/Hz + NF(dB) + 10log BW (Hz)

Insert a carrier until the power in a specified bandwidth is doubled. S=N
## Sensitivity Results

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>MDS (dBm)</th>
<th>NF (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.2</td>
<td>-137</td>
<td>10</td>
</tr>
<tr>
<td>123</td>
<td>-138</td>
<td>9</td>
</tr>
<tr>
<td>145.1</td>
<td>-141</td>
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<td>223</td>
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<td>7</td>
</tr>
<tr>
<td>1039</td>
<td>-142</td>
<td>5</td>
</tr>
</tbody>
</table>
Receive Phase Noise
5MHz IF Output Bandwidth
Configuration #1

RxPander Down Converter

5MHz IF

SDR-IQ Receiver

USB_1

SpectraVue

USB_2

40 to 1700MHz
Configuration #2

40 to 1700MHz

RxPander Down Converter

5MHz IF

USB Virtual COM Port

VT100 Terminal 432.123MHz

"His Master's Voice"
To Do's

- Fix some PCB issues.
- Fix FM filter return loss
- See if able to make board ~$100 MSRP
- Layout for different TCXO
- Make small run to see if viable product.
More Info:

- (www.moetronix.com/RxPander) Will eventually have more information as this develops.