Matchstiq S1x Hardware User's Manual

Version 0.3

EPIQ SOLUTIONS

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Revision History

Date	Revision	Description
06/07/2018	0.1	-Initial draft -Updated Matchstiq S10 H/W Users manual to also included S11 and S12 content -Updated URLs and document hyperlinks -Added Appendix A
01/03/2019	0.2	-Updated Figure 4
03/02/2022	0.3	-Updated Figure 3, added notes to section 7, updated Appendix A

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1 About this Document

This document provides an overview of the Matchstiq™ S1x SDR hardware platforms, associated capabilities, and basic usage. It is provided with the purchase of a Matchstiq S1x unit.

2 Legal Considerations

Matchstiq is distributed all over the world. Each country has its own laws governing transmission and reception of radio frequencies. The user of the Matchstiq platform and associated software is solely responsible for insuring that it is used in a manner consistent with the laws of the jurisdiction in which it is used. Many countries, including the United States, prohibit the reception of certain frequency bands, or receiving certain transmissions without proper authorization. Again, the user is solely responsible for the user's own actions.

3 Proper Care and Handling

The Matchstiq unit is fully tested by Epiq Solutions before shipment, and is guaranteed functional at the time it is received by the customer, and ONLY AT THAT TIME. Improper use of the Matchstiq unit can cause it to become non-functional. In particular, a list of actions that may cause damage to the hardware include the following:

- Opening up the unit while it is powered up
- Handling the unit without proper static precautions (ESD protection) when the housing is removed or opened up
- Connecting a transmitter to the RX port without proper attenuation
- Executing custom software and/or an FPGA bitstream that was not developed according to guidelines

The above list is not comprehensive, and experience with the appropriate measures for handling electronic devices is required.

4 Introduction

This guide provides an overview of the Matchstiq S1x SDR hardware platform, associated capabilities, and basic usage. This includes the following:

- System level block diagram of the platforms
- Overview of the externally and internally accessible hardware ports
- Powering the system up and down
- Logging into a Matchstiq unit
- Executing applications on a Matchstiq unit

All documentation and support for Matchstiq S1x is provided through Epiq Solutions' support website [2], which can be found at:

https://www.epiqsolutions.com/support

Note that there are separate product support forums for each of the different Matchstiq platform variants available from Epiq Solutions, including Matchstiq S1, Matchstiq Z1, and Matchstiq S1x / S2x.

It is necessary to register prior to accessing the relevant information for your purchase.

5 References

[1] **Epiq Solutions Main Website**
https://www.epiqsolutions.com

[2] **Epiq Solutions Support Website**
https://www.epiqsolutions.com/support

[3] **Epiq Solutions' Sidekiq MiniPCIe Card Product Page**
https://www.epiqsolutions.com/sidekiq

[4] **Gateworks Ventana GW5100 Product Page**
http://www.gateworks.com/product/item/ventana-gw5100-network-processor

[5] **Sidekiq FPGA Developer's Manual**
https://epiqsolutions.com/support/viewforum.php?f=44

[6] **Gateworks JTAG usage wiki page**
http://trac.gateworks.com/wiki/jtag_instructions

[7] **Gateworks GPIO usage wiki page**
http://trac.gateworks.com/wiki/ventana/DigitalIO

[8] **OpenWRT Linux distribution for Gateworks Ventana computer module wiki page**
http://trac.gateworks.com/wiki/OpenWrt

[9] **Wi2Wi W2SG0008i GPS receiver module datasheet**
http://www.wi2wi.com/location-and-navigation/gps/w2sg0008i#documentation

[10] **Gateworks GPS usage wiki page**
http://trac.gateworks.com/wiki/gps

[11] **Gateworks OpenWRT + GPS wiki page**
http://trac.gateworks.com/wiki/OpenWRT/GPS

6 Terms and Definitions

Term	Definition
1PPS	1 Pulse Per Second
A/D (ADC)	Analog to Digital converter
AGC	Automatic Gain Control
CPU	Central Processing Unit
D/A (DAC)	Digital to Analog converter
dB	Decibel
dBm	Decibels referenced to one milliwatt (mW)
DC	Direct Current
DMA	Direct Memory Access
ERA	Epiq RF Analyzer
ESD	ElectroStatic Discharge
FPGA	Field Programmable Gate Array
GbE	Gigabit Ethernet
GHz	Gigahertz
GPS	Global Positioning System
HDMI	High Definition Multimedia Interface
I/O	Input/Output
I/Q	In-Phase / Quadrature Phase
JTAG	Joint Test Action Group
kHz	Kilohertz
LED	Light Emitting Diode
LVDS	Low-voltage Differential Signaling
MAC	Media Access Control
MHz	Megahertz
NMEA	National Marine Electronic Association
OTG	On-The-Go
PC	Personal Computer
PDK	Platform Development Kit
PoE	Power over Ethernet
RF	Radio Frequency
Rx	Receive
SCP	Secure CoPy
SDK	Software Development Kit

SDR	Software Defined Radio
SLC	Single-level cell (1 bit per cell)
SMA	SubMiniature A (a style of RF connector)
SRFS	System RF Server
SSH	Secure SHell
TCVCXO	Temperature Compensated Voltage Controlled Crystal Oscillator
Tx	transmit
UART	Universal Asynchronous Receiver Transmitter
uSD	microSD
USB	Universal Serial Bus

Table 1: Terms and Definitions

7 System Overview

Matchstiq S1x are small form factor software defined radio transceivers that provide unprecedented capability and flexibility while maintaining an aggressively low power consumption. Matchstiq S1x combines Epiq Solutions' Sidekiq MiniPCIe card [3] with a custom variant of the Gateworks Ventana GW5100 single board Linux computer module [4] to provide a complete software defined radio platform. The features of the platform include the following:

- **Epiq Solutions' Sidekiq MiniPCIe Software Defined Radio Card**
  - Single RF transceiver covering 70 MHz to 6 GHz (S10/S11) and 1 MHz to 6 GHz (S12)
  - Supports RF channel bandwidths up to 50 MHz
  - Flexible gain controls to adapt to the current RF environment (both manual gain and AGC)
  - Flexible clocking options to support symbol rate sampling at the A/D and D/A converters
  - A/D sample rates up to 61.44 Msamples/sec (12-bits 'I', 12-bits 'Q')
  - D/A sample rates up to 61.44 Msamples/sec (12-bits 'I', 12-bits 'Q')
  - Xilinx Spartan 6 LX45T FPGA for signal processing and data transport to host Linux computer module
  - Supports x1 PCIe (Gen1.1, 2.5 Gbps) and USB 2.0 high speed interface to host.

- **Gateworks Ventana GW5100 Linux Single Board Computer Module**
  - Freescale I.MX6 (quad-core ARM Cortex A9 CPU @ 800 MHz) running Linux
  - 2 GB of SLC Flash memory, 1 GB of DDR3-800 RAM
  - Integrated GPS receiver (Wi2Wi W2SG0008i, based on SiRF Star IV chipset), with 1PPS routed to Sidekiq
  - RJ45 interface supporting 10/100/1000 Base-T Ethernet (supports Passive Power over Ethernet)
  - USB OTG (micro-B connector) interface for additional peripheral/connectivity options
  - HDMI (micro-D connector) video output port
  - Bi-color status LED
  - Real-time clock with battery backup
  - Run-time loadable/executable software applications

- **System**
  - Size: 4.41” x 1.65” x 1.13” (S10/S11) 4.41” x 2.00” x 1.43” (S12)
  - Weight: 5.6 oz (S10/S11) 7.5 oz (S12)
  - Typical power consumption: 5.5W (typical Rx only application, 1000 Base-T Ethernet link)
  - RF Interfaces (Tx antenna, Rx antenna, GPS antenna): SMA
  - Power Input from 8V to 42V DC (via Lemo EGG.0B.302.CLL receptacle)

Block diagrams of the major sub-systems in the Matchstiq S1x units are shown in Figure 1 - 3.

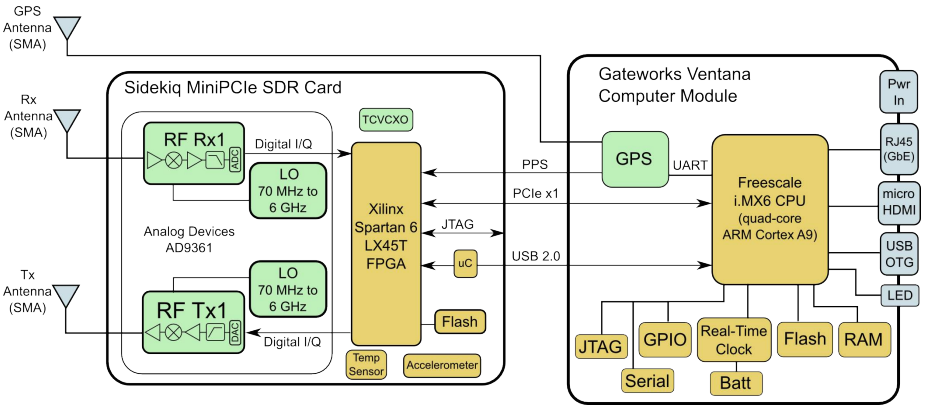

Figure 1: Matchstiq S10 system block diagram

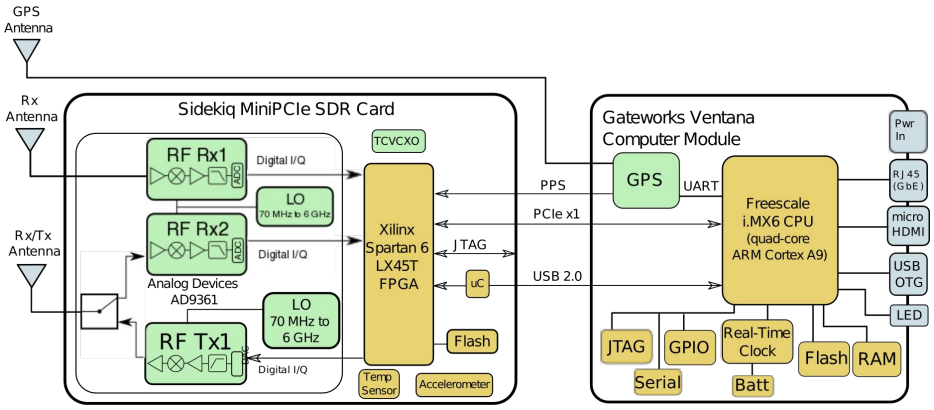

Figure 2: Matchstiq S11 system block diagram

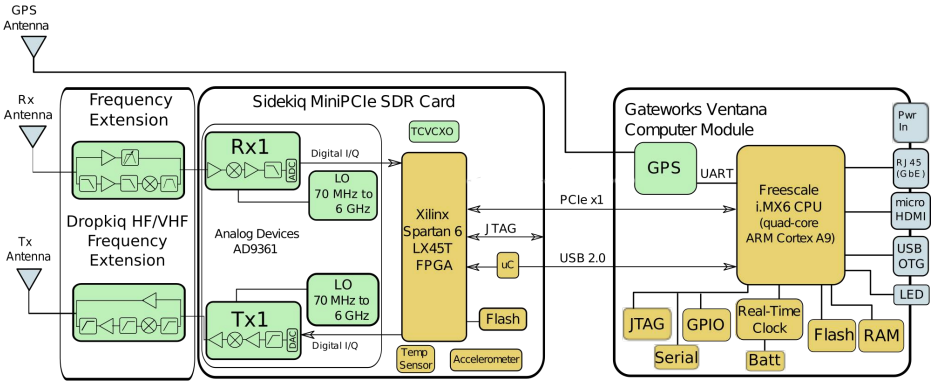

Figure 3: Matchstiq S12 system block diagram

Notes:

- 1PPS support on Matchstiq S10/S11 requires custom FPGA bitstream
- 1PPS and Fast-frequency hopping (FFH) are not supported on Matchstiq S12

7.1 Externally Accessible I/O Ports

Matchstiq S1x has user I/O ports on both the front panel and the rear panel of the unit. The front panel of the unit contains the following ports:

- **RJ45 Ethernet:** This port is used to provide access to the 10/100/1000 Base-T Ethernet interface. This is the primary interface used for connecting the unit to an external computer network. This interface also supports passive Power over Ethernet, allowing the Matchstiq S1x unit to receive both power and Ethernet connectivity via a CAT5/6 Ethernet cable with the appropriate power injector. Contact Epiq Solutions for details.
- **DC Power Input:** This port is used to provide input power to the platform. Input voltages between 8V DC and 42V DC are supported. The input power receptacle is the Lemo EGG.0B.302.CLL. The mating connector, the Lemo FGG.0B.302.CLAD35Z, can be found on the AC/DC power adapter included with the Matchstiq S1x unit.
- **Status LED:** This dual-LED status LED is used to provide visual feedback to the user. This LED includes both a green LED as well as a red LED. Both green and red LEDs can be turned on simultaneously to provide an orange color.

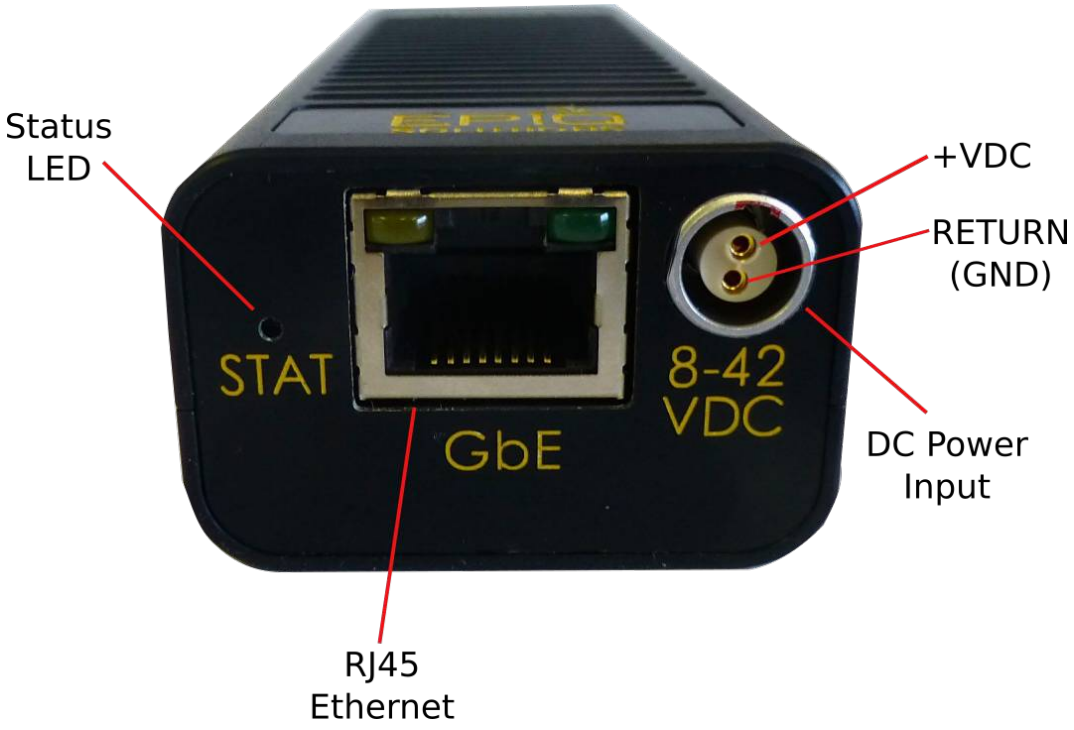

Figure 4: Matchstiq S1x front panel I/O

The rear panel of the unit also contains user I/O ports. This includes the following:

- **Rx:** This SMA port provides a 50 ohm interface to connect an external receive antenna to the RF receiver. **Note: The maximum safe RF input to this port without damage is +20 dBm.**
  - *The Matchstiq S11 can operate as two phase coherent receivers (Rx1 & Rx2) or as 1 RX + 1 TX*
- **Tx:** This SMA port provides a 50 ohm interface to connect an external transmit antenna to the RF transmitter.
- **GPS:** This SMA port provides a 50 ohm interface to connect either a passive or active GPS antenna for the internal GPS receiver. An active GPS antenna is recommended, with a 3V DC bias provided on the center pin. **Note: The maximum safe RF input to this port without damage is +10 dBm.**
- **microUSB:** This microUSB port provides a USB OTG port that can support operation as either a USB host or a USB device. By default, this port is configured for USB host mode and provides 5V DC at 500 mA to power USB peripherals plugged in to this interface.
- **microHDMI:** This microHDMI interface port provides a video output interface through a standard micro-D connector.

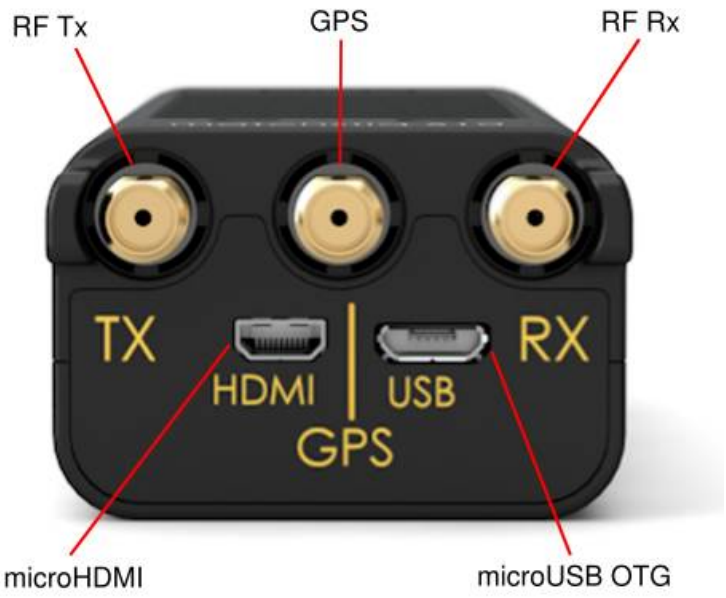

Figure 5: Matchstiq S10 & S12 rear panel I/O

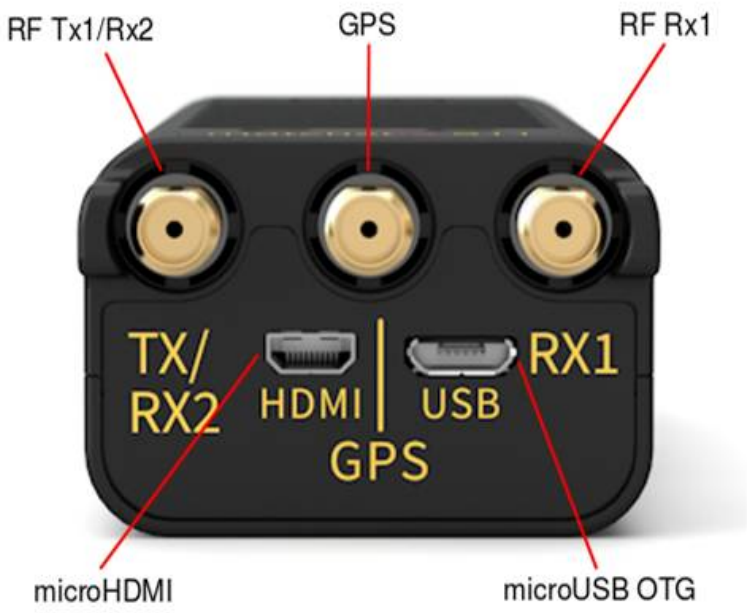

Figure 6: Matchstiq S11 rear panel I/O

7.2 Internally Accessible I/O Ports

Matchstiq S1x also has several I/O ports that are only accessible on the inside of the unit due to the limited front/rear panel space. These ports are enumerated below:

- **JTAG for Xilinx Spartan 6 LX45T FPGA on Sidekiq:** The JTAG port for the FPGA included on Sidekiq is accessible via a special MiniPCIe extension cable that must be inserted in to the MiniPCIe slot on the GW5100 computer module in place of Sidekiq. This extension cable then routes to an external Sidekiq JTAG board, where the Sidekiq MiniPCIe card is inserted. This Sidekiq JTAG board provides access to standard JTAG programming headers. See the Sidekiq FPGA Developer's Manual [5] for details regarding usage of the Sidekiq JTAG board (the Sidekiq FPGA Developer's Manual is only available to customers who have purchased either the Matchstiq S10 Platform Development Kit or the Sidekiq Platform Development Kit). For details of accessing this internal port, see Appendix A.
- **JTAG for GW5100 Computer Module:** The JTAG port for the GW5100 is available on a 2x5 pin header with designator J10 on the GW5100 computer module. This provides low level access to the JTAG interface on the i.MX6 CPU, as well as the 2GB flash device on the GW5100. The appropriate JTAG adapter for connecting a PC to this JTAG interface (Gateworks part # GW11033) is included in the Matchstiq S10 Software and Platform Development Kits. The JTAG interface is accessed through a dedicated USB serial port provided via the JTAG adapter, and typically enumerates on a host Linux PC as /dev/ttyUSB0 (assuming no other USB serial port devices are plugged in to the host PC). Note: This JTAG interface is not needed for standard usage. It is primarily used to perform recovery of the GW5100 computer module in the event that it is required. For details of accessing this internal port, see Appendix A. For details of using the GW11033 JTAG adapter with the GW5100 computer module, see [6].

- **Serial Console for the GW5100 Computer Module:** A standard serial console (UART) is available on a 2x5 pin header with designator J10 on the GW5100 computer module. This is the same header where JTAG can be found. The JTAG adapter [6] also provides access to this serial console via the JTAG adapter's USB interface when connected to a host Linux PC. This serial port typically enumerates on the host Linux PC as /dev/ttyUSB1 (assuming no other USB serial port devices are plugged in to the host PC). The primary use of this serial console is to allow access to the unit in cases where the Ethernet interface and the USB OTG interface are not available. For details on accessing the serial console, see [6].
- **GPIO + UART Interfaces for the GW5100 Computer Module:** There are four 3.3V GPIO lines provided internally on the GW5100 computer module on a 2x5 pin header with designator J11. These pins are connected directly to the i.MX6 CPU and can be accessed through Linux user-space using the sysfs interface provided by default with the OpenWRT Linux distribution installed on the GW5100. In addition, this same header includes two 3.3V logic-level UARTs. A 3.3V supply rail and GND rail are also provided. For details of using these GPIO signals, see [7] for details.

Note: For normal operation, it is not recommended to open up the Matchstiq S1x units in any environment other than an ESD-safe environment. When opening up the Matchstiq S1x unit to access these ports, it is imperative to exercise extreme care in handling of the unit since the internal electronic subsystems will be exposed.

7.3 Powering Up Matchstiq S1x

Matchstiq automatically powers up whenever the appropriate Lemo power cable is plugged into the power input receptacle on the unit. Once plugged in, the complete Linux boot sequence automatically begins. This sequence takes approximately 25 seconds to complete. The Ethernet network initialization takes another ~15 seconds after booting is complete in order for the Ethernet interface to be available for connection.

Note: The Status LED illuminates a solid green until the Linux kernel has fully booted (after approximately 25 seconds) after which it defaults to a blinking green “heartbeat”.

Matchstiq S1x also supports passive Power over Ethernet (PoE) as a means to power the unit. In this scenario, power is supplied through the RJ45 Ethernet connector. Any input voltage between 8V DC and 42V DC can be utilized through the PoE interface. The following guidelines should be used when power is supplied through the RJ45 Ethernet connector:

- The positive input voltage is applied to pins 1-2 data pair and pins 4-5 data pair of the RJ45 cable.
- The negative input voltage is applied to pins 3-6 data pair and pins 7-8 data pair of the RJ45 cable.
- The positive inputs are all diode protected so that powering through one will not backfeed the others.
- The RJ45 connector is rated for 0.6A maximum current per data pair for a total of 1.2A for both data pairs.
- The RJ45 connector is not a hot plug connector and **ALL CABLE CONNECTIONS SHOULD BE MADE BEFORE POWER IS APPLIED.**

7.4 Connecting Matchstiq S1x to a Host PC

Once the unit is powered up and the Linux kernel has booted, the typical way to connect Matchstiq S1x to a host PC is through the RJ45 Ethernet interface. This interface has a default static IP address of **192.168.2.140**. In order to connect to this interface from a host PC, the host PC should have an IP address on the same 192.168.2.xxx subnet (such as 192.168.2.1). The user should be able to ping the Matchstiq S1x unit from a terminal shell on the host PC using the following command entered in to the terminal shell:

```
$ ping 192.168.2.140
PING 192.168.2.140(192.168.2.140) 56(84) bytes of data.
64 bytes from 192.168.2.140: icmp_req=1 ttl=64 time=0.323 ms
64 bytes from 192.168.2.140: icmp_req=2 ttl=64 time=0.390 ms
64 bytes from 192.168.2.140: icmp_req=3 ttl=64 time=0.225 ms
64 bytes from 192.168.2.140: icmp_req=4 ttl=64 time=0.405 ms
64 bytes from 192.168.2.140: icmp_req=5 ttl=64 time=0.343 ms
--- 192.168.2.140 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3999ms
rtt min/avg/max/mdev = 0.225/0.337/0.405/0.064 ms
```

Another method of connecting the Matchstiq S1x to a host PC is through the USB OTG (micro-B connector) interface. This interface has a default static IP address of **192.168.3.99**.

```
$ ping 192.168.3.99
PING 192.168.3.99 (192.168.3.99) 56(84) bytes of data.
64 bytes from 192.168.3.99: icmp_seq=1 ttl=64 time=0.306 ms
64 bytes from 192.168.3.99: icmp_seq=2 ttl=64 time=0.262 ms
64 bytes from 192.168.3.99: icmp_seq=3 ttl=64 time=0.239 ms
64 bytes from 192.168.3.99: icmp_seq=4 ttl=64 time=0.244 ms
64 bytes from 192.168.3.99: icmp_seq=5 ttl=64 time=0.247 ms
--- 192.168.3.99 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4086ms
rtt min/avg/max/mdev = 0.239/0.259/0.306/0.030 ms
```

With a successful ping session complete, network connectivity between the Matchstiq S1x and the host PC has been confirmed. From here, the user can proceed to establish a secure shell (SSH) connection to the Matchstiq S1x unit from the host Linux PC. The default login credentials are:

username: root

password: root

```
epiq@HostLinuxBox $ ssh root@192.168.2.140
root@192.168.2.140's password:
```

```
     === Matchstiq S1x / S2x ===
         === Release 12.2 ===

root@OpenWrt-sn....:~#
```

Congratulations, you have now established an SSH connection to the Matchstiq S1x unit and are logged in. The default Linux distribution installed on Matchstiq S1x is called OpenWRT. This is a popular Linux distribution typically used for embedded wireless routers and other networking devices. Additional details of OpenWRT and its usage on the Gateworks GW5100 Ventana computer module can be found in [8].

7.5 Executing Application

At power-up, each Matchstiq unit can automatically launch a user's software application if desired. Default application execution is provided by using the standard Linux init.d initialization scripts. For example, one possibility is to launch a software application by adding it to the /etc/init.d/rc.local script.

The SRFS (System RF Server) application is enabled by default at power-up on S1x units. You will need to stop this service if you wish to run any of the test applications without a failure message.

To stop the **srfs_rx service** from running this power cycle: `$ /etc/init.d/srfs_rx stop`

Each Matchstiq unit ships with a set of test/validation applications that can be used to exercise different functionality in the radio system. Matchstiq S1x can really be thought of as a small embedded computer platform hosting Epiq Solutions' Sidekiq MiniPCIe SDR card. Thus, the test applications delivered on this platform are centered around demonstrating the functionality of Sidekiq. The executable binaries for these test applications are all installed on the unit at /root/sidekiq_image_current/test_apps/. The source code for these test applications are delivered as part of the Software and Platform Development Kit, along with the libsidekiq Linux userspace library. A partial list of the utility applications shipped with each Matchstiq unit is shown below:

- **rx_samples:** an application for configuring the RF receiver and c/init.d/srfs_rx stoprecording contiguous blocks of I/Q data to a file stored on the unit
- **tx_samples**: an application for configuring the RF transmitter and transmitting I/Q data that has previously been stored in a file on the unit
- **read_temp**: a simple application for reading the current temperature of the unit

These applications can be launched just like any normal Linux command line application would be executed on the unit. The majority of the test apps explain their usage if the application is executed without any command line arguments.

Note: The test apps contained in the Matchstiq S1x unit are intended to demonstrate usage of the libsidekiq Linux userspace library, and provide a basic starting point for users interested in developing their own software applications using the SDK. These test apps are not intended to be full-featured or optimized for execution.

7.6 Copying Files Between a Host PC and the Matchstiq Unit

The simplest way to copy files to/from the Matchstiq unit is to use the secure copy, or SCP, command line application. This is available by default in most major Linux distributions, and a Windows version called winscp is also available.

The syntax for copying a file from the host PC to the Matchstiq unit is:

$ scp <full path to file> root@<IP address of Matchstiq>:<full destination path on device>

For example, to copy a file called “myapp” from the host PC to the root directory on a Matchstiq unit with an IP address of 192.168.2.140, the following command would be used:

```
$ scp myapp root@192.168.2.140:/root/
```

Copying the myapp from the Matchstiq unit back to the host PC follows a similar command line, only in reverse:

```
$ scp root@192.168.2.140:/root/myapp /home/user/
```

8 RF Specifications

Matchstiq S1x utilizes the Sidekiq SDR MiniPCIe card. Additional RF performance specifications for this card can be found in the Sidekiq product spec sheet [2].

Matchstiq	S10	S11	S12
Operating Modes	One RF receiver and one RF transmitter	One RF receiver and one RF transmitter or as Two phase coherent RF receivers	One RF receiver and one RF transmitter
Rx Pre-Select Filtering	---	---	7-band filters (sub-octave from 400MHz to 6 GHz)
RF Tuning Range	70 MHz to 6 GHz	70 MHz to 6 GHz	1 MHz to 6 GHz
RF Channel Bandwidth	Up to 50 MHz	Up to 50 MHz	Up to 50 MHz
Typical Rx Noise Figure	< 8dB	< 8dB	< 8dB
Typical Rx IIP3	-10 dBm	-10 dBm	-10 dBm
Rx Sample Rate Range	200 Ksamples/sec to 61.44 Msamples/sec	200 Ksamples/sec to 61.44 Msamples/sec	200 Ksamples/sec to 61.44 Msamples/sec
Tx Sample Rate Range	200 Ksamples/sec to 61.44 Msamples/sec	200 Ksamples/sec to 61.44 Msamples/sec	200 Ksamples/sec to 61.44 Msamples/sec
ADC & DAC sample width	12-bits	12-bits	12-bits
Rx Gain Range	0 - 76 dB, 1dB steps	0 - 76 dB, 1dB steps	0 - 76 dB, 1dB steps
Tx Gain Range	0 to 89.75 dB, 0.25 dB steps	0 to 89.75 dB, 0.25 dB steps	0 to 89.75 dB, 0.25 dB steps
Typical Tx Output Power	+13 dBm < 2 GHz +10 dBm > 2 GHz	+13 dBm < 2 GHz +10 dBm > 2 GHz	+3 dBm Lowband (< 200MHz) +13 dBm Highband (< 2GHz) +10 dBm Highband (> 2 GHz)

Table 2: RF Specifications

8.1 Matchstiq S12 Frequency Extension and Pre-Select Filtering

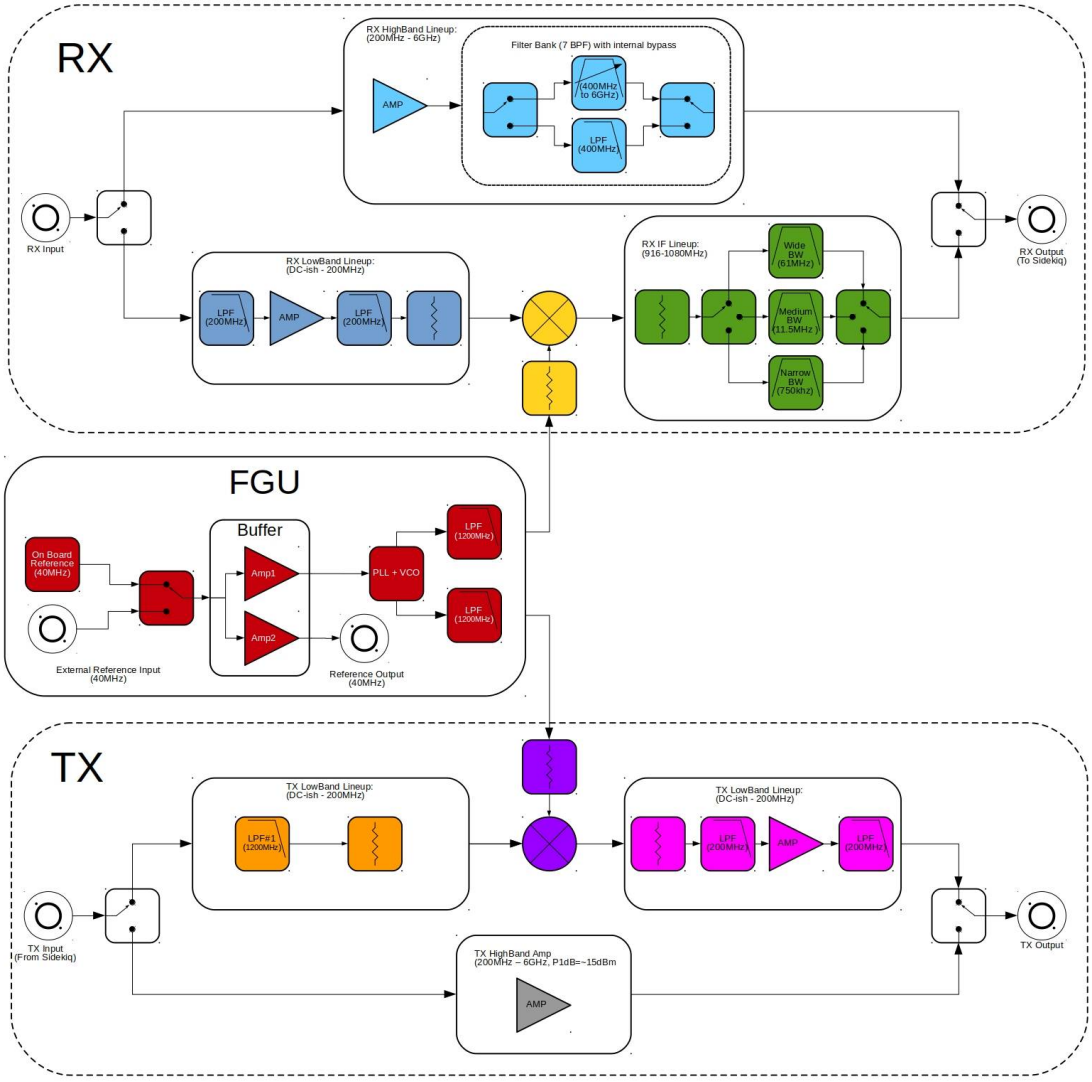

Figure 7: S12 Frequency Extension & Filtering

- The high-band Rx path (70MHz - 6GHz) is routed through a sub-octave preselect filter where the signal is passed on to Sidekiq.
- The low-band Rx path (1 MHz - 200MHz) is routed through a block up-converter then through a software selectable set of SAW filters at the high IF of ~ 1GHz. This selects the bandwidth of interest, wide BW of 61MHz, medium BW of 11.5 MHz, or narrow of 750kHz. The signal is then passed on to Sidekiq where it is tuned to the high IF frequency, receiving the post-filtered signal.
- The high-band Tx path (70MHz - 6GHz) routes the Sidekiq Tx output through an LNA and over to the Tx SMA output.

- The low-band Tx path (1MHz - 200MHz) routes the Sidekiq Tx output through a low-pass filter, a block down-converter, a low-pass filter, LNA, another low-pass filter, and over to the Tx SMA output.

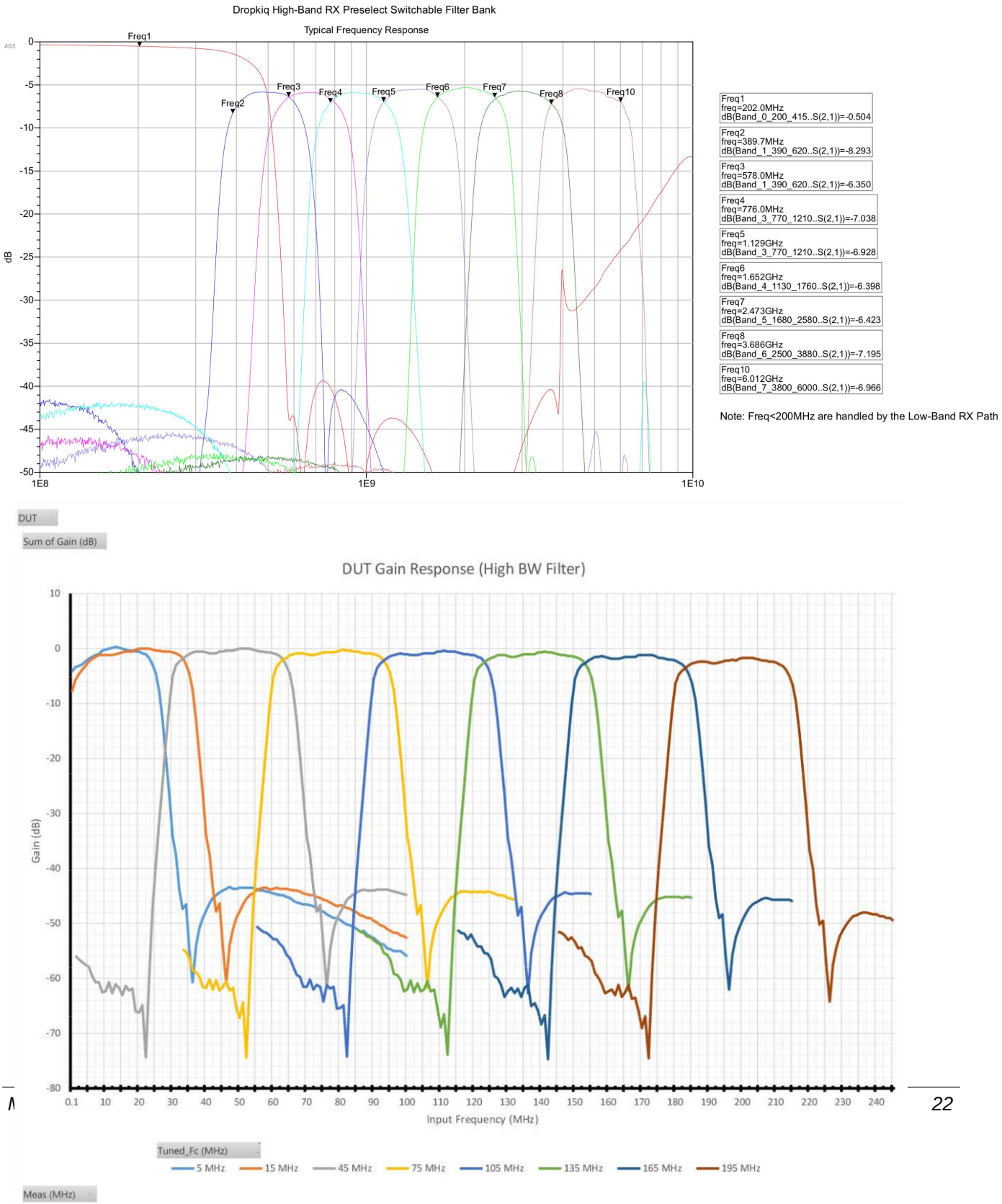

Figure 9: S12 Low-Band Rx Pre-select Filter Frequency Response

9 Clock Specification

The Sidekiq SDR MiniPCIe card utilizes a common 40 MHz TCVCXO reference clock with typical stability of ± 1PPM. This reference clock is shared between the RF front end for LO tuning and sample rate generation. In addition, this same reference clock is made available to the FPGA as a clock input. The TCVCXO can be warped ± 6 PPM using a dedicated D/A converter onboard Sidekiq. See the Sidekiq Hardware User's Manual [2] for details.

10 GPS Specification

The Gateworks GW5100 computer includes an on-board GPS receiver based on the SiRF Star IV GPS chipset. The part number for this GPS receiver is the Wi2Wi W2SG0008i [9]. This receiver connects to the i.MX6 CPU through a serial port to provide either binary or NMEA navigation and time information. In addition, the PPS signal from the GPS receiver is routed to an input pin (pin H3) on the Spartan 6 FPGA located on the Sidekiq SDR card. This PPS signal is also routed to a hardware interrupt on the i.MX6 CPU.

Additional details of using the GPS receiver on the GW5100 can be found at the following links:

http://trac.gateworks.com/wiki/gps [10]
http://trac.gateworks.com/wiki/OpenWrt/GPS [11]

11 Power Consumption

Power consumption of the Matchstiq S1x is heavily dependent on the functionality of the system. It is often quite difficult to estimate power consumption for a specific application (software-only, software + FPGA, different I/O interfaces being utilized, etc) until the application is available for execution on the unit to test. Here are some general guidelines that can be used when estimating power consumption of the Matchstiq S1x unit, based on the functionality that is being utilized:

Functional Description	Typical Power Consumption (in W)	Notes
GW5100 with quad-core i.MX6 CPU board	1.7	
OpenWRT Linux kernel loaded at prompt	0.28	3.10.x Linux kernel (or later)
100 Mbps Ethernet link established	0.11	
1000 Mbps Ethernet link established	0.50	
100 Mbps UDP iperf client	0.81	
400 Mbps UDP iperf client	1.18	
HDMI output connected to external display	0.18	Power of external display not included
GPS searching for fix	0.15	
GPS fix acquired	0.10	
Sidekiq receiving samples at 15.36 Msamples/sec tuned to 751 MHz	2.1	
Sidekiq performing FDD transmit at 915 MHz (+10 dBm output power), receive at 2.4 GHz, 5 Msamples/sec	2.6	

Notes:

- S10/S11 power consumption: 5.5W (typical Rx only application, 1000 Base-T Ethernet link)
- S12 power consumption: ~7.2W - 8.4W with rx_samples: rate = 20MHz, freq = 180MHz (Low-Band Rx) 1.8GHz (High-Band Rx), 1000 Base-T Ethernet link.
- Dependent on input supply voltage

12 Understanding Data Transport on Matchstiq S1x

Matchstiq S1x is a complex system combining a variety of high-speed analog and digital interfaces. Understanding the various data transport capabilities between the different hardware sub-systems is critical when evaluating the platform for suitability for a given task. The goal of this section is to provide insight in to the expected performance, and understand where improvements may be feasible in the future.

12.1 Transporting Quadrature Baseband Samples between the RF Front End and the FPGA

The Sidekiq SDR card integrated in to Matchstiq S1x is responsible for supporting the transport of quadrature (I/Q) baseband samples between the RF front end and the Xilinx Spartan 6 FPGA. Separate transmit and receive interfaces are used to transport samples between the baseband A/D and D/A converters integrated in to the RF IC and the FPGA. Both the transmit and receive interfaces utilizes their own 6-bit wide LVDS bus, where both the 'I' and 'Q' samples are multiplexed on to this bus 6-bits at a time.

The maximum sample rate between RF IC and the FPGA is 61.44 Msamples/sec. This transport rate is not anticipated to change, as the maximum RF channel bandwidth supported is 50 MHz (limited by the analog baseband filters in the RF IC), which can be sufficiently digitized with a sample rate of 61.44 Msamples/sec.

12.2 Transporting Data between the FPGA and Freescale i.MX6 CPU

A PCIe x1 (Gen1.1) interface connects the FPGA to the i.MX6 CPU. The PCIe root complex is provided directly by the i.MX6. This single lane (x1) interface operates at a theoretical maximum rate of 2.5 Gbps. After 8b/10b coding, the theoretical maximum data transport rate is 2 Gbps. This equates to 250 MB/sec. However, in practice, the achievable sustained transport rate is lower than this.

Please refer to the Sidekiq Software Development Kit manual, Appendix 8 – Assessing Throughput Performance for guidance on using the pre-built Sidekiq benchmarking test applications which include *rx_benchmark, tx_benchmark, and xcv_benchmark* on the Matchstiq S1x unit.

One of the test applications delivered on the Matchstiq S1x unit is called *rx_benchmark*. This application measures the achievable transport speed of the PCIe interface between the FPGA and i.MX6 CPU. Typically, the *rx_benchmark* application can achieve throughputs in the range of 150 MB/sec. The current continuously sustainable data transport rate between the FPGA and CPU (without dropping any samples) is ~80 MB/sec, equating to approximately 20 Msamples/sec when using unpacked sign-extended 16-bit 'I' and 16-bit 'Q' samples. Typically, even this level of data will overwhelm the ARM CPU if any level of processing of the data is required. There are applications where simple snapshot recording of samples to RAM can be utilized at higher sample rates, followed by post-processing of the samples in non-real time. This data transport performance is expected to be improved with additional refinements to the DMA transport between the FPGA and CPU. Note: This throughput can also be increased by utilizing a packed mode of data transport, where each I/Q sample only occupies 24-bits instead of 32-bits. This increases the throughput to 26.67 Msamples/sec, at the expense of needing to perform additional processing to either pack (on transmit) or unpack (on receive) the samples on the CPU.

12.3 Transporting Data between the RJ45 Ethernet Interface and an External Ethernet Device

The 10/100/1000 Base-T Ethernet interface integrated in to Matchstiq S1x is provided directly by the Ethernet MAC in the i.MX6 processor. While this Ethernet interface is capable of negotiating and establishing a 1000 Base-T link, due to an errata in the i.MX6 processor, the Ethernet MAC is only capable of sustaining a data transport rate of approximately 400 Mbits/sec (~50 MB/sec). If transporting a contiguous stream of unpacked I/Q samples, sign-extended from 12-bits to 16-bits for each 'I' and 'Q' sample, the maximum possible sustainable sample rate is 12.5 Msamples/sec. Packing of the I/Q samples (where one I/Q sample pair can be packed in to 24-bits instead of 32-bits), the maximum sustainable sample rate can be increased to 16.67 Msamples/sec.

13 Appendix A – Matchstiq S1x Statement of Volatility

Statement of Volatility				
Model: **Matchstiq S1x (S10/S11/S12)**	Part Number: **ES002-110/113/114**	Manufacturer: **Epiq Solutions**		
		Street Address: **3740 Industrial Avenue**		
		City: **Rolling Meadows**	State: **IL**	Zip: **60008**

Volatile Memory

Does the item contain volatile memory (i.e., memory whose contents are lost when power is removed)?
☒ Yes ☐ No

If the answer is 'Yes', please provide the following information for each type (use additional sheets if required):

Type (SRAM, DRAM, etc.):	Size:	User Modifiable:	Function:	Process to Clear:
Sidekiq FPGA	**2 MB**	☒ Yes ☐ No	**Block RAM inside FPGA for application storage**	**Remove power**
GW5104 DRAM and CPU Registers	**2 MB**	☒ Yes ☐ No	**Main CPU RAM and Configuration of CPU**	**Remove power**
GW5104 GSC Registers	**512 MB**	☒ Yes ☐ No	**System Controller, Secure EEPROM storage**	**Remove coin cell battery**

Non-Volatile Memory

Does the item contain non-volatile memory (i.e., memory whose contents are retained when power is removed)?
☒ Yes ☐ No

If the answer is 'Yes', please provide the following information for each type (use additional sheets if required):

Type (BBRAM, Flash, EEPROM, etc.):	Size:	User Modifiable:	Function:	Process to Clear:
Sidekiq EEPROM	**16 KB**	☐ Yes ☒ No	**Holds factory settings and firmware image**	**Must be sent back to factory to clear**
Sidekiq Flash	**4 MB**	☒ Yes ☐ No	**Used by on-board microcontroller for system management procedures**	**Cleared with software test application provided**
CPU Efuses	**See Ref. Manual**	☐ Yes ☒ No	**Holds CPU configuration**	**One time programmable, cannot clear**
Nand Flash	**2 GB**	☒ Yes ☐ No	**OS and file storage**	**Cleared with Linux software commands for writing to flash such as nand erase, etc.**

Media

Does the item contain media storage capability (i.e., removable or non-removable disk drives, tape drives, memory cards, etc.)?

☐ Yes ☒ No

If the answer is 'Yes', please provide the following information for each type (use additional sheets if required):

Type (Disk, Tape, etc.): Removable: ☐ Yes ☐ No	Size:	User Modifiable: ☐ Yes ☐ No	Function:	Process to Clear:

Additional Information:

For the ERA application running on Matchstiq S1x:
- Log files are stored in volatile memory (in /tmp and /var/log, which are RAM disks on the S1x) so those files will not persist after a reboot or power cycle.
- There is a User Trace function that can store an instantaneous snapshot of FFT trace data to the S1x (Settings->Traces->User Traces->Create New). This feature stores the frequency and span of the originally captured signal and the FFT power data at the time of storage. This data is stored in non-volatile memory and will persist after a reboot or power cycle (contact Epiq Solutions if this is an issue).
- ERA cannot record I/Q samples to non-volatile memory without a Pro license. All data is processed in RAM and never written to disk.
- ERA on the S1x cannot store screenshots due to browser security permissions
- The RX LO on the Sidekiq will remain tuned to the last tuned frequency until power is lost
- ERA can change the config file on exit. It will attempt to reload and reparse the original configuration, update the recording paths if there were any changes, and overwrite the original config file. As it reparses the original file, any comments that were originally in the config file are stripped and removed. The S1x version currently doesn't allow changes to the recording path, so none of the values in the configuration should change.