TangerineSDR

A Modular Open Source Software Defined Radio

for
HamSCI, Satellite, Experimenters and Academics

Scotty Cowling, WA2DFI

HamSCI Workshop
March 19, 2021
What is the TangerineSDR Project...? 

The TangerineSDR Project is a modular, open source hardware and software platform for development of all components of a Software Defined Radio.

It is also a group of volunteers led by TAPR, dedicated to the building of a pool of open-source Software Defined Radio design information.

Kind of like openHPSDR. Kind of like ORI. Kind of like HamSCI. But **different**.
TangerineSDR

We gratefully acknowledge support of this project from NSF Grants AGS-2002278, AGS-1932997, and AGS-1932972.

TAPR would also like to acknowledge the generous ARDC grant in support of the prototype build.
What is a TangerineSDR radio?

A TangerineSDR radio has the following features:

- Wide-range cost-based performance
  - From $300 to $1000+
- Based upon an open source model (OHL/NCL hardware, GPL software)
- Extremely modular, configurable and expandable
- Advances the State of the Radio Art
What is a TangerineSDR radio?

A TangerineSDR radio has four basic components:

- Data Engine baseboard
- RF Modules (RFM) – two supported
- Clock Module (CKM)
- Compute Engine (typically an SBC Host Computer)
What is a TangerineSDR radio?

TangerineSDR System
Hardware Features

TangerineSDR Features

- FPGA-based Gb Ethernet direct sampling receiver
- Full receive coverage from 100kHz to 60MHz
- Web-based configuration
- Multiple UDP streams cover all bands from 160-6m
- Dual GbE, USB 3.0 and USB 2.0 simultaneous I/O
- Full transmit capability is future option
Hardware Features

TangerineSDR DE Features

- Altera/Intel 10M50D AF672I6G FPGA 50K LEs
- 512MByte (256Mx16) DDR3L SDRAM
- 4Mbit (512K x 8) QSPI serial flash memory
- 512Kbit (64K x 8) serial EEPROM
- μSDXC memory card up to 2TByte
Hardware Features

TangerineSDR DE Features

- 11-15V wide input, low noise SMPS
- 3-port GbE Switch (Dual GbE data interfaces)
- Cryptographic processor with key storage
- Temperature sensors (FPGA, ambient)
- Power-on reset monitor, fan header
Hardware Features

TangerineSDR Data Engine
Hardware Features

Future TangerineSDR DE Boards

- Larger, faster FPGAs
- More DRAM storage
- More non-volatile (SATA, SSD, etc) storage
- Higher speed data ports (10GE, 40GE, USB 3.2, etc)

BUT...

The same RFM ports allow reuse of RF boards
Hardware Features

TangerineSDR PSWS/HF RX Module

- AD9648-125 dual 14-bit 122.88Msps ADC
- 0dB/10dB/20dB/30dB remotely switchable attenuator
- LTC6420-20 20dB LNA
- Fixed 55MHz Low Pass Filter
- Optional user-defined plug-in filter
- On-board, switchable 50-ohm calibration noise source
- On-board low-noise power supplies
- Dual SMA antenna connectors
Hardware Features

TangerineSDR PSWS/HF RX Module

[Diagram of TangerineSDR PSWS/HF RX Module]

- **AD9648-125**
- **LT6420-20**
- **14b ADC**
- **LPF**
- **FILTER OPTION**
- **ATN SEL**
- **50-OHM NOISE SOURCE**

**Connectors:**
- M.2 CONN (140 PIN)
- LVDS OVF
- LVDS DATA
- LVDS CLK
- SPI
- CLK
- SPI EXP

**Power Supplies:**
- +5V
- +3.3V
- +1.8V
- +12V

**Antennas:**
- REV XA3
- SMA

**Frequency Range:**
- 100kHz - 60MHz

© 2021 Scotty Cowling WA2DFI
Hardware Features

TangerineSDR PSWS/HF RX Module
Hardware Features

Tangerine SDR RF Modules

- Personal Space Weather Station Receiver (no TX needed)
- VLF Receiver Module for 10kHz to 200kHz reception
- P4G RX and P4G TX modules or P4G TRX single module
- AD9361 MIMO transceiver module (70MHz – 6GHz)?
- Lime LMS7002M SDR Module (100kHz – 3.8GHz)?
- Lime LMS8001+ SDR Module (100kHz – 12GHz)?

Thank you to Tom McDermott N5EG for the PSWS RFM design!

Jonathan Rizzo KC3EEY will talk on the VLF RFM at 12:00PM today
TangerineSDR CKM Clock Module

- Rakon RPT7050A Ultra Stable TCXO
  - Sub 0.1ppm frequency stability
  - RMS phase noise down to 0.13ps
- High performance ublox ZED-F9T GPS
- Silicon Labs very low-jitter Si5345A multi-channel synthesizer
- Integrates directly with Data Engine
- Useable as a near-laboratory standard in optional carrier board
Hardware Features

ASSEMBLY DRAWING PRIMARY

TangerineSDR
SynthDO CKM

© 2021 Scotty Cowling WA2DFI
Hardware Features

TangerineSDR CKM Clock Modules

- SYNTDO CKM High Performance
  - High performance ublox ZED-F9T dual band GPS

- SYNTDO Mid-grade performance (mfg option)
  - ublox NEO-M8T single-band GPS

- SYNTDO Low-cost (mfg option)
  - ublox NEO-M9N single-band GPS, no pps output

John Ackermann, N8UR, will tell you all about it right after my talk!
LEAF

Low-speed Expansion Adapter Fixture

40-pin RPi
LOW-SPEED

RPi HAT

75-pin TSDR M.2
HIGH-SPEED

TSDR LEAF
## SDR Feature Comparison

<table>
<thead>
<tr>
<th>Board</th>
<th>type</th>
<th>RX ADC</th>
<th>TX DAC</th>
<th>data i/f</th>
<th>user i/f</th>
<th>DSP</th>
<th>Freq</th>
<th>Max BW</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>TangerineSDR</td>
<td>Direct</td>
<td>14b@122M</td>
<td>n/a</td>
<td>GbE/UDP+USB 3</td>
<td>Web</td>
<td>10M50</td>
<td>100k-60M</td>
<td>20M</td>
<td>~$500</td>
</tr>
<tr>
<td>RTL-SDR HF</td>
<td>Direct</td>
<td><a href="mailto:8b@28.8M">8b@28.8M</a></td>
<td>n/a</td>
<td>USB 2</td>
<td>USB 2</td>
<td>n/a</td>
<td>raw I/Q</td>
<td>1.6M</td>
<td>$25</td>
</tr>
<tr>
<td>RTL-SDR VHF+</td>
<td>Mix</td>
<td>10b@125M</td>
<td>14b@122M</td>
<td>GbE</td>
<td>UDP</td>
<td>7010</td>
<td>300k-500M</td>
<td>60M</td>
<td>$212</td>
</tr>
<tr>
<td>Red Pitaya 125-14</td>
<td>Direct</td>
<td>10b@122M</td>
<td>10b@122M</td>
<td>GbE</td>
<td>UDP</td>
<td>7020</td>
<td>DC-50M</td>
<td>60M</td>
<td>$604</td>
</tr>
<tr>
<td>Red Pitaya 122-16</td>
<td>Direct</td>
<td>16b@122M</td>
<td>14b@122M</td>
<td>GbE</td>
<td>UDP</td>
<td>7010</td>
<td>DC-50M</td>
<td>60M</td>
<td>$604</td>
</tr>
<tr>
<td>Kiwi SDR</td>
<td>Direct</td>
<td><a href="mailto:14b@66.7M">14b@66.7M</a></td>
<td>n/a</td>
<td>10/100 Ethernet</td>
<td>Web</td>
<td>XC7A35</td>
<td>10k-30M</td>
<td>30M</td>
<td>$299</td>
</tr>
<tr>
<td>HackRF One</td>
<td>Mix</td>
<td>8b@22M</td>
<td>10b@22M</td>
<td>USB 2</td>
<td>USB 2</td>
<td>XC2C64</td>
<td>1M-6G</td>
<td>20M</td>
<td>$299</td>
</tr>
<tr>
<td>HPSDR Atlas</td>
<td>Direct</td>
<td>16b@122M</td>
<td>14b@122M</td>
<td>10/100 Ethernet</td>
<td>GbE</td>
<td>3C40+</td>
<td>10k-55M</td>
<td>768k</td>
<td>~$1500</td>
</tr>
<tr>
<td>HPSDR Hermes</td>
<td>Direct</td>
<td><a href="mailto:12b@76.8M">12b@76.8M</a></td>
<td><a href="mailto:12b@153.6M">12b@153.6M</a></td>
<td>GbE</td>
<td>UDP</td>
<td>4CE22</td>
<td>130k-38.4M</td>
<td>384k</td>
<td>~$900</td>
</tr>
<tr>
<td>Hermes Lite</td>
<td>Mix</td>
<td>12b@160M</td>
<td>12b@640M</td>
<td>USB 3</td>
<td>USB 3</td>
<td>4CE40</td>
<td>100k-3.8G</td>
<td>61.44M</td>
<td>$315</td>
</tr>
<tr>
<td>LimeSDR USB</td>
<td>Mix</td>
<td>12b@61M</td>
<td>12b@61M</td>
<td>USB 2</td>
<td>USB 2</td>
<td>7010</td>
<td>325M-3.8G</td>
<td>20M</td>
<td>$249</td>
</tr>
<tr>
<td>Pluto</td>
<td>Mix</td>
<td>16b@122M</td>
<td>n/a</td>
<td>USB 3</td>
<td>USB 3</td>
<td>CYUSB</td>
<td>0-30M</td>
<td>8M</td>
<td>$190</td>
</tr>
<tr>
<td>RX-188 HF</td>
<td>Direct</td>
<td>8b@32M</td>
<td>n/a</td>
<td>USB 3</td>
<td>USB 3</td>
<td>CYUSB</td>
<td>30M-1.8G</td>
<td>2.4M</td>
<td>$100</td>
</tr>
</tbody>
</table>
What can I use it for?

Target Applications

- HamSCI Personal Space Weather Station (PSWS)
- Phase 4 Satellite Ground Station (P4G)
- Academic uses to teach SDR and FPGA techniques
- Amateur Communications SDR
- Experimenters’ (Amateur and non-Amateur) SDR
- Remote Ham Radio
- Others?
Personal Space Weather Station

Server Data Engine
- 50K LE FPGA
- 5Gb/s USB 3.0
- 2x GbE

Mid-grade RX
- Dual 14b ADC
- 122.88Msps

Not Used

GPSDO
- I2C
- SPI
- UART

Magnetometer

Internet

Client Computer
- (Single Board or Desktop)
  - Local User Display(s)
  - Local Data Storage
  - Local Data Reduction
  - Processed Data to HamSCI Servers

HamSCI Public Database

© 2021 Scotty Cowling WA2DFI

http://hamsci.org
Phase 4B Satellite Ground Station

- **Server Data Engine**
  - 50K LE FPGA
  - 5Gb/s USB 3.0
  - 2x GbE

- **Internet**

- **Client Computer**
  (Single Board or Desktop)
  - Local User Display(s)
  - Local Data Storage
  - Channel allocation

- **Mid-grade RX**
  - 14b ADC
  - 122.88Msps
  - Undersample

- **Mid-grade TX**
  - 14b DAC
  - 122.88Msps
  - Baseband

- **GPSDO**

- **I2C**
- **SPI**
- **UART**

- **GbE**

© 2021 Scotty Cowling WA2DFI

http://hamsci.org
Amateur HF Experimenter

Server Data Engine
50K LE FPGA
5Gb/s USB 3.0
2x GbE

Premium RX
16b ADC
122.88Msps

Premium TX
14b DAC
210Msps

Client Computer
(Single Board or Desktop)
- Local User Display(s)
- Local Data Storage
- Accessory Controls
- CW Skimmer

Remote User(s)

Internet

© 2021 Scotty Cowling WA2DFI
Low Cost Remote Radio

Server Data Engine
- 50K LE FPGA
- 5Gb/s USB 3.0
- 2x GbE

Remote User(s)

Low Cost RX
- 12b ADC
- 80Msps

Low Cost TX
- 12b DAC
- 80Msps

© 2021 Scotty Cowling WA2DFI
Personal Space Weather Station

Software Defined Radio
- Radio Beacon Monitor
  - RBN, PSKReporter, WSPR, Beacons
- HF Noise Characterizer
- GPS TEC Receiver
- Lightning Detector
- Traveling Ionospheric Disturbance Detector

Computer
(e.g. Single Board Computer)
- Local User Display
- Local Data Reduction
- Sends Data to Server

Antenna

GPS Disciplined Oscillator

Magnetometer

HamSCI Public Database

Internet
Software Features

What can I do with it besides PSWS?

- WSPR monitor
- FT8 monitor
- Simultaneous reception of all bands, *while in use as PSWS*
- Notifications via e-mail
- Full digital mode operation once transmit is implemented
- Server to multiple radio clients on local network

Bill Engelke AB4EJ will give a software demo at 12:20PM today
TAPR’s MISSION

Support Digital Radio development with:

R&D funding
  - Breadboard prototypes
  - Alpha PCBs

Early volume production
  - Put leading edge technology into many hands

Result: A growing pool of contributors and experimenters with subsequent advancement of the radio art
Coming Up in September

ARRL/TAPR Digital Communications Conference
September 17-19, 2021
Charlotte, NC
Our Web Page

TangerineSDR.com

Our E-mail Listserv

Post:
TangerineSDR@lists.tapr.org

Subscribe:
lists.tapr.org/mailman/listinfo/