



# Wrangler Theory of Operations

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Rev B

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This manual provides a technical overview of the Wrangler Seismic Recorder.

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## Revision History

Rev	Date	Reason for Change	Pages
0.1	2018-03-01	Initial development	All
A	2019-07-18	Initial release	All
B	2019-11-06	Update all sections	All

## Legal Notices

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## Notation Conventions

The following notation conventions are used throughout REF TEK documentation:

Notation	Description
ASCII	Indicates the entry conforms to the American Standard Code for Information Interchange definition of character (text) information.
Binary	Indicates the entry is a raw, numeric value.
Hex	Indicates hexadecimal notation. This is used with both ASCII characters (0 – 9, A – F) and numeric values.
BCD	Indicates the entry is a numeric value where each four bits represents a decimal digit.
FPn	Indicates the entry is the ASCII representation of a floating-point number with n places following the decimal point.
<n>	Indicates a single 8-bit byte. When the contents are numeric, it indicates a hexadecimal numeric value; i.e. <84> represents hexadecimal 84 (132 decimal). When the contents are capital letters, it represents a named ASCII control character; i.e. <SP> represents a space character, <CR> represents a carriage return character and <LF> represents a line feed character.
MSB	Most Significant Byte of a multi-byte value.
MSbit	Most Significant Bit of a binary number.
LSB	Least Significant Byte of a multi-byte value.
LSbit	Least Significant Bit (bit 0) of a binary number.
YYYY	Year as a 4-digit number
DDD	Day of year
HH	Hour of day in 24-hour format
MM	Minutes of hour
SS	Seconds of minute
TTT	Thousandths of a second (milliseconds)
III	Unit ID number
n, ns	nano, nanosecond; $10^{-9} = 0.000000001$
u, us	micro, microsecond; $10^{-6} = 0.000001$
m, ms	milli, millisecond; $10^{-3} = 0.001$
K, KHz	kilo, kilohertz; $10^3 = 1,000$
M, MHz	mega, megahertz; $10^6 = 1,000,000$
G, GHz	giga, gigahertz; $10^9 = 1,000,000,000$
Kb, KB	kilobit, kilobyte; $2^{10} = 1,024$
Mb, MB	megabit, megabyte; $2^{20} = 1,048,576$
Gb, GB	gigabit, gigabyte; $2^{30} = 1,073,741,824$



### WARNING

This alert warns of a potential hazard which, if not avoided, could result in severe injury or even death.



### CAUTION

This alert warns of a potential hazard or unsafe practice that could result in minor injury or property damage or irretrievable data loss.

**NOTE: This page intentionally blank.**

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Your REF TEK support team

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## 1 System Overview

The REF TEK® Wrangler™ Data Acquisition System (DAS) can be broken down into various subsystems:

- Power Management
- LEDs
- Networking
- Web UI
- Timekeeping
- A/D Converter and Sampling
- Datastream Parameters and Triggering
- Data Storage
- Telemetry
- Sensor Control
- Auxiliary Data

Each of these subsystems is described in one or more of the following sections.



## 2 Power Management

Every attempt is made to minimize the power usage of Wrangler. For this reason, various hardware subsystems are power-cycled rather than being powered continuously. These include:

- GPS
- USB
- Wi-Fi

Wrangler will automatically boot-up up as soon as external power is supplied. A magnetic switch is located under the yellow triangle logo on the label (in between the "F" and "T" in "REF TEK"). Holding a magnet to the switch for 3 seconds tells the unit to perform an orderly shutdown. Holding a magnet to the switch for 8 seconds causes an immediate and abrupt hardware shutdown. Briefly waving the magnet over the switch activates the LEDs and enables the Wi-Fi. The LEDs and Wi-Fi act as a pair and are always either both on or both off at the same time; there is no case where one is on without the other one also being on. The LEDs and Wi-Fi are automatically enabled at power-up for 30 minutes. The on-time will be automatically extended in 5 minute increments if the user is connected to the Wrangler Wi-Fi. Waving the magnet over the magnetic switch while the LEDs and Wi-Fi are already turned on causes the Wi-Fi module to be re-initialized and the connection to any connected mobile device will be dropped. The on-time is automatically extended while in use, therefore the user is discouraged from waving the magnet over the switch while the LEDs and Wi-Fi are already turned on. Whether turned on automatically after power-up or turned on by a wave of the magnet over the switch, the LEDs and Wi-Fi are both disabled after 30 minutes of on-time and when activity over the Wi-Fi connection ceases in order to save power.

A backup battery is supplied in the unit to preserve the contents of SRAM and states of certain devices when power is lost unexpectedly. However, the backup battery is disconnected on an intended shutdown, such as when the unit is in storage. This prolongs the life of the backup battery while still providing backup during an unexpected outage. In this case, the backup battery disconnects from the system after at least 30 days.

An orderly shutdown performs the following actions:

- Flush any remaining data to disk (when recording to disk).
- Write active parameters to non-volatile storage.
- Disconnect the battery backup from the system.
- Terminate system power.

Waving the magnet on a unit which still has power connected following an orderly shutdown will power the unit back up.

When power is disconnected from the unit unexpectedly, or after performing an orderly shutdown, the unit will automatically power up when power is reconnected.



### 3 LEDs

Wrangler displays various status conditions using 16 bi-color LEDs. In general, a green light indicates a positive working condition and a red light indicates a warning or error condition. The following lists the conditions and their meaning for the LEDs:

LED	Off	Green Solid	Green Blink	Red Blink	Red Solid
TIME	n/a	Reference Clock locked within the last hour	Reference Clock last locked between 1 – 4 hours ago	Reference Clock last locked longer than 4 hours ago	Reference Clock has not locked since boot
ACQ	n/a	Acquisition is on and no non-continuous triggers are active	Acquisition is on and at least one non-continuous trigger is active	n/a	Acquisition is off
V-IN	n/a	Input voltage is at or above 13.0 V	Input voltage is less than 13.0 V and $\geq 11.5$ V	Input voltage is below 11.5 V and not in LVD mode	Input voltage is below 11.5 V and in LVD mode
WIFI	Wi-Fi is off	Wi-Fi is on and the mobile app is connected via Wi-Fi	Wi-Fi is on but the mobile app is not connected via Wi-Fi	Wi-Fi is turning on	n/a
SLINK	No clients connected	One client is connected	Multiple clients are connected	n/a	n/a
RTPD1	Not configured	Connected	n/a	n/a	Not connected
RTPD2	Not configured	Connected	n/a	n/a	Not connected
ERR	No other LEDs are red	n/a	n/a	n/a	At least one other LED is Red Solid or Red Blink
RAM%	n/a	Less than 20% total RAM used	Between 20% and 80% total RAM used, and at least one RTP link using less than 20% of total RAM	Between 20% and 80% total RAM used, and at least one RTP link using more than 20% of total RAM	More than 80% total RAM used
USB%	n/a	Less than 33% total USB used	Between 33% and 66% total USB used	Between 66% and 99% total USB used or more than 99% total USB used and Disk Wrap is enabled	More than 99% total USB used and Disk Wrap is disabled
USB	n/a	USB off and no data read or write errors	n/a	USB on	USB off and a read or write error occurred
CLOUD	Not used - Reserved for future use.				



## 4 Networking

### 4.1 Overview

Wrangler includes support for IP communications. The applications supported by the Wrangler unit are the Web UI, sFTP server, Command server, SeedLink server and RTP (REF TEK Real-Time Protocol) client.

#### 4.1.1 IP Addresses

As shipped from the factory, Wrangler defaults to a link-local IP address. This allows connection of the unit to any local network without worrying about an IP conflict. The IP address can then be changed to either a static IP or DHCP address. Refer to the Wrangler Quick Start Guide that comes with the unit to see the default link-local IP address of the Wrangler and instructions on how to connect to the Wrangler for the first time.

#### 4.1.2 Ports

Wrangler uses the following IP ports:

Service	Port	Protocol
Web UI	80	TCP
FTP, sFTP	21(plain text), 990 (TLS)	
SeedLink	18000	TCP
RTP1	2543 (changeable)	UDP
RTP2	2543 (changeable)	UDP
Command server	5000	TCP
Ping (echo request)	n/a	ICMP

### 4.2 Web UI

The primary user interface of Wrangler is a built-in set of HTML pages that are referred to as the Web UI and which can be viewed in one of two ways. The first way is over the Wrangler Wi-Fi connection using the "REF TEK Recorder Setup" available from both major "App" stores. See the Wrangler Quick Start guide for information on downloading the App to your mobile device. The second method for viewing the Web UI is by using a standard web browser connected to Wrangler using its Ethernet port. The Web UI can be accessed by pointing a browser to the IP address of the Wrangler

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unit. The Web UI has been designed for use on both large screens and mobile device screens. The Web UI auto-detects the screen size and adapts accordingly.

The Web UI is divided into five main sections: Status, Monitor, Control, Parameters, and Login. For security purposes, the Wrangler Web UI works with three different login levels which help to prevent unauthorized access to the unit. Level 1 does not require the user to login. It only grants the user access to the Status screen. When the user initially connects to the Web UI they are brought directly to the Status screen. The Status screen does not have any user input buttons or fields; it simply allows the user to see the various status reports of the Wrangler unit. Since there is no user input allowed on the Status screen, no login is required.

Login level 2 is the “user” login level. With the “user” login level, the user has access to the Status, Monitor, and Control sections. The Control screens allow the user to do general control functions on the Wrangler unit, such as formatting the USB stick, Starting/Stopping Acquisition, and performing all sensor control functions including locking, unlocking, centering, and calibrating the sensor. The “user” login level does not give the user access to change the key parameters of the Wrangler unit.

Login level 3 is the “admin” login level. With the “admin” login level, the admin has access to the Status, Monitor, Control, and Parameter sections. The Parameter screens give the user the ability to control all of the Wrangler’s parameters including all of the recording and networking parameters.

As shipped from the factory, Wrangler prompts the user to set an admin level password the first time they connect to the unit. It is recommended that the user also set the user level password at the same time.

After logging into the Wrangler Web UI (via web browser or mobile app) as either “user” or “admin”, both accounts will remain logged in until there is 20 minutes of inactivity. After 20 minutes of inactivity, the accounts will be automatically logged off. A successful login is only valid for the specific device (PC or mobile device) which was used to log in. Someone trying to connect to the Wrangler Web UI from a different device will be required to login from that device as well, even if someone is already logged in from the first device. An immediate logout can be forced by going to the main Login section of the Web UI and clicking the “Log out” button.

### 4.3 FTP (File Transfer Protocol)

Wrangler includes an FTP server to enable transfer of files from/to the DAS. The FTP server allows up to two FTP clients at one time. Additional connection attempts will be refused by Wrangler.

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The Wrangler FTP server has a two minute time-out period. If no activity occurs on the FTP link for two minutes, the FTP server will close the connection. If a client connection is not properly terminated Wrangler will time-out after 30 seconds of inactivity and close the connection. This will allow another client to then connect to the FTP server.

FTP login (authentication) uses the same username and password as the user level login defined for standard command and control (same as the Web UI login credentials). FTP only requires the user level login credentials, but it also accepts the admin login credentials.

The Wrangler FTP server works with standard FTP clients, such as FileZilla.

#### 4.4 SeedLink

Wrangler includes a SeedLink server which is active when recording data in MiniSEED (MSD) format with the SeedLink recording destination enabled in the datastream recording parameters. Wrangler supports two simultaneous SeedLink connections.

More details about the SeedLink server are given in a subsequent section.

#### 4.5 RTP

Wrangler supports two independent RTP links. The typical use is to telemeter data to two different RTPD server IP addresses. The default port is the port registered with IANA; UDP port 2543.

More details about RTP are given in a subsequent section. See the RTPD user manual for more details on setting up the required central server RTPD software.

#### 4.6 Command Server

Wrangler includes a Command server for direct IP transmission of commands. For more information about the commands, see the Wrangler Command Format document.



## 5 Timekeeping

This section explains how time is handled in the Wrangler.

### 5.1 Overview

Wrangler contains a Real Time Clock (RTC) that provides initial time at power up. Thereafter, time is maintained by a combination of a field programmable gate array (FPGA), a voltage controlled crystal oscillator (VCXO) and firmware. The time can be changed by the user or set using an external time source. The RTC is updated whenever time is set.

Internal time is maintained as seconds since January 1, 2000 and sub-seconds. Internal time can be synchronized to an external time source.

### 5.2 Phase Measurement

Both phase error and drift error are measured and corrected by Wrangler. Phase errors and clock corrections are recorded to the State of Health log to allow precise time corrections during post-processing of recorded data.

### 5.3 External Time Sources

Wrangler's internal time can be synchronized to one of three supported external time sources: a Trimble Acutime360 GNSS receiver, a Precision Time Protocol (PTP) master clock or a Network Time Protocol (NTP) time source. Wrangler phase-locks its internal 1Hz signal to the external reference. The accuracy of time is dependent on which source is used. GNSS provides the most accurate time while NTP is the least accurate.

#### 5.3.1 Acutime360 GNSS receiver

The Trimble Acutime360 GNSS receiver provides various time and status messages and a 1Hz pulse to Wrangler. Wrangler decodes the messages to determine when time is stable and to compare its internal time with the GNSS time. When the GNSS receiver reports that its time is accurate, Wrangler uses the GNSS receiver's 1Hz pulse to compare and adjust its own internal 1Hz to. After alignment, Wrangler's internal 1Hz is accurate within +/- 1 microSecond of the external reference. The Acutime360 GNSS 1Hz pulse is accurate to approximately 15 nanoSeconds (1 Sigma).

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## GPS Duty Cycle

This option allows the user to set exactly how the external GNSS receiver will be used to phase lock the internal VCXO. The available options are Continuous, Duty-Cycle, and OFF. When in Duty-cycle mode, the external GNSS receiver is powered up once per hour at 40 minutes past the hour. It remains on for 20 minutes at most, but shuts off as soon as accurate time is achieved. In Continuous mode, the external GNSS receiver is always powered and the Wrangler unit will continuously phase-lock its internal 1Hz signal to the external receiver's 1Hz signal. In OFF mode, the external GNSS receiver is turned off until this setting is changed by the user.

For almost all applications, the Duty-cycle setting is the correct setting and provides very accurate timing while also allowing power savings by cycling the external GNSS receiver off.

### 5.3.2 PTP

PTP requires the presence of a PTP master clock on the same local network as the Wrangler unit. The recommended clock is the Trimble Thunderbolt Grandmaster clock.

The accuracy of PTP reference seen by Wrangler is highly dependent on the network configuration. Under ideal conditions, the Wrangler unit can use PTP to adjust its clock within 10 microseconds of the PTP reference clock.

### 5.3.3 NTP

Wrangler can also use Network Time Protocol (NTP) to adjust its internal time. The accuracy of NTP is highly dependent on the network configuration. Using NTP, Wrangler can adjust its time to within 0.5 seconds of the NTP reference.



## 6 ADC Sampling

### 6.1 Scope

This section describes the conversion of the analog output of a sensor into the digital data output by the A/D converter. FIR filters are used to produce additional sample rate data from the direct output of the A/D converter.

### 6.2 A/D Sample Rate

Wrangler uses a high-quality Successive-Approximation-Register (SAR) A/D converter with integrated digital filter to digitize the analog data. The digital filter provides several selectable output rates.

### 6.3 Recorded Data Sample Rate

The sample rate for recorded data is a combination of the A/D output sample rate and filter-decimation performed by Wrangler's CPU firmware. Firmware filtering only occurs when the A/D is set to output 1000 samples per second. A fixed set of additional sample rates are then generated using the firmware filters. Only certain combinations of sample rates are allowed.

The following sample rates may be recorded in any combination: 1000, 200, 100, 50, 40, 20, 10, 5, 1, and 0.1. These rates are derived by the firmware through a fixed sequence of filter stages.

The following rates are available for recording at a single sample rate ONLY: 4000, 2000, 500, 250, and 125.

All channels of a given data stream use the same firmware filter sequence.

### 6.4 Filter Coefficients

The filter coefficients for each of the firmware filter chains are stored in the station XML file which is generated by the Wrangler unit. The station XML can be downloaded through the Wrangler Web UI by going to the Control -> System tab and locating the station XML section near the bottom of the tab. Select the Stream for which you wish to download the station XML file and click the "Download" button.



## 7 Datastream Parameters and Triggering

### 7.1 Overview

The hardware and software of the Wrangler unit allows collection of data continuously, or selectively, in accordance with the particular data recording parameters that you select. Most of the Wrangler data recording operations are controlled by the datastream and trigger parameters.

By selecting datastream parameters in the Web UI, you can activate up to four datastreams, and include channels as desired in each datastream, along with selecting a sample rate and data encoding for each datastream. You must activate at least one datastream to cause Wrangler to collect data.

This section provides detailed explanations of datastreams and data acquisition triggers; it includes:

- Definitions for common terms related to datastreams and triggers
- An explanation of datastreams and datastream parameters
- An explanation of the following supported triggers:
  - Continuous
  - Event (with external in)
  - External
  - Level
  - Time Interval
  - Time List
  - Vote (with external in)
  - Calibration

A command trigger is also provided in the Web UI which causes a trigger to occur on a specified datastream, with the exception of streams configured with the Continuous trigger type.

A hardware external trigger output signal is provided that asserts when any stream has declared a trigger, with the exception of the Continuous, External, and Calibration trigger types. Whether a particular stream asserts the external trigger output signal upon declaring trigger is configurable for each stream. For Vote and Event trigger types, the external trigger input may be used as an additional trigger source for that stream. Whether a particular Vote or Event triggered stream triggers on the external trigger input is configurable for each stream. The external trigger input is the only trigger source for the External trigger type.

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A sensor calibration may occur manually or automatically at a user scheduled time. For a scheduled calibration, all non-continuous datastreams which are enabled will be triggered to record for the duration of the calibration. The trigger type field in the data is overridden to be type "CAL", and the record length is overridden with the record length specified in the scheduled calibration setup. With a manual calibration (started by user command), the trigger behavior depends on the trigger type. For data-dependent triggers (Level, Event, Vote), the manual calibration does NOT automatically cause a stream to trigger. If the trigger thresholds are met while the calibration is in process, the stream will trigger as it normally would. This is meant to be used to validate the data-dependent trigger configuration. For data-independent triggers (Time, Time List, External), a manual calibration does cause the stream to trigger. In this case the trigger type is overridden with the CAL type, but the record length is as specified for the stream.

There are three special streams: damp/undamp (stream 5), calibration signal (stream 8), and auxiliary/mass-position (stream 9). These streams have fixed trigger configurations. The damp/undamp stream is configured as Continuous type with a fixed length. The calibration signal stream is configured as type: "Calibration" with a duration that is based on the calibration signal configuration. Under the datastream parameters tab in the Web UI, the calibration signal stream allows the user to configure the sample rate and recording destination. The auxiliary/mass-position stream is fully user configurable except that it always uses a Continuous type trigger.

For MRF data, there are two flags in data packet headers that may be set based on calibration or sensor test output signals. The calibration flag is set if the trigger type is CAL, a calibration output is ongoing when the packet is created, or when the accelerometer test output is ongoing when the packet is created. The sensor test flag is set if the accelerometer test output is ongoing when the packet is created.

## 7.2 Definitions of Common Terms

This section provides definitions for several important terms related to datastreams and triggers.

Datastream/Trigger Term	Definition
Datastream	The combination of specified input channels, sample rate, data encoding, trigger and recording destinations.
Sample Rate	The number of samples per second that the DAS records from the input channel(s).
Compression (Data Encoding)	How data is encoded in recording packets. This can be 32-bit integer or one of several compression encodings.
Trigger Type	The mechanism that determines when a DAS records data.
Event	The activation of any trigger (and the data associated with that specific trigger activation).
Record Length	<p>The minimum amount of time a DAS will record data for a single event, beginning with any pre-event data and ending with any post-event data.</p> <p>The expected number of samples a given record will contain is the product of the record length (in seconds) x the sample rate (per second).</p> <p>The actual number of samples in a given record can vary from the expected number of samples, depending on the trigger type.</p>
Pre-trigger/Pre-event	The amount of data (in seconds) to be collected immediately prior to a trigger.
Post-trigger/Post-event	The amount of data (in seconds) to be collected following a de-trigger.

## 7.3 Datastream Parameters

The datastream parameters determine how many datastreams are active, which channels are included in each datastream, the sample rate and data encoding for each stream, and the type of trigger mechanism that Wrangler uses to determine when to activate the stream and collect data.

As you select datastream parameters, keep in mind the maximum throughput for the DAS system and data recording peripherals. Although Wrangler offers up to four different, simultaneously active datastreams with sampling rates of up to 4000 samples per second, the system may not handle the maximum settings for all these parameters for any extended recording period.

The following chart lists and explains the available datastream parameters for Wrangler. Note that the default values are explained as they are interpreted by Wrangler, not necessarily as they appear on the user interface.

Parameter	Value Range	Explanation
Channel(s)	1, 2, 3, 4, 5, 6	The channels included in the given datastream. The default is null; if you do not select any channels, the datastream is not activate.
Sample Rate	0.1, 1, 5, 10, 20, 40, 50, 100, 125, 200, 250, 500, 1000, 2000, 4000 sps	The number of samples per second that the DAS records from the input channel(s).
Data Encoding	MSD: 32, Steim1, Steim2  MRF: 32, Steim1, Steim2, Mux Compressed	The encoding of data recorded for the given datastream
Trigger Type	One of the following: Continuous Event External Level Time Interval Time List Vote	The particular trigger mechanism Wrangler will use to determine when to record data for the particular datastream. Trigger types and available trigger parameters are explained below.

## 7.4 Maximum Pre-Event Lengths Calculation

Wrangler has a fixed amount of RAM dedicated as pre-event buffer space for triggered datastreams. The dedicated pre-event buffer is divided and allocated as datastreams are enabled. Continuous datastreams used a fixed length, two second data buffer. The formula for calculating available pre-event space for triggered data streams is:

**Number of bytes used  
by a data stream =**

$$= \left( (\text{Sample Rate} * \text{Included Channels} * 4) + (120 * M) \right) * \text{Seconds of Pre-Event}$$

Where:

M=1 when the sample rate is 500 sps and lower

M=2 when the sample rate is 1000 sps

M=4 when the sample rate is 2000 sps

M=8 when the sample rate is 4000 sps

Seconds of Pre-Event = 2 for any continuous datastream

To figure out the total number of bytes used by all datastreams, repeat the above calculation for each enabled datastream, and combine the results of each individual calculation to find the total number of bytes required for your desired setup.

The total number of bytes that Wrangler has available for pre-event is 2,095,000. If your final result after combining the values for all of the individual stream calculations exceeds 2,095,000 then you will need to reduce the pre-event time on one or more streams to get below 2,095,000.

### Examples:

- 1) One Triggered stream at 200 sps, 3 Channels, with 700 seconds of pre-event:

$$\left( (200 * 3 * 4) + (120 * 1) \right) * 700 = \mathbf{1,764,000 \text{ bytes required (OK setup)}}$$

- 2) Two Triggered streams, one at 100 sps, 6 channels, with 300 seconds of pre-event and the second at 200 sps, 3 channels, with 180 seconds of pre-event:

$$\left( (100 * 6 * 4) + (120 * 1) \right) * 300 = 756,000 \text{ bytes required (Stream 1 bytes used)}$$

$$\left( (200 * 3 * 4) + (120 * 1) \right) * 180 = 453,600 \text{ bytes required (Stream 2 bytes used)}$$

$$\mathbf{\text{Total Required bytes: } 756,000 + 453,600 = 1,209,600 \text{ (OK setup)}}$$

- 3) Three streams, one continuous stream at 100 sps, 6 channels, a triggered stream at 200 sps, 3 channels, with 300 seconds of pre-event and an additional triggered stream at 1000 sps, 3 channels, with 60 seconds of pre-event:

$$\left( (100 * 6 * 4) + (120 * 1) \right) * 2 = 5,040 \text{ bytes required (Stream 1 bytes used)}$$

$$\left( (200 * 3 * 4) + (120 * 1) \right) * 300 = 756,000 \text{ bytes required (Stream 2 bytes used)}$$

$$\left( (1000 * 3 * 4) + (120 * 2) \right) * 60 = 734,400 \text{ bytes required (Stream 3 bytes used)}$$

$$\mathbf{\text{Total Required bytes: } 5,040 + 756,000 + 734,400 = 1,495,440 \text{ (OK setup)}}$$

- 4) Three streams, one continuous stream at 100 sps, 6 channels, a triggered stream at 200 sps, 3 channels, with 300 seconds of pre-event and an additional triggered stream at 1000 sps, 3 channels, with 120 seconds of pre-event:

$$\left( (100 * 6 * 4) + (120 * 1) \right) * 2 = 5,040 \text{ bytes required (Stream 1 bytes used)}$$

$$\left( (200 * 3 * 4) + (120 * 1) \right) * 300 = 756,000 \text{ bytes required (Stream 2 bytes used)}$$

$$\left( (1000 * 3 * 4) + (120 * 2) \right) * 120 = 1,468,800 \text{ bytes required (Stream 3 bytes used)}$$

$$\mathbf{\text{Total Required bytes: } 5,040 + 756,000 + 1,468,800 = 2,229,840 \text{ (Setup Invalid)}}$$

---

## 7.5 Continuous Trigger

### 7.5.1 Description

The Continuous trigger records data continuously as soon as acquisition is started. Data recorded with a datastream using a continuous trigger type is broken up into separate events based on the user specified record length. Continuous Trigger events are time-aligned when the record length specified divides evenly into 24 hours (86400 seconds). Each time acquisition is started, Wrangler adjusts the record length of the first event so that it ends on the last sample before the alignment point that is calculated. All subsequent events will start exactly at the alignment time and record the amount of data specified by the record length. If Wrangler has to adjust the internal clock due to a time set, it will terminate the current event after the adjustment is made and start a new event with a record length that ends on the last sample before the alignment time. All subsequent events will be properly time aligned.

Record lengths that do not divide into 24 hours will not be time aligned. Therefore all events recorded will be equal to the record length specified.

### 7.5.2 Examples

Record Length: 1 hour:  $86400 / 3600 = 24$  events per 24 hours.

Events will be time aligned. The first event will be shortened so that all subsequent events will start at HH:00:00.000.

Record Length: 20 minutes:  $86400 / 1200 = 72$  events per 24 hours.

Events will be time aligned. The first event will be shortened so that all subsequent events will start at HH:00:00.000, HH:20:00.000 and HH:40:00.000.

Record Length: 3601 seconds:  $86400 / 3601 = 23.9933$  events per 24 hours.

Events will NOT be time aligned.

The first event and all subsequent events will be 3601 seconds in length.

### 7.5.3 Continuous trigger parameters

The following chart describes the only parameters the DAS requires to use a continuous trigger.

Parameter	Value Range	Explanation
Record Length	60 to 99999 seconds	The amount of time that Wrangler will record data for each event. When the record length is reached a new event will be started. This field defaults to 3600
Trigger Time	YYYY:DDD:HH:MM:SS	The initial start time includes the year, day-of-year, hour, minute, and second. Wrangler begins recording when its internal time matches or exceeds the start time. When an old time is specified, Wrangler becomes recording as soon as acquisition is started. This field defaults to 2000:001:00:00:00.

## 7.6 Event trigger (with optional External Input)

The Event trigger specifies that data will be recorded when the ratio between the Short Term Average (STA) and the Long Term Average (LTA) of the data exceeds a specified ratio for a minimum number of trigger channels. Only channels that are included in the datastream may be used as trigger channels, but all included channels are recorded, even if they are not trigger channels. The length of the recording is always at least the length specified by the record length, but may be longer when a de-trigger ratio is specified. The post-trigger length is only used in conjunction with a de-trigger ratio.

This section provides a general description, a detailed explanation of the event trigger parameters plus an explanation of event trigger calculations and some basic event trigger parameter sets to help guide you in using the event trigger.

### 7.6.1 Event Trigger Description

An event trigger requires the DAS to perform complex calculations on the data. The DAS uses each sample from a trigger channel to calculate a short term average (STA) and a long term average (LTA). The user has the option to apply a high pass filter and/or a low pass filter to the sample before using it to calculate the two averages. An event is detected (triggered) when the ratio between the STA and the LTA exceeds the user-specified value. The DAS de-triggers when the STA/LTA ratio returns to a level below the user-specified de-trigger ratio, data will then continue to be recorded for the post-trigger length. If you do not specify a de-trigger ratio, the DAS terminates the event when the record length is reached. In either case, the recorded data is always at least as long as the record length.

### 7.6.2 Event trigger parameters

The following chart describes the parameters that Wrangler requires to declare an event trigger.

Parameter	Range	Value Range Explanation
Record Length	1 to 99999 seconds	The minimum length of the recording for each event, including pre-event and post-event data. If you do not set a de-trigger ratio, Wrangler ensures all recording events have lengths equal to the setting in this field.
Trigger Channels	1,2,3,4,5,6, or any combination	The channels used for trigger detection. Only include channels which are already included in the datastream recording.
Minimum Number of Channels	1 to 6	The number of trigger channels which must meet the trigger criteria before Wrangler will declare an event trigger. This value must not exceed the number of trigger channels included in the event calculations.
Trigger Window	0.1 to 99.9 seconds	The time interval during which the minimum number of channels (above) must all meet the trigger criteria for Wrangler to declare an event. This parameter has no effect when you include only one channel in the datastream or require only one channel to trigger.
Pre-Event Length	0 to 300 seconds	The amount of preceding data that Wrangler will record with an event before recording the event itself.
Post-trigger	0 to 99999 seconds	The amount of time that Wrangler extends the recording after the de-trigger is declared. A value of zero indicates no post-trigger. This field defaults to zero.
STA Length	0 to 999.9 seconds	The number of seconds over which the DAS averages data using a running (exponential) average for STA. The DAS uses filtered data (if selected) for this calculation.
LTA Length	0.1 to 9999.9 seconds	The number of seconds over which the DAS averages data using a running (exponential) average for LTA. The DAS uses filtered data (if selected) for this calculation. You will usually select a value for the LTA length greater than that for STA length.
Trigger Ratio	0.1 to 99.9	The value that the STA/LTA ratio must exceed for the DAS to declare an event trigger (assuming minimum number of channels criteria is also met).
De-trigger Ratio	0 to 99.9	The value that the STA/LTA must return below after the DAS declares an event trigger before the DAS will declare a de-trigger. This parameter defaults to zero, which causes the DAS to de-trigger after the STA/LTA ratio falls below the trigger ratio.
LTA Hold	On or Off (toggle)	A function that, when enabled, causes the DAS to maintain a constant LTA. The DAS holds the LTA constant from the time it activates an event until either the de-trigger time (if the de-trigger ratio is not zero) or the end of the record (based on record length). By default, the LTA hold function is enabled.
External Trigger Out	On or Off	Asserts the external trigger output signal when this stream is triggered. Default is off.
External Trigger In	On or Off	Causes this stream to trigger when the external trigger input signal is asserted. Default is off.

## 7.7 External trigger

The External trigger specifies that data will be recorded when an external level is detected by Wrangler on the external trigger input line. Wrangler terminates the event

when the record length is reached. An external trigger can synchronize Wrangler's recording with other equipment, such as an air gun or clock.

### 7.7.1 Description

Physically, Wrangler's trigger in and out signals are an RS-485 differential signal pair. Wrangler declares an external trigger when it detects a high level ( $>0.2V$ ) on the external differential trigger pair ( $Trig+ > (0.2V + Trig-)$ ). Internally, Trig+ is pulled to GND and Trig- is pulled to +5VDC.

### 7.7.2 External trigger parameters

The following chart lists and explains the parameters that Wrangler requires to use an external trigger.

Parameter	Value Range	Explanation
Record Length	1 to 99999 seconds	The amount of time that Wrangler will record data, including the pre-trigger length, for each event. This field defaults to 3600
Pre-trigger Length	0 to 300 seconds	The amount of data that Wrangler will record with each event before recording the event itself.

## 7.8 Level Trigger

A level trigger activates when the absolute value of the digital data exceeds a specified threshold. Wrangler terminates the event when the record length is reached.

### 7.8.1 Description

Wrangler compares data from all channels included in the level trigger datastream to determine when to declare a level trigger. The trigger activates when the amplitude of the digital value of a single sample on a single channel exceeds the threshold. The user has the option to apply a high pass filter and/or a low pass filter to the sample before using it to compare against the trigger threshold. The trigger level threshold can be specified in one of three different units:

- mG's (milliG's)
- Percent of full scale.
- Digital counts.

If sensor sensitivity information is not available from the sensor itself, Wrangler assumes the presence of an accelerometer with a sensitivity of 2.5 Volts/G.

## 7.8.2 Level trigger parameters

The following chart lists and explains the parameters that Wrangler requires to use a level trigger.

Parameter	Value Range	Explanation
Record Length	1 to 99999 seconds	The amount of time that the DAS will record data, including the pre-trigger length, for each event. This field defaults to 60
Pre-trigger Length	0 to 300 seconds	The amount of data that the DAS will record with each event before recording the event itself.
Trigger Level	Counts: 0 to MAX G: 0.0001 to 100 %FS: 0 to 99	The absolute value range either in: Counts, mG's, or percent of Full Scale above which the input signal will cause a trigger to be declared.
High-Pass Filter	Off 0.1 or 2	High-Pass Filter corner frequency in Hz. This filter is a 4-pole filter at 0.1 Hz or 2 Hz or Off (no filtering).
Low-Pass Filter	Off or 12	Low-Pass Filter corner frequency in Hz. This filter is a 4-pole filter at 12 Hz or Off (no filtering).
External Trigger Out	On or Off	If enabled, Wrangler will assert the external trigger output signal when this stream is triggered.

## 7.9 Time Interval trigger

The Time Interval trigger specifies that data will be recorded at specified time intervals beginning when an initial time is reached.

### 7.9.1 Description

A Time Interval trigger event activates when the unit's internal time matches a specified time. Wrangler terminates the event when the record length is reached.

You can set the Time Interval trigger to repeatedly activate for a fixed or infinite number of times, at a specified time interval. The start time for the time trigger should be later than the current time. Wrangler uses the start time to calculate the next trigger time whenever parameters are implemented (including during power-up). It uses the previous trigger time to calculate subsequent triggers.

### 7.9.2 Time Interval trigger parameters

The following chart lists and explains the parameters that Wrangler requires to use a Time Interval trigger.

Parameter	Value Range	Explanation
Record Length	1 to 99999 seconds	The amount of time that the DAS will record data. This field defaults to 3600.
Start Time	YYYYDDHMMSS	The start time includes the year, day-of-year, hour, minute, and second. The DAS begins recording when its internal time matches the start time. The default is 2000:001:00:00:00
Number of Triggers	0 to 9999	The number of times the DAS will record an event. Zero indicates an infinite number of recordings. This field defaults to 1.
Repeat Interval	DDHMMSS	The length of time between the start of one recording event and the start of the next, specified in days, hours, minutes, and seconds.
External Trigger Out	On or Off	Asserts the external trigger output when this stream is triggered if On is selected.

## 7.10 Time List trigger

The Time List trigger specifies that data will be recorded at specified times.

### 7.10.1 Description

A Time List trigger event activates when the unit's internal time matches one of up to eleven specified times. Wrangler terminates the event when the record length is reached.

### 7.10.2 Time List trigger parameters

The following chart lists and explains the parameters that Wrangler requires to use a Time List trigger.

Parameter	Value Range	Explanation
Record Length	1 to 99999 seconds	The amount of time that the DAS will record data. This field defaults to 3600.
Time 1 ... Time 11	YYYYDDHMMSS	You can activate up to eleven Time entries. Specify the year, day-of-year, hour, minute and second at which you want the DAS to start recording the selected datastream.
External Trigger Out	On or Off	Asserts the external trigger output when this stream is triggered is On is selected.

## 7.11 Vote trigger (with External Trigger Input)

The Vote trigger specifies that data will be recorded when the votes for triggered channels reach the Trigger Minimum Votes. Wrangler terminates the event when votes

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for de-triggered channels reaches the De-trigger Minimum Votes. The external trigger input line can also be used to cause a trigger of a vote trigger datastream.

### 7.11.1 Description

A channel is declared to be triggered when it exceeds its individual trigger threshold level. If its trigger threshold level is not specified, it is set to MAX and the channel will never trigger. A channel is marked as de-triggered when it drops below its individual de-trigger threshold level. If its de-trigger threshold level is not specified, it is set equal to its Trigger threshold level. Different threshold levels can be used for triggering and de-triggering a particular channel.

Threshold levels can be specified as Gs (with up to 1 place of precision behind the decimal point), percent of full scale, or counts. All thresholds must use the same units. If sensor sensitivity information is not available from the sensor itself, the DAS assumes 2.5 volts per G for converting from a threshold level specified in G's to digital counts.

Trigger votes are only calculated before a trigger is declared. A channel is used to detect a trigger when its Trigger Channel Votes is non-zero. When a channel exceeds its individual trigger threshold level, its votes are included in the trigger vote count for the duration of the Trigger Window. If the trigger vote count reaches or exceeds the Trigger Minimum Votes, Wrangler declares a trigger. If the Trigger Minimum Votes is not specified, it is set to MAX and a trigger will never be declared. After a trigger is detected, the Trigger Window for each trigger channel is cleared.

De-trigger votes are only calculated after a trigger is declared. A channel is used for de-triggering when its De-trigger Channel Votes is non-zero. When a channel falls below its individual de-trigger threshold level, its votes are included in the de-trigger vote count. When the de-trigger vote count reaches or exceeds the De-trigger Minimum Votes, Wrangler de-triggers the event. If the de-trigger vote count drops below the De-trigger Minimum Votes during the Post-trigger Length, Wrangler cancels the de-trigger and extends the recording until the de-trigger criteria is met again. If the De-trigger Minimum Votes is not specified, it is set to zero.

When enabled as part of the Voter trigger, the external trigger input line forces and maintains a trigger while it is active.

The length of the recording is always at least the length specified by the Record Length, but may be longer depending on when the de-trigger conditions are met.

## 7.11.2 Vote trigger parameters

The following chart lists and explains the parameters that Wrangler requires to use the Vote trigger.

Parameter	Value Range	Explanation
Record length	1 to 99999 seconds	The minimum amount of data the DAS will record for an event, beginning with the pre-trigger data.
Pre-trigger length	0 to 300 seconds	The amount of additional data the DAS will record with an event from just prior to the trigger.
Post-trigger length	0 – 99999 seconds	The amount of additional data the DAS will record with an event from the time of the de-trigger.
Level Units	G % else	Levels are specified: In Gs as % of Full Scale in digital counts
Trigger Channels	1 - 6	Channel 1 – 6; up to 6 channels may be specified.
Trigger channel votes	0 - 9	The number of votes assigned to a corresponding channel for detecting a trigger.
Trigger channel level	Cts: 0 to MAX Gs: 0.0001 to 100 %FS: 0 to 99	The absolute value for a corresponding channel above which it is triggered.
Trigger minimum votes	1 - 99	Total trigger votes needed to trigger an event.
Trigger window	0.1 – 99.9 seconds	The time window in which the number of trigger votes must exceed the minimum trigger votes for the DAS to activate an event.
De-trigger channel votes	0 - 9	The number of votes assigned to the corresponding channel for detecting a de-trigger.
De-trigger channel level	Cts: 0 to MAX Gs: 0.0001 to 100 %FS: 0 to 99	The absolute value for a corresponding channel below which it is de-triggered.
De-trigger minimum votes	1 - 99	Total de-trigger votes needed to de-trigger an event.
High Pass Corner Freq.	Off, 0.1 or 2	Hi-Pass Filter corner frequency in Hz. This is a 4-pole filter at 0.1Hz, 2 Hz or Off (no filtering).
Low Pass Corner Freq.	Off or 12	Lo-Pass Filter corner frequency in Hz. This is a 4-pole filter at 12 Hz or Off (no filtering).
External Trigger Out	On or Off	Asserts the external trigger output signal when this stream is triggered.
External Trigger In	On or Off	Trigger this stream when the external trigger input is asserted.

## 7.12 Calibration trigger

The Calibration trigger specifies that data will be recorded when a sensor calibration starts.

### 7.12.1 Description

When a calibration starts, Wrangler declares trigger and records for the duration of the calibration signal plus some time before and after the signal while the CAL\_EN line is asserted.

### 7.12.2 External trigger parameters

There are no configuration options for this trigger type.



## 8 Data Storage

The primary data storage for Wrangler is an industrial-grade USB flash drive. This is located under the removable screw-on cap. The disk should never be removed while the LED inside the well is RED.

**NOTE: Due to the large variability of USB flash devices available on the world market, Trimble cannot guarantee a USB flash disk will work in a REF TEK data recorder unless it is sold through Trimble itself. Trimble ensures compatibility through communications with USB manufacturers and rigorous in-house testing. Some USB manufacturers refuse to provide adequate information or factory controls to ensure that the product being sold today is the same as the product sold earlier under the same part number. USB disks not purchased from Trimble may work at one temperature but not at another, or may fail all together.**

**NOTE: For optimal performance with Wrangler, USB Flash disks should ALWAYS be formatted by the recorder. Wrangler will detect when the USB Flash disk is not formatted optimally and AUTOMATICALLY FORMAT THE DISK.**

### 8.1 Disk Operation Voltage Control

Disk operations are enabled by default, but are suspended when the Wrangler's input voltage drops below a user-settable minimum voltage. Disk operations are re-enabled when the voltage returns above a user-settable re-enable voltage. The re-enable voltage must be greater than, or equal to, the minimum voltage. By default, the minimum voltage is set to 10V and the re-enable voltage is set to 10.5V. These values cannot be set higher than 11.5V. They should not be set lower than 9V, since the Wrangler hardware will automatically shut down the entire unit when the input voltage reaches approximately 9V.

### 8.2 Disk Recording

Data is recorded to disk on a stream by stream basis as enabled by the user. The same stream can be recorded to both telemetry and disk simultaneously. When data is recorded to more than one location, it is not overwritten in RAM until it has been written to all selected locations.

### 8.2.1 Dump Threshold

The Wrangler Dump Threshold is fixed at 66%. When RAM usage reaches 66%, the USB disk is powered-up and data from all datastreams that have disk recording enabled is written to disk.

### 8.2.2 Disk Wrap

Disk Wrap allows overwriting of the oldest data recorded to disk. When Disk Wrap is disabled, disk recording stops when the disk is full. When Disk Wrap is enabled and the USB disk is nearly full, the oldest data directory is deleted and recording continues. In effect, the disk functions as a circular buffer containing the most recent data. The Disk Wrap setting can be found in the Wrangler Web UI under the Control->Disk menu.

## 8.3 Disk file system

Data on disk is written using a FAT32 filesystem with long file name support. Data is organized into subdirectories as in a REF TEK data archive. The subdirectory structure looks like this:

```

\yyyyddd
  \iiii
    \s
      \s
        \yyyyddd
          \iiii
            \s
              \s

```

where:

yyyyddd	Represents the 4-digit year and 3-digit day of year when a particular file begins
iiii	Represents the UnitID of the unit that recorded the data
s	Represents the datastream number of the data. The SOH log is recorded as stream 0

Data is written into files by event. The file name looks like this:

```
hmmstttuuu_IIIIIIIIII
```

where:

hmmstttuuu	Represents the hour, minute, second, millisecond, microsecond of the first sample in the file
IIIIIIIIII	Represents the hexadecimal length of the file in microseconds

**NOTE: State of health files are named in a similar manner but are based on the time of the first entry into the file.**



## 9 SeedLink Server

### 9.1 Overview

Wrangler has a built-in SeedLink server which supports two incoming SeedLink connections. Each link operates independently. SeedLink data is only available when data is recorded in miniSEED (MSD) format. The user must also configure at least one datastream to be recorded to the SeedLink recording destination, by checking the "SeedLink" box under the Parameters->Datastream menu for the datastream that they want to be recorded to SeedLink. When the SeedLink recording destination is selected for any datastream, the data produced by that datastream is stored in the Wrangler's internal non-volatile SeedLink server ring-buffer.

### 9.2 SeedLink Connection

#### 9.2.1 SEED Network Code and Station Code fields

The Wrangler Web UI station name field allows for six characters to be entered. The first five characters are used as the Station code when recording in miniSEED data format (blockette 50 field 3). All six characters are used when recording in the native REF TEK MRF data format.

Similarly, the Wrangler Web UI allows four characters to be entered for use as a network code. The first two characters entered by the user are used to fill in the network code field (blockette 50 field 16) when recording in miniSEED data format. All four characters are used when recording in the native REF TEK MRF data format.

#### 9.2.2 SEED Location code field

When recording in miniSEED data format, Wrangler uses a combination of the datastream and channel number to fill out the SEED Location code field. The first character of the Location code field is set equal to the DAS datastream number, and the second character is set equal to the channel number.

For example, data recorded by Wrangler for datastream 3, channel 2 will have the Location code field of the miniSEED packets set to '32'. Similarly, packets for channel 6 of datastream 3 will have the Location code field set to '36'.

---

### 9.2.3 SeedLink Discovery

When a SeedLink client connects to the Wrangler's SeedLink server, Wrangler responds with a list of all possible Location ID and Channel ID combinations. The Wrangler's response to the SEEKLink client includes a list of all possible Stream/Channel combinations.

The possible Wrangler stream/channel combinations are (37 total):

- Stream 1, Channels 1-6 (For a six channel unit)
- Stream 2, Channels 1-6 (For a six channel unit)
- Stream 3, Channels 1-6 (For a six channel unit)
- Stream 4, Channels 1-6 (For a six channel unit)
- Stream 5, Damp/Undamp Calibration Datastream, Channels 1-6
- Stream 8, Calibration Signal Recording Datastream, Single Channel only (with its own A/D separate from those used for the main input channels 1-6).
- Stream 9, Auxiliary Channels Recording Datastream, Aux. Channels 1-12

The SeedLink client is responsible for requesting the Channel ID(s) that it wants to receive from Wrangler. The client can receive everything (all data) from a Wrangler unit or apply a filter to receive only specific channels/stream combinations. Wrangler allows up to two filters to be used by each SeedLink client. The client can use the SeedLink defined wildcard character ("?") to include a wildcard in the filter request. For example, the client can request the data from all channels for a given stream by using the "?" character in Location code request. For stream 1's data, the filter would be sent as "1?" to the Wrangler unit.

If the SeedLink client applies a filter for a channel and stream combination that does not exist in the SeedLink buffer (i.e., has not been configured to be recorded to the SeedLink buffer in the datastream parameters), Wrangler will not send any data.

### 9.2.4 SeedLink data ring-buffer

Wrangler has 8 GB of non-volatile internal memory which it uses exclusively as a ring buffer for SeedLink data. The only user configuration that affects this buffer is the selection of which datastreams are recorded to this ring buffer. Wrangler fills the ring-buffer with the latest data and automatically deletes the oldest data from the buffer as space for new data is needed.

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## 10 RTP Telemetry

### 10.1 Overview

Wrangler supports two REF TEK Real-Time Protocol (RTP) telemetry links. Each link operates independently and each link connects to an RTPD server IP address and port number specified in the Wrangler Web UI. RTP telemetry is available whether data is recorded in MSD or MRF recording format.

**NOTE: The two independent RTP links should never be pointed to connect to the same RTPD.**

### 10.2 RTP Mode selection

In addition to setting the RTP server address and port number for each RTP link, the Wrangler Web UI also has three user selectable modes for each RTP link. The modes are defined as "Sequential + Toss", "Sequential + Keep", and "Rapid + Backfill". The modes define the properties of how data is transmitted from Wrangler to RTPD, and how Wrangler handles the data recorded during any period of time that the RTP Link might be down.

#### 10.2.1 Sequential Mode

Sequential RTP data transmission guarantees that packets are received and sorted into sequential order by RTPD. Every packet sent by Wrangler is acknowledged by RTPD. Any packet for which Wrangler does not receive an acknowledge, is re-transmitted after a few seconds. Wrangler and RTPD use a 64 packet sliding window, meaning that Wrangler will not transmit the 65<sup>th</sup> packet until it has received the acknowledge for packet number 1. RTP is a full-error correcting protocol, and while the link is up and connected packets will not be lost.

##### 10.2.1.1 "Sequential Mode + Keep"

When using the "Sequential Mode + Keep" mode, when an RTP link goes down Wrangler keeps all of the existing data in its RAM which was not already acknowledged by RTPD. Wrangler continues collecting data until the RAM used by data destined for that specific RTP link reaches 20% of the total Wrangler RAM. Once the 20% threshold is reached all new data is dropped (while the old data is held in RAM). Once the RTP link is reconnected, the old data is transmitted from RAM and current data is recorded to RAM once the used percentage drops below 20%.

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### 10.2.1.2 “Sequential Mode + Toss”

When using the “Sequential Mode + Toss” mode, when the RTP link goes down and Wrangler all of the existing data in its RAM which was not already acknowledged by RTPD. Wrangler continues collecting data until the RAM used by data destined for that specific RTP link reaches 20% of the total Wrangler RAM. When the 20% threshold is reached, Wrangler throws away all of the data for that RTP link from its RAM. Wrangler continues to toss new data until the RTP link is re-established. When the RTP link is reconnected, data transmission resumes with current data.

### 10.2.2 “Rapid Mode + Backfill”

Rapid mode allows delivery of data out of order. Rapid Mode puts a priority on the newest data. This is useful for Event Early Warning deployments. In this mode, data which is not successfully transmitted after multiple attempts is ‘spooled’ to a file on the USB disk for retransmission later as bandwidth becomes available.

When the RTP Link goes down and “Rapid Mode + Backfill” is selected, Wrangler will spool all data destined for that link to files on the USB disk until the RTP link is reconnected. Data is spooled (written) to the USB disk, once the data destined for that RTP link consumes >1 MB of RAM. When the RTP Link is reconnected, transmission resumes with current data. Backfill data is read from the spooled files on the USB disk and transmitted to RTPD as bandwidth allows. Priority is always given to current data.

The number of days of backfill data to store on the USB disk can be set in the Wrangler Web UI on a per link basis, under the Control->Disk menu. The minimum number of whole backfill days to keep on the disk is one. The default is seven days. With the seven day default setting, the Wrangler will always keep seven full day directories of backfill data for each RTP link that is down. Wrangler will begin filling the day directory for an eighth day of backfill data and Wrangler will deleted the oldest day prior to creating the directory for the ninth day of backfill.



## 11 Auxiliary Data

### 11.1 Auxiliary Channels

Up to 12 channels of auxiliary data may be recorded as a continuous, 16-bit data stream (stream 9). Three auxiliary channels and 3 mass position channels are provided on each of the 2 sensor connectors.

The auxiliary channels can be configured for single-ended or differential input in pairs. When a pair of channels is configured as a differential input, its upper channel is not available. The channel pairs are 1/2, 3/4 and 5/6.

The single-ended auxiliary channels have an input range of +/- 10v. Look in the station XML file to see the bit weight for the auxiliary channels of your unit. These channels are recorded as auxiliary channels 1 – 6. The mass position channels are recorded as channels 7-12.

### 11.2 Recording Auxiliary Channels

The auxiliary data can be recorded by setting up the Auxiliary Data Parameters. When recorded, all included auxiliary and mass position channels are recorded at the same interval (0.1, 1 or 10 seconds) using simple decimation. The auxiliary data is recorded as Data Stream 9. When encoded as integer, it is 16-bit integer encoding.

### 11.3 Auxiliary Connector Signals

The Wrangler Auxiliary channel inputs have the following pin-out:

Channel Connector	Pin	Name	Single-ended	Differential
1-3	a	Aux1	Chn 1	Chn 1+
1-3	b	Aux2	Chn 2	Chn 1-
1-3	c	Aux3	Chn 3	Chn 3+
1-3	X	MassPos1	Chn 7	Chn 7+
1-3	Y	MassPos2	Chn 8	Chn 7-
1-3	Z	MassPos3	Chn 9	Chn 9+
4-6	a	Aux4	Chn 4	Chn 3-
4-6	b	Aux5	Chn 5	Chn 5+
4-6	c	Aux6	Chn 6	Chn 5-
4-6	X	MassPos4	Chn 10	Chn 9-
4-6	Y	MassPos5	Chn 11	Chn 11+
4-6	Z	MassPos6	Chn 12	Chn 11-



## 12 Sensor Control

This Section describes the sensor control signals available in the Wrangler Seismic Recorder.

### 12.1 Sensor Control Signals

#### 12.1.1 Channel Connector Signals

Each of the Wrangler channel connectors has the following pin-out:

Pin	Name	Direction	Description
A	CH1+	In	Channel 1/4 input+
B	CH1-	In	Channel 1/4 input-
C	CH2+	In	Channel 2/5 input+
D	CH2-	In	Channel 2/5 input-
E	CH3+	In	Channel 3/6 input+
F	CH3-	In	Channel 3/6 input-
G	AGND	-	Analog Ground
H	Power	Out	Sensor power out to the sensor (Tracks main input voltage)
J	PGND	-	Power Ground
K	CalSig	Out	Calibration signal (+/- 5VDC)
L	CalEn	Out	Calibration enable
M	Center	Out	Sensor mass re-center
N	Lock	Out	Sensor lock
P	Unlock	Out	Sensor unlock
R	Undamp	Out	Sensor undamp
S	UVW Enable	Out	Sensor UVW enable
T	Accel Test+	Out	RS-485 Accelerometer test signal+
U	Accel Test-	Out	Rs-485 Accelerometer test signal-
V	Sensor ID	In/Out	Sensor ID bi-directional 1-wire interface
W	DGND	-	Digital Ground
X	Mass Pos 1	In	Sensor Mass Position 1/4
Y	Mass Pos 2	In	Sensor Mass Position 2/5
Z	Mass Pos 3	In	Sensor Mass Position 3/6
a	Aux1	In	Auxiliary data input channel 1/4
b	Aux2	In	Auxiliary data input channel 2/5
c	Aux3	In	Auxiliary data input channel 3/6

## 12.1.2 Sensor Signal Usage

Sensors vary in the number, type and polarity of control signals they support. The following table shows some common sensors used with Wrangler and how each line is driven when active. Signals which are not used by a specific sensor are always Lo.

Sensor type 'Other' is unique in that each control line is specified as Active High or Active Low. In addition, the Ctrl Active time must be specified, allowable values are 0.1 – 99.0 seconds. The Undamp and CalEn lines are used by the Damp/UnDamp Test as described in a following section.

Sensor	Lock	Unlock	UVW	Undamp	Center	CalEn	CalSig	Test+/-	MassPos	Ctrl Active
REF TEK 147A	-	-	-	-	-	-	Y	Hi	-	-
REFTEK 151B	-	-	-	-	Lo	Hi	Y	-	3	7.0 secs
REF TEK Colt	Lo	Lo	-	-	Lo	Lo	Y	-	3	8.0 secs
Guralp 3T	Lo	Lo	-	-	Lo	Lo	Y	-	3	7.0 secs
STS Family	Hi	Hi	-	-	Hi	Hi	Y	-	3	7.0 secs
Trillium Family	Hi	Hi	-	-	Hi	Hi	Y	-	3	7.0 secs
Other	H/L	H/L	H/L	H/L	H/L	H/L	Y	-	3	User Defined

## 12.2 Mass re-center

Mass re-centering can be performed on-demand or automatically. Manual re-centering is performed by activating the 'Re-center' button on the Sensor Control page of the Wrangle Web UI. Automatic re-centering is performed by entering parameters into the Sensor Auto Re-Center page of the Web UI.

### 12.2.1 Automatic Mass Re-Center Parameters

The following parameters control automatic re-centering:

Parameter	Range	Description
Enable	On/Off	Enable/disable automatic re-centering for a sensor
Level Vertical	0.0 – 9.90	Voltage threshold to exceed before Wrangler issues the re-center command. Vertical refers to the threshold setting for Mass Position 1.
Level Horizontal	0.0 – 9.99	Voltage threshold to exceed before Wrangler issues the re-center command. Horizontal refers to the threshold setting for Mass Position 2 and 3.
Attempts/Cycle	1 - 20	Maximum attempts per re-center cycle,
Attempt Sleep Time	5 – 59	Minutes to suspend sampling; 0 = disable
Cycle Interval	0 – 99	Days between re-center cycles, 0 = disabled

### 12.2.2 Automatic Mass Re-Centering Description

When enabled, the mass position is sampled periodically for each channel, to determine if the sensor needs to be re-centered. At Power Up or after Reset, a 3 hour wait time occurs before sampling of the masses begins. This delay allows the sensor to settle.

Once sampling begins, new values are taken once per minute. If there is a data dependent event in progress, sampling is delayed for the amount of minutes specified in the "Attempt Sleep Time" field. This ensures that an automatic mass re-center command cannot be issued to a sensor during an event. The samples taken once per minute are used to create a 16 sample running average for each mass position channel. The running average for each channel is used for comparison to the associated "Vertical" or "Horizontal" thresholds. When the average exceeds the threshold for any one mass position channel, a mass re-center command is issued and sampling is suspended for the "Attempt Sleep Time" specified. After issuing the mass re-center command, when sampling resumes, a new running average is started.

If the 16th sample taken exceeds the Vertical or Horizontal threshold, a re-center command is issued and the re-center attempts counter is incremented. If 17 or more samples are taken before the running average exceeds the Vertical or Horizontal threshold and a re-center command is issued, the re-center attempts counter is set to zero. Whenever a re-center command is issued and the re-center attempts counter equals the "Attempts/Cycle" value, re-centering is suspended for "Cycle Interval" days. After the "Cycle Interval" sleep period, the process starts over and a new 16 sample running average is begun.

Changing Sensor Types cause the process to start over with the 3 hour wait.

Issuing a manual re-center command causes an "Attempt Sleep Time" sleep period and also clears the running average and re-center attempts counter.

Issuing a Calibration Command causes the once a minute reading to be suspended. Readings are resumed "Attempt Sleep Time" minutes after the Calibration has finished.

## 12.3 Sensor Calibration

A calibration waveform can be sent to a sensor to measure its response. A button on the Sensor Control page allows manual activation of the selected waveform. The definition of the calibration signal waveform and the optional schedule for automatic calibration are entered on the Sensor Calibration Signal page.

The calibration output signal is created by a 16-bit D/A that produces up to a +/-5 Volts waveform on the Calibration Signal output pin. The waveform is defined by a table of D/A values stored internally that are written to the D/A using DMA. The table is created based on the Calibration Signal Parameters entered by the user. In addition, up to two WAV files can be downloaded to the unit to be used as the calibration waveform.

### 12.3.1 Calibration Signal Waveform Parameters

The following parameters provide control over the calibration waveform:

Parameter	Range	Description
Enable	On/Off	Enable waveform for a sensor
Duration	1-9999	Integer seconds duration of standard calibration signal
Amplitude	0.01 – 5V	Plus and Minus peak voltage
Signal	Menu list	Output signal desired
Sine Frequency	Menu list	Sine only: frequency of sine wave
Step Width	1-4999	Step: Width of Pulse in seconds. Each pulse reverses polarity.
Step Interval	1-4999	Step: Interval between pulses in seconds. Each pulse reverses polarity.
File 1	WAV	User WAV file
File 2	WAV	User WAV file

### 12.3.2 Calibration Schedule Parameters

The following parameters provide control over the calibration schedule:

Parameter	Range	Description
Enable	On/Off	Enable automatic calibration schedule for a sensor
Start Time	YYYY:DDD:HH:MM:SS	Time for first calibration to begin: year, day-of-year, hour, minutes seconds
Repeat Interval	DD:HH:MM:SS	Time interval between calibration cycles: days, hours, minutes, seconds
Number of Calibrations	0 – 9999	Number of calibration cycles, including the initial cycle time; 0 = infinite
Record Length	1 - 9999	Duration of calibration cycle. (seconds)

### 12.3.3 Standard Waveform Characteristics

#### Step signal

The Step signal is a bi-polar step function. The Width specifies the width of each pulse. The Interval determines the time from the start of one pulse to the start of the next pulse. Pulses alternate between positive and negative voltage of the specified amplitude. The D/A is updated each millisecond.

#### Sine signal

The Sine signal is a sine wave centered at 0v with the specified peak amplitude and the specified frequency. The available frequencies are 1, 2, 4, 5, 8, 10, 20, 25, 40, 50, or 100. The D/A is updated each millisecond.

#### Noise signal

The Noise signal is pseudo-random noise centered at 0v with the specified peak amplitude. The noise signal was synthesized using the MatLab rand() function, which produced 600000 points. The D/A is updated each millisecond.

### 12.3.4 Built-In Fixed Waveform Characteristics

There are six pre-defined calibration waveforms:

Signal Type	Duration	Amplitude	Frequency Content	Comments
Random-SP	60 sec.	0.01 – 5V	Random Noise	D/A sample rate 1000 sps
Random-LP	300 sec.	0.01 – 5V	Random Noise	D/A sample rate 200 sps
Random-BB	3000 sec.	0.01 – 5V	Random Noise	D/A sample rate 20 sps
Swept-SP	60 sec.	0.01 – 5V	Swept Sinewave	D/A sample rate 1000 sps
Swept-LP	3000 sec.	0.01 – 5V	50 sec. – 100 Hz	D/A sample rate 20 sps
Swept-BB*	60 sec. 300 sec. 3000 sec. (3360 Total)	0.01 – 5V No Output 0.01 – 5V	Swept Sinewave 2500 sec. – 2 Hz No Output Swept Sinewave 50 sec. – 100 Hz	D/A sample rate 1000 sps Settling Time D/A sample rate 20 sps

### 12.3.5 User WAV File Characteristics

Users can load up to two WAV files to use as calibration signals. These WAV files must be copied to the USB drive for loading into Wrangler's internal memory. Once uploaded to Wrangler's internal memory the files are retained indefinitely in non-volatile memory until they are overwritten by one or more newer files. On the Parameters->Sensor Calibration Signal Web UI page, there is space for the user to enter one or two WAV filenames to be loaded from the USB drive. If the user wants to load two WAV files into the Wrangler's internal memory, they must be loaded simultaneously. When the user

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selects the “Load New Waves” button, Wrangler first erases its internal WAV file buffer to make space for the new WAV file(s). The file extension for uploaded files must be .WAV.

After loading the file(s), the filename will show up as an available calibration signal in the calibration signal selection menu in the Wrangler Web UI. Wrangler’s internal waveform memory supports up to 8,388,000 combined samples for the two user uploaded waveforms. There are no restrictions for minimum or maximum size on either of the uploaded WAV files, the only restriction is that total number of samples between the two files must be less than 8,388,000.

The WAV files must adhere to the WAV definition for single-waveform, 16-bit signals. Trimble has utility programs to convert seismic signals recorded by the Wrangler’s normal seismic input channels into the appropriate WAV files. The utilities are called MRF2WAV, MSD2WAV, and PAS2WAV corresponding to the input data format that they read and convert to a WAV file output. The utilities are a part of the RTI software suite. See the RTI documentation for more information.

Wrangler supports the following data sample rates for the WAV files: 64000, 32000, 25600, 16000, 21800, 8000, 6400, 4000, 3200, 2000, 1600, 1000, 800, 500, 400, 320, 250, 200, 160, 125, 100, 80, 50, 40, 25, 20, 10, 5, 4, 2 and 1.

## 12.4 Sensor ID

Wrangler can read sensor information from various REF TEK sensors which support the REF TEK Sensor ID protocol. These sensors contain a 1-wire interface to an internal PROM device that contains the sensor information. This information includes such sensor information as:

- Make and model
- Number of channels
- Output signal sensitivity by channel
- Poles and Zeros

When connected to a REF TEK sensor which supports the Sensor ID function, the sensor information is read from the sensor’s PROM automatically and Wrangler will use the sensor information to automatically populate the station XML file.

## 12.5 Sensor Damp/UnDamp

Wrangler can perform a Damped/Undamped test when Sensor Type ‘Other’ is selected in the Sensor Model field of the Web UI. The Damped/Undamped test causes, Wrangler to outputs two signals, the CalEn signal and a damping control signal, to the sensor.

The sensors output signals are recorded and Wrangler calculates and returns the results based on the analysis of the data.

When the Damp/Undamped test command is received, Wrangler stops data acquisition (and trigger detection). A temporary set of stream parameters are implemented for stream 5 for the channels associated with the sensor to test. The output destinations are set to all of the stream/destinations selected before the command was issued. The sample rate is set to 1000 sps with Steim-2 data compression.

Wrangler calculates and returns the value for  $y_1$ , which is the difference in amplitude of the sensor output when the CalEn signal is activated. This value is calculated by taking a data average while the CalEn signal is activated minus the average of the data while CalEn is deactivated.

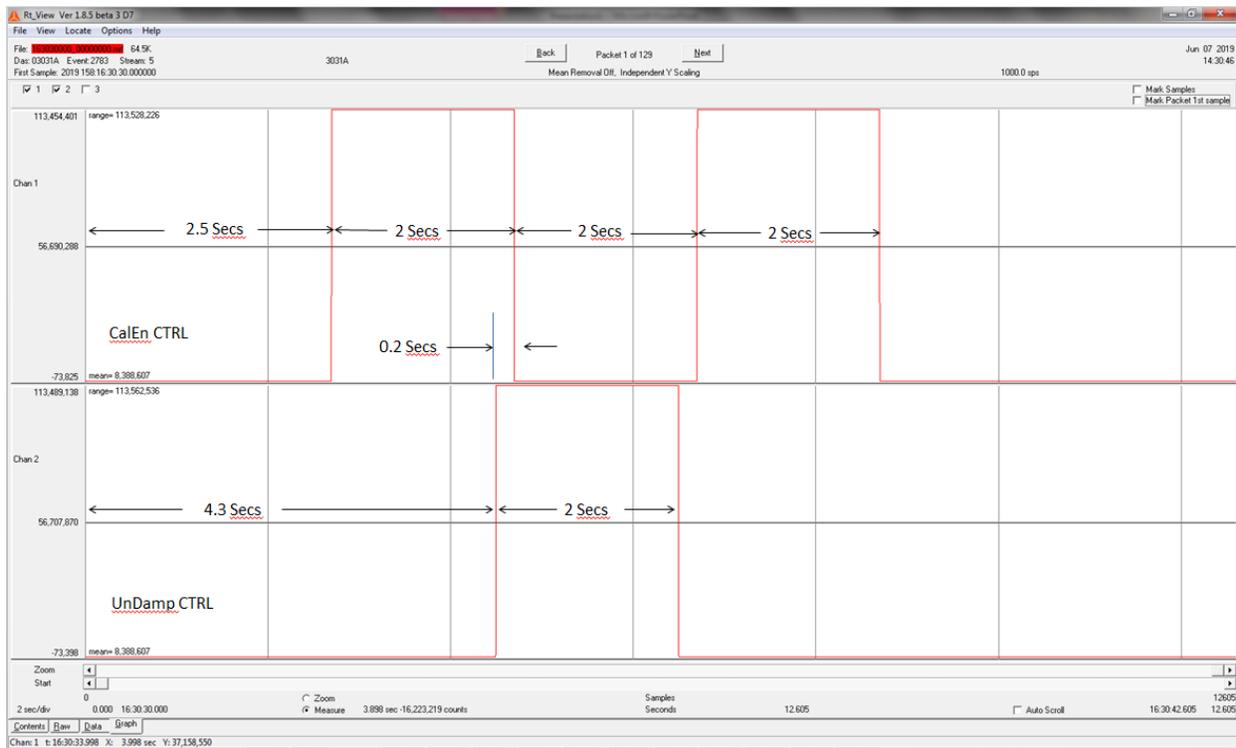
Wrangler also calculates and returns the peak value  $y_2$ , which is the maximum overshoot of the response to the CalEn test pulse (with damping turned on).

Wrangler also measures the period of the oscillation by deactivating the CalEn signal while damping is disabled.

The damp-coefficient is calculated using the  $y_1$  and  $y_2$  values.

After the Damp/UnDamp test is completed and recorded to stream 5, the Wrangler DAS restores the original users' parameters and restarts acquisition.

Recording of the CalEn (Chan 1) and UnDamp (Chan 2) signals applied to the sensor control lines for the Damp/UnDamp Test.



Wrangler starts the Damp/UnDamp test and sets the CalEn and Undamp control line to the deactivated state.

After approximately 2.5 secs the CalEn line is activated for 2 seconds.

After 1.8 seconds the UnDamp line is activated for 2 seconds.

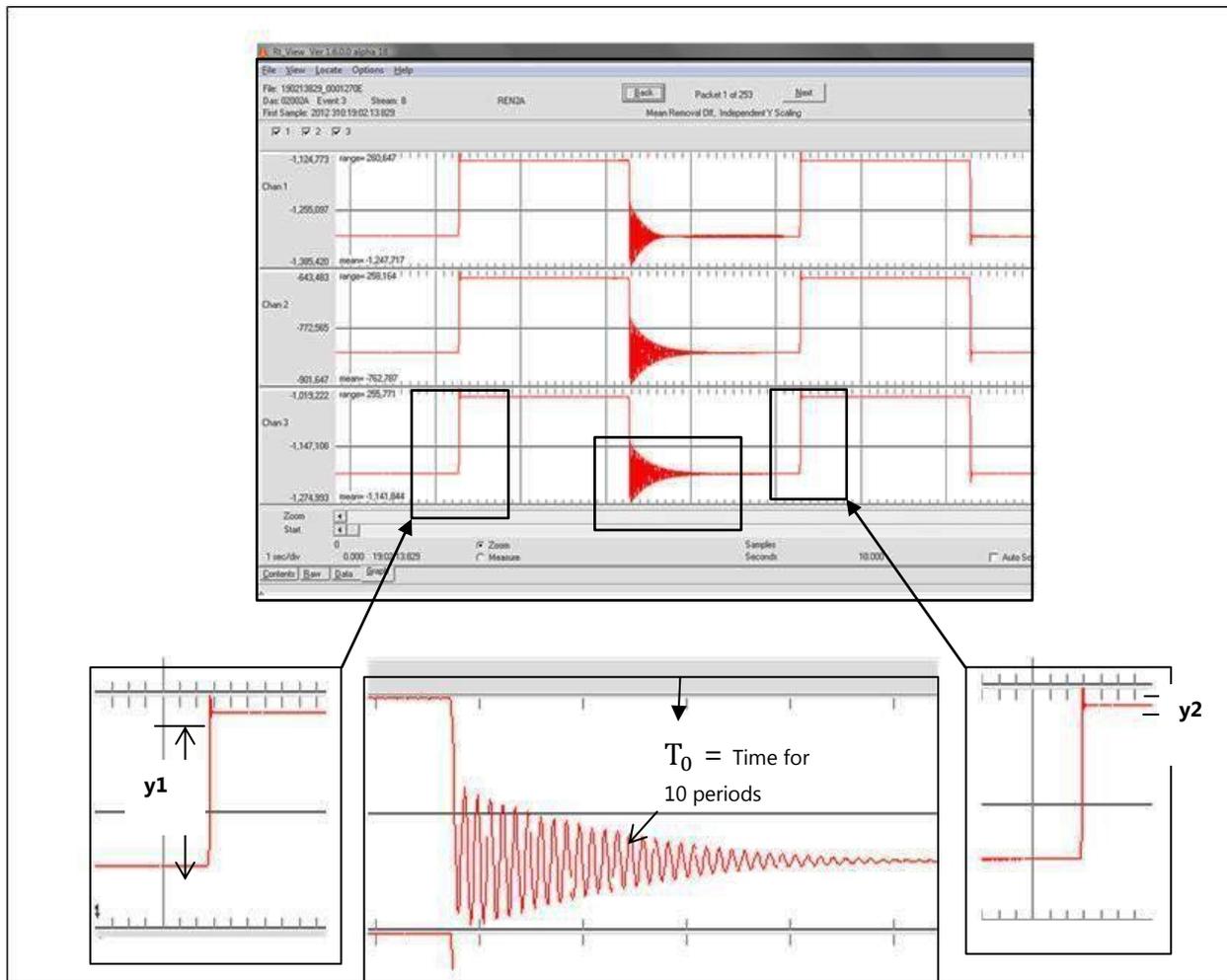
After 0.2 seconds the CalEn line is deactivated for 2 seconds.

After 1.8 seconds UnDamp control line is deactivated.

After 0.2 seconds the CalEn line is activated for 2 seconds.

CalEn line is deactivated and after 3.5 seconds, acquisition is stopped, Test Complete.

Original user parameters applied, normal operation is resumed.



The damping coefficient Dc can be calculated as follows:

$$Dc = \frac{\lambda}{\sqrt{\pi^2 + \lambda^2}} \text{ where } \ln \frac{y1}{y2}$$

Undamped oscillation period can be calculated as follows:  $T = \frac{T_0}{10}$