Time series file specifications for MTU-8A, RXU-8A, MTU-5C, MTU-2C and MTU-5D

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Applies to

HARDWARE

- MTU-8A, RXU-8A, MTU-5C, MTU-2C, MTU-5D and derivatives

SOFTWARE/FIRMWARE

- Firmware contained in the hardware listed above, v2.0 and later until new notice.

File location and fragmentation conventions within the instrument card

The MTU-8A, RXU-8A and MTU-5C and MTU-2C generate natively 24KS/s time series data, while MTU-5D generates 96 KS/s time series. The conventions described hereby are subject to modifications for future feature releases.

The following sections describe the standards and convention of file naming, file organization, and data payload generate by out instrument family: MTU-8A, RXU-8A, MTU-5C, MTU-2C and MTU-5D.

Recording folders

A recording is represented by a set of files that describe the configuration, operation and data recorded by the instrument. The instrument will place all recordings in a folder called “recdata” at the root folder of the SD card.

Each recording is stored in its own uniquely identified folder. The name of the folder containing a recording will have the following convention:

12345_2016-04-29-202957

Where, in the example above:

- ***12345***: Is the 5 digit string indicating the serial number of the instrument.
- ***2016-04-29***: Is the GPS date (UTC + leap seconds) when data started being recorded.
- ***202957***: Is a 6-character string representing the GPS time when data started being recorded. The first two characters are the hour in 24-hour format, the next two characters are the minute, and the last two characters are the second.

Files and folders contained in a recording folder

- ***backend.log*** : Contains information regarding the operation of the instrument
- ***config.json*** : Contains the configuration that the receiver used for this particular recording
- ***recmeta.json*** : Metadata associated with the recording created by the instrument.
- ***empower_recmeta.json*** : If present, it means that EMpower^{TM} processing software, has interacted with the recording, creating an enhanced copy of recmeta.json. This is required since more comments and information can be added by the person working on data evaluation and processing, allowing us to leave the copy generated by the instrument intact.
- ***recmeta.json.bak*** : Safety backup of recmeta.json
- ***stats*** : A file containing recording statistics (experimental).
- ***One or more folders named as numbers*** : These folders are the data folders. Each folder contains sequential files of the time series recorded by one channel of the instrument. To know which front panel connector generated the time series in each folder, consult the panel map in “*recmeta.json*”.

Format for the storage of continuous time series

Data file names

The naming conventions for the files created by the instrument are as follows:

`AAAAA_BBBBBBBB_C_DDDDDDDD.bin`

Where:

- ***AAAAA***: Is the 5 digit string indicating the serial number of the instrument.
- ***BBBBBBBBB***: 32-bit unsigned hexadecimal label indicating the GPS timestamp of the start time of the recording, which along with the serial number, makes a unique ID for the recording. This timestamp is Unix-epoch based, but uses GPS time instead of GMT time as its base. Note that for time series with versions previous to 4 (before instrument firmware v2.0), this timestamp was one second behind the real GPS time due to an issue between the GPS chip hardware and its driver. Raw time series version 4 and up have the correct timestamp.
- ***C***: A hexadecimal label indicating the channel id (same as the folder name that contains the file) that the file corresponds to, starting at zero.
- ***DDDDDDDD***: 32-bit unsigned hex label indicating the index of this file in the sequence of fragmented files. Fragmentation happens every minute, allowing to store 8100 years worth of continuous data. This fragmentation period is fixed as of now, but might be configurable in the future is a good reason for changing it is detected.

Data file header contents

Each sequential file contains a header. The header specifies meta-data related to the recording of a particular channel. Data payload is stored right after the header. This ensures that useful processed information can be extracted from a single file, even if the rest of the recording files are lost. The format of the header is described in ***Table 1***.

The header fields are packed as little endian unless otherwise specified in the notes in ***Table 1***.

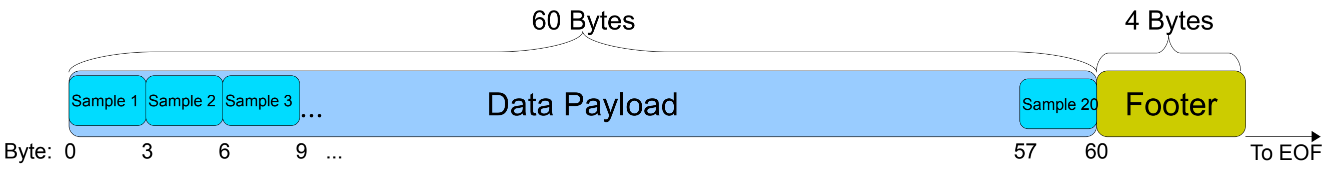
Data payload specification

The payload data in each continuous time series file is arranged in consecutive blocks of 64 bytes, called frames. The contents of each 64-byte frame is as follows:

DataFrame
Total length: 64 Bytes = 20 samples + Footer

- 60 bytes worth of sampled data, arranged as twenty consecutive 3-byte (24-bit) sample values, signed, big endian.
- 4 bytes containing a frame footer, arranged as an unsigned little endian integer, from which:
  - The most significant bit is a flag for internal usage.

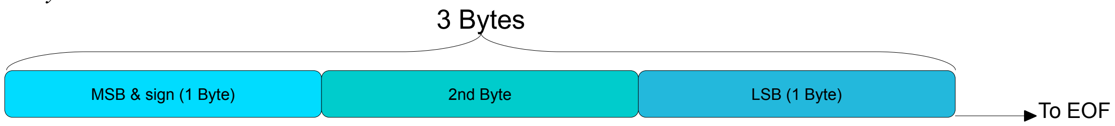
- The 3 next most significant bits are used as a hardware saturation count for the frame (explained below)
- The remaining bits are used as a sequential, unsigned frame counter, which increases every frame. This counter is used to detect frame transfer loss during transmission.



Consideration: Note that the sample data and the frame counter have different endianess while unpacking data.

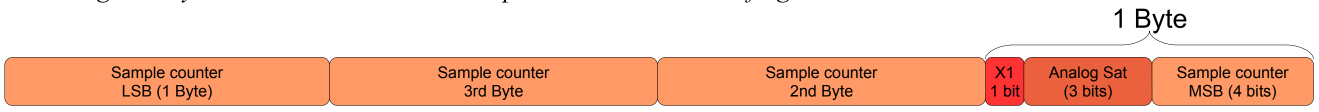
DataFrame.Payload.Sample

Total length: 3 Bytes



DataFrame.Footer

Total length: 4 Bytes = 28-bit little endian sample counter + X1 1-bit flag + 3-bit saturation counter



DataFrame.Footer.SampleCounter

The sample counter is packed as little-endian. To unpack, copy the 4 bytes of the footer in an unsigned 32-bit integer and mask the result with (& 3F) to obtain the value of the counter.

DataFrame.Footer.AnalogSat

These flags indicate if there was saturation detected in the analog front end of electric channels. If any of the bits of this field is non-zero, it indicates that the front end saturated at some point while acquiring data for this frame (20 samples).

NOTE that this field does not flag digital saturation, and it is up to the higher processing layer to detect when digital values are close to the limits of the A/D range to detect digital saturations.

DataFrame.Footer.X1

This field is for internal hardware usage only.

Format for the storage of decimated time series

Objective

The principal objective of decimating the continuous time series at the original A/D sampling rate is to reduce the amount of data in mass storage, enabling the user to transfer a recording in shorter time, and to use less storage capacity for recording and archiving data.

Data file names

The naming conventions for the file created by the instrument are as follows:

AAAAA_BBBBBBBB_C_DDDDDDDD.td_E

Where:

- ***AAAAA***: Is the 5 digit string indicating the serial number of the instrument.
- ***BBBBBBBB***: 32-bit unsigned hexadecimal label indicating the GPS timestamp of the start time of the recording, which along with the serial number, makes a unique ID for the recording. This timestamp is Unix-epoch based, but uses GPS time instead of GMT time as its base.
- ***C***: A hexadecimal label indicating the channel id (same as the folder name that contains the files) that the file corresponds to, starting at zero.
- ***DDDDDDDD***: 32-bit unsigned hex label indicating the index of this file in the sequence of fragmented files. Normally, fragmentation happens every six minutes or ten minutes depending on the decimation scheme programmed, allowing to index more than 10,000 years worth of decimated data files.
- ***E***: Is a multi-character string that indicates the sampling rate of the payload contained by the file. For instance, the file containing segmented data decimated and sampled at 24000 samples/second will have the extension ".td_24K", and the file for the same recording containing (potentially continuous) data decimated and re-sampled at 150 samples/second will have the extension ".td_150".

Format specification

To fulfill the objective of decimation there are two types of files

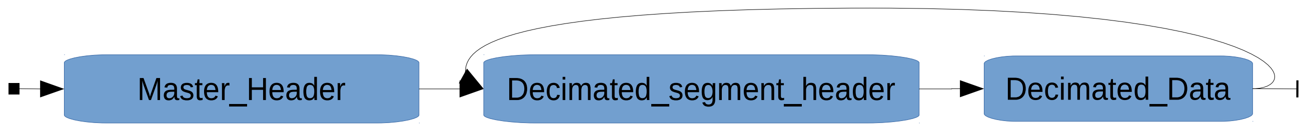
1) When the sampling rate generated by the decimation process is relatively high, we only save discontinuous segments of the data samples at these higher rates to allow for data reduction while still preserving a statistical representation of the signal at higher frequencies. Files saved in this fashion are known as ***Decimated Segmented Files***.

2) To have frequency resolution to the lowest frequency that the length of the recording would allow, we need to save a continuous time series. To save space in the disk, this is done at the lowest sampling rate of a decimation file set. Files decimated in this fashion are known as ***Decimated Continuous Files.***

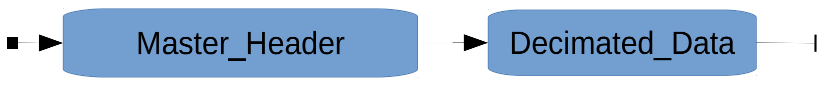
A decimation routine for MT recordings will normally store data at more than one sampling rate in a recording. There will be a sequence of files per sampling rate being saved. The names of the files are described in the section *Data File Names* above.

The content of the two types of files is described in the sections below.

DecimatedSegmentedFile:



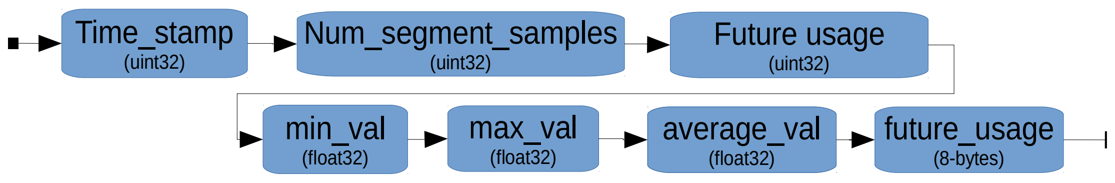
DecimatedContinuousFile:



DecimatedFile.MasterHeader:

This header is present in both *Decimated Segmented Files* and *Decimated Continuous Files, and is d*efined in ***Table 2***, at the end of this document.

DecimatedSegmentedFile.DecimatedSegment.Header:

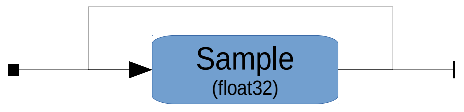


This sub-header is only present in *Decimated Segmented Files.*

Each segment has a time stamp of the first frame (or segment) of the originating time series that was decimated to obtain the sampling rate for this segment. Note that this time-stamping scheme will not account for digital processing delays. This timestamp is Unix-epoch based, but uses GPS time instead of GMT time as its base. Note as well that for decimated time series with versions previous to 0x3 (before instrument firmware v2.0), this timestamp was one second behind the real GPS time due to an unexpected delay between the GPS chip hardware and its driver. Decimated time series version 3 and up (described in this document) will have the correct timestamp.

The fields **min_val**, **max_val** and **average_val** contain the minimum, maximum and average voltages measured within this data segment, in Volts.

DecimatedFile.DecimatedData:



Decimated data will be packed as a raw sequence of IEEE 754 single precision floating point (32 bits) samples, scaled to "Volts at instrument input" by default. This applies to both *Decimated Segmented Files* and *Decimated Continuous Files.*

Implementation specifics

Note that at the time of release of this document, the main header does not have a mechanism to allow distinction between *Decimated Continuous* and *Decimated Segmented* files. Instead, for MT recordings with multiple sampling levels, by default, files with extension "td_150" and "td_30" are stored as *Decimated Continuous Files*, while files containing higher sampling rates are be stored as *Decimated Segmented Files*.

Due to the definition above based on the file extension, if you program your receiver to sample continuously at a rate lower than the native sampling rate (for instance 2400 Samples/sec), the files generated will have the format of *Decimated Segmented Files*, although the files contain continuous data.

Note as well that files that contain discontinuous segments of time series at the native sampling rate generated by a decimated recording will be stored as *Decimated Segmented Files*. This means that the samples will be stored as float32 values, in Volts.

Finally, you will notice that for files that store *Decimated Continuous* data, the start of the data contained is one second after the start of the recording given by the *Master Header* of the file. This is because the decimation process requires filtering the input data. The filters used in the decimation process require the bed with samples to be initialized. The first second of native sampling rate data is used to initialize those filters, so the output of decimated data is enabled only one second after the original data started being recorded.

Finally, the timestamps for raw time series previous to version 4, and for decimated time series previous to version 3 are one second behind the actual GPS time. This was caused by an inconsistency between the GPS chip and its driver. The time series versions described for this document (generated by firmware 2.0 and above) do not have this problem anymore, but we mention this in case that the reader needs to synchronize data generated by old and new firmware.

Tables

Field name	Size [bytes]	Offset [bytes]	Data Type	Value and notes
File type	1	0	uns. Byte	0x1 (1206 *MT continuous time series file)
File version	1	1	uns. Byte	0x4
Header length	2	2	uint16	=128, for version 0x4
Instrument assembly type	8	4	char[]	Example: XX999FFF, the last three characters should be spaces for released products
Instrument serial number	8	12	char[]	Example: 99999 (Last two characters should be filled with null chars)
Recording ID	4	20	uint32	Timespamp at which the recording started, as the number of seconds elapsed since January 1st, 1970, 00:00:00 hours GPS time
Channel ID	1	24	uns. Byte	Starting at 0
File sequence	4	25	uint32	Starting at 0, increase every file
Fragmentation period	2	29	uint16	Time period covered (length) of each sequential file [s]
Acquisition board model	8	31	char[]	Example: XX999FFF, the last three characters should be spaces for released boards
Acquisition board serial	8	39	char[]	Example: 99999 (Last two characters should be filled with null chars)
Acquisition board firmware fingerprint [R]	4	47	uint32	Pack as binary, converting the string returned by the instrument to 32 bit uint.
Hardware configuration fingerprint	8	51	Byte[] (binary)	Hardware configuration flags, internal usage
Sampling rate base	2	59	uint16	Examples: 24000 (or 9600 for MTU-5D, use exponent)
Sampling rate exponent	1	61	sig. Byte	'=0 for sampling rates between 1-65000, non-zero otherwise
Bytes per sample [R]	1	62	uns. Byte	(3) for undecimated time series
Frame size	4	63	uint32	MSByte = Footer length (4) 3 LSBytes = Total frame size (64)
Reserved (Decimation node)	2	67	uint16	Default to 0
Frame count rollovers	2	69	uint16	Starts at 0, +=1 every frame count overflow
GPS Longitude	4	71	float32	WGS84
GPS Latitude	4	75	float32	WGS84
GPS Elevation above mean sea level	4	79	float32	WGS84
GPS Horizonral resolution (future)	4	83	uint32	[mm]
GPS Vertical resolution (future)	4	87	uint32	[mm]
Timing and location status	4	91	Byte	FlagsByte + NumSatByte + Stability_uint16
Future expansion	2	95	int16	(to be defined)
Future expansion	4	97	int32	(to be defined)
Count of saturated frames in the file	2	101	uint16	To read this value, if most significant bit is 0 = Read the number as is (i.e. 16-bit unsigned integer) 1 = Read the next 15 bits as a number, and multiply x16
Count of missing frames in the file	2	103	uint16	Stops counting at (overflow-1)
Battery Level	2	105	uint16	[mV]
Signal Level, Minimum in this file	4	107	IEEE 754 float	Volts at instrument input
Signal Level, Maximum in this file	4	111	IEEE 754 float	Volts at instrument input
Future Expansion	13	115	-	
Total Bytes	128			

***Table 1**. Continuous data file header format*

Field name	Size [bytes]	Offset [bytes]	Data Type	Value and notes
File type	1	0	uns. Byte	0x2 (1206 *MT decimated time series file)
File version	1	1	uns. Byte	0x3
Header length	2	2	uint16	=128, for version 0x3
Instrument assembly type	8	4	char[]	Example: XX999FF, the last two characters should be spaces for released products
Instrument serial number	8	12	char[]	Example: 99999 (Last two characters should be filled with null chars)
Recording ID	4	20	uint32	Taken from the hex UNIX time stamp of the time at which the recording started
Channel ID	1	24	uns. Byte	Starting at 0
File sequence	4	25	uint32	Starting at 1, increase every file
Fragmentation period	2	29	uint16	Time period covered (length) of each sequential file [s]
Acquisition board model	8	31	char[]	Example: XX999FF, the last two characters should be spaces for released boards
Acquisition board serial	8	39	char[]	Example: 99999 (Last two characters should be filled with null chars)
Acquisition board firmware fingerprint [R]	4	47	uint32	Pack as binary, converting the string returned by the instrument to 32 bit uint.
Hardware configuration fingerprint	8	51	Byte[] (binary)	Hardware configuration flags, internal usage
Sampling rate base	2	59	uint16	For the data payload contained for this file. Examples: 24000, 150, or for 96KS/s, it would read 9600, use exponent
Sampling rate exponent	1	61	sig. Byte	Base 10, use 0 unless field above is not sufficient
Bytes per sample [R]	1	62	uns. Byte	(4) for decimated time series
Future expansion	8	63	Byte[]	(to be defined)
GPS Longitude	4	71	float32	WGS84
GPS Latitude	4	75	float32	WGS84
GPS Elevation above mean sea level	4	79	float32	WGS84
GPS Horizonral resolution (future)	4	83	uint32	[mm]
GPS Vertical resolution (future)	4	87	uint32	[mm]
Timing and location status	4	91	Byte	FlagsByte + NumSatByte + Stability_uint16
Future expansion	6	95		(to be defined)
Reserved	4	101		Reserved
Battery Level	2	105	uint16	[mV]
Reserved	12	107		Reserved
Decimation scheme ID	4	119	uint32	Numerical identifier of the decimation scheme used for this time series
Future expansion	5	123		(to be defined)

Table 2. *Decimated data file header format*