CMG-DM24S12AMS

Acquisition and Monitoring System

Operator's guide

Part MAN-D24-0002

Designed and manufactured by
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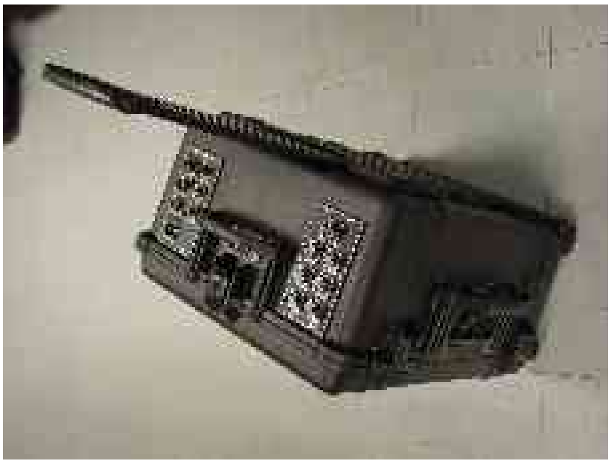
Contents

1 Introduction

The Güralp CMG-DM24S12AMS 12-channel acquisition and monitoring system is a self-contained seismic data collection station specially configured to operate 12 single-component CMG-5U strong motion accelerometers. It combines all the features of the CMG-DM24 3 or 6-channel digitiser with an integrated laptop PC for viewing and transmitting the recorded data.

The housing of the digitiser is made from high impact copolymer polypropylene with mil-spec connectors fitted on to metal plates. There is also a small internal pocket for storing cables or documentation. The unit features a roller trolley design for ease of transportation.

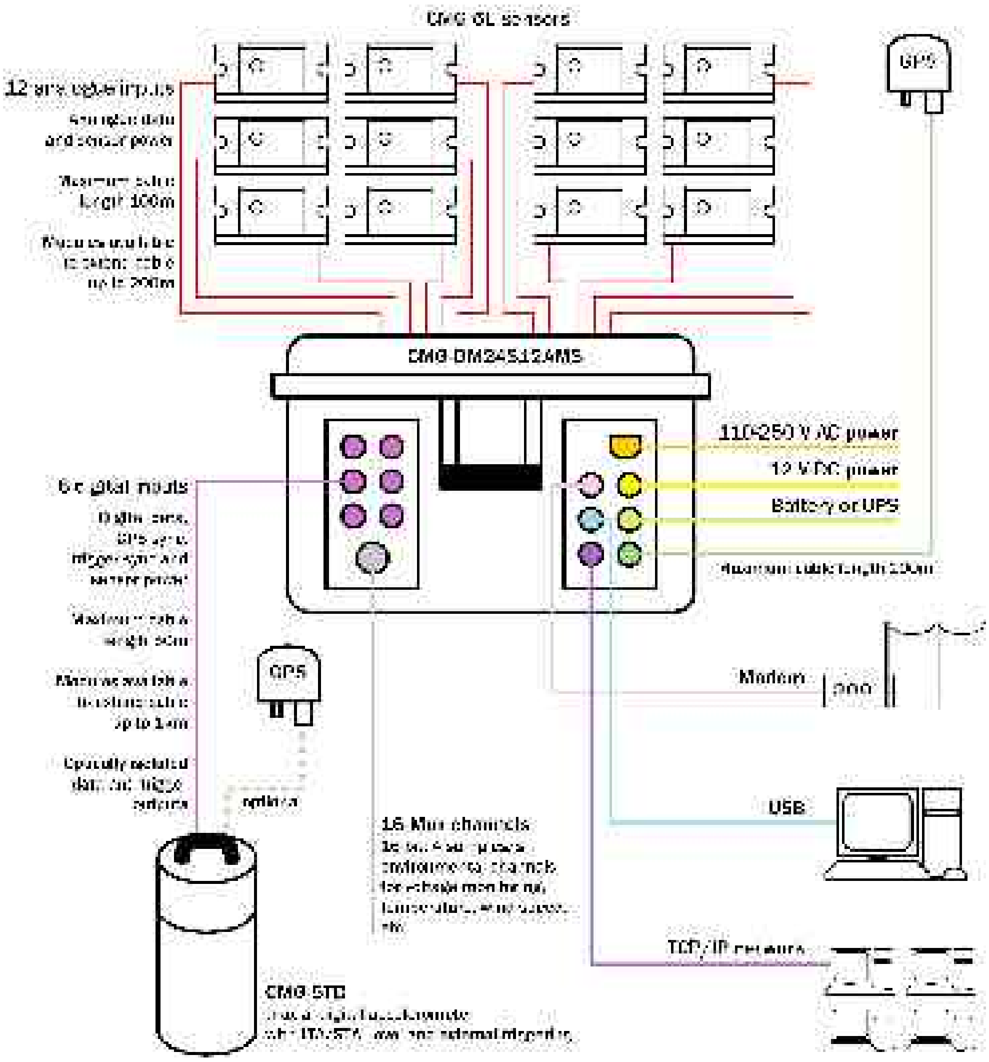


The integrated laptop PC is supplied with Güralp Systems' Scream! software pre-installed. Using the PC, you can process incoming data and transfer it to any compatible storage device over a telephone line (modem) or network connection.

Care must be taken when handling the integrated PC, which is a standard laptop model. In particular, you should not force the screen lid closed. Closing the lid would cause the PC to enter hibernation mode, and halt all data collection. Instead, you should rest the lid on the rubber stops fitted to the PC's keyboard, so that the PC remains active and the digitiser functions as expected. There is sufficient room within the DM24S12AMS unit to allow you to leave the PC in this state and still close the outer case completely.

Note: Because the integrated PC requires ventilation, the DM24S12AMS is not completely waterproof. The water level must not be allowed to reach the ventilation grilles on the sides, front and rear of the box at any time.

A typical setup for a DM24S12AMS acquisition and monitoring system is shown below.



Here, the twelve CMG-5U uniaxial sensors can be distributed throughout a building to capture its response to ground motion, while a digital CMG-5TD unit is embedded in the ground nearby to capture the ground motion itself. Data from all thirteen instruments is fed into the DM24S12AMS, where it can be stored and processed on-site or alternatively sent across a local network or the Internet. If required, up to five further digital instruments can be connected to the DM24S12AMS (not shown).

The DM24S12AMS unit's 12 analogue input connections are each identical to the output connection of the Güralp CMG-5U. These connections also serve as the sensors' 12V power supply. If required, other types of sensor may also be wired to a DM24S12AMS module.

Using compatible connections, you can control all the sensors through the module, either using its integrated PC or from a remote location on your network. The digitiser can also provide common calibration and GPS timing signals to all the sensors.

All DM24 digitiser units are fitted with high-impedance, low-noise, differential input pre-amplifier modules.

In addition to the main 24-bit analogue inputs, the digitiser module features an additional 16 slow rate 16-bit resolution analogue inputs. The inputs to the slow rate channels are through the connector marked *AUXILIARY INPUTS*. These inputs are all single-ended and use a fixed sample rate of 4 samples/s.

The *DIGITAL A − F* connectors are provided for use with Güralp Systems digital output seismometers (such as the CMG-3TD) or accelerometers (CMG-5TD). Like the analogue inputs, the *DIGITAL A − F* connectors can supply power to the digital sensors. Alternatively, if required, the *DIGITAL A − F* can be used as serial interfaces (*e.g.* to remote installations connected by modem.)

The DM24S12AMS unit can be powered either from 110 – 250V AC mains power, or from a 12 V DC power source. In addition, a *BATTERY/UPS* connector is provided, for attaching to a rechargeable battery or UPS. If power is provided through one of the other sockets, the battery will be recharged at 14 V. There is also an external USB port, and a standard parallel port within the casing.

For more details on the internal design of the DM24S12AMS, see Chapter 4, "Inside the DM24S12AMS".

1.1 Feature overview

- A built-in Digital Signal Processor (Motorola 56002) provides simultaneous multiple sample rate data streams at user selectable rates. Up to 4 streams of data for each component are available at sample rates from 1 to 200 samples/s.

- A precision microprocessor-controlled time base synchronizes Analogue to Digital Converters, and DSP and time-stamps data blocks.

- Time synchronization to external GPS or serial time code.

- A control microprocessor (Hitachi H8) formats and buffers data in an on-board 512k RAM ring buffer.

- Efficient data storage and transmission using the Güralp Compressed Format.

- Serial data output (RS232) at user selectable baud rates—options of RS422, DPSK or fibre-optic.

- Built-in microprocessor system configuration and sensor control, including locking and unlocking, centring and calibration.

- Low system power consumption, less than 3W (excluding the integrated PC)

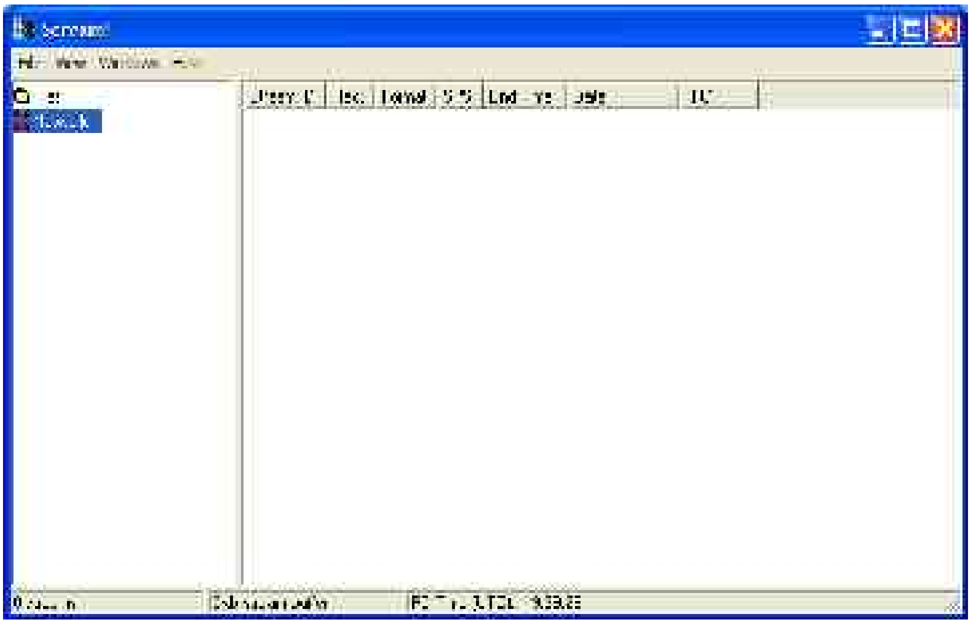
- Flash EEPROM for program code and filter coefficients.

2 Quick start

1. If you are using a GPS timing signal to synchronize your instruments, first connect a GPS receiver to the digitiser's *GPS* socket.

2. Power up the system. The DM24S12AMS module can take power from the mains, or from any ~12 V DC supply such as a battery or UPS. If a rechargeable battery is connected to the *BATTERY/UPS* socket, and enough external power is provided, the battery will be recharged as required.

3. Open the lid of the unit, and power up the built-in laptop PC, which is configured to automatically run the latest version of Güralp's Scream! software. After a short while, Scream!'s main window will open:



4. Scream! will then connect to the digitiser. The DM24S12AMS houses two separate 6-channel digitiser modules, which work on *CH 1-6* and *CH 7-12* respectively. After a short wait, the two modules should appear under **Local** in the left hand pane, each on its own Com port.

5. Whilst **Local** is selected in the left-hand pane, the list on the right details all the data streams coming from any instrument directly attached to the DM24S12AMS. Clicking on **Network** will display all data coming from networked instruments or other Scream! servers, if there are any. Clicking on the entry for a particular digitiser picks out streams coming from that digitiser; likewise, clicking on a **Com**<u>**xx**</u> entry will display only streams attached to a particular Com port.

6. The columns in the table provide useful information about each stream.

   Stream ID: A unique name for the data stream, being a combination of six letters A – Z and numbers 0 – 9. Streams ending in "00" carry status information about the internal digitiser, whilst other streams contain data coming from connected instruments. The slow-rate environmental channels (Mux channels) generally have Stream IDs ending in "M*x*" where *x* is a hexadecimal digit (0 – 9 or A – F), whilst other Stream IDs are used for seismic data from attached instruments.

   Rec.: Whether the data stream is currently being recorded to the hard disk.

   Format: The format of the data the stream is producing; one of 8, 16 or 32 bit.

   SPS: The sampling rate of the data stream, in samples per second. Status streams ending in "00" do not constantly output data and have an *SPS* of 0. By default, the stream list is sorted in order of sample rate, with the status streams at the bottom.

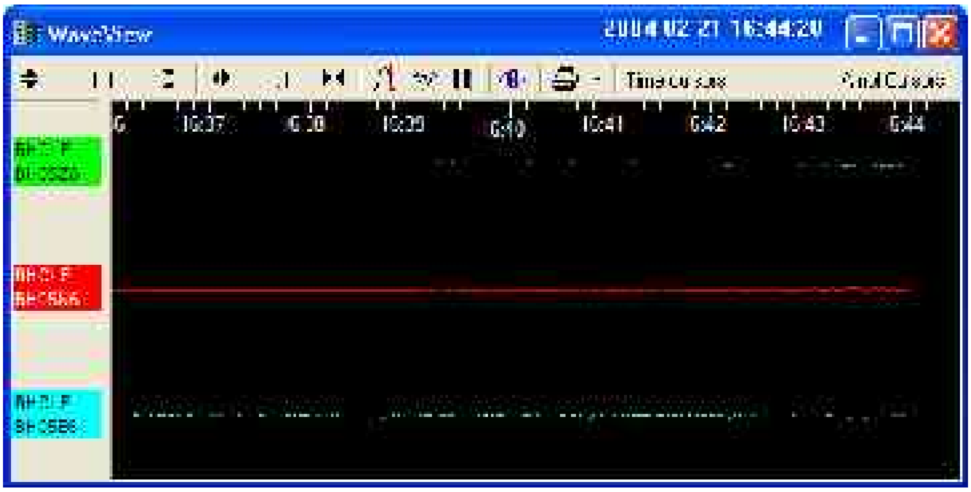
   End time: The time the data stream last sent data to Scream!. The time is taken from the digitiser's internal clock, which can be set from signals coming from an attached GPS receiver (see "GPS" in Section 4.1).

   Date: The date the data stream last sent data to Scream!.

RIC: The 'Reverse Integrating Constant'. In effect this is the value of the last sample received. This is most useful for reading mass positions or other environmental streams.

7. You can now connect a Güralp CMG-5U sensor to one of the *CH 1 – 12* connectors on the side of the unit. See Section 5.2, "Installing CMG-5U sensors" for more details.

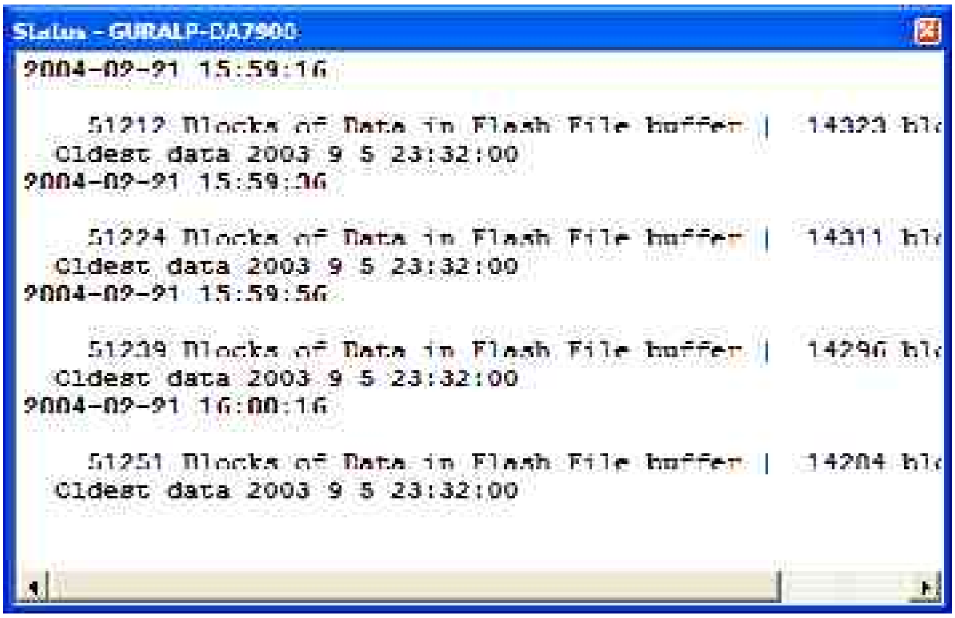
8. Double-click on one of the streams to open a *WaveView* window for viewing the data.



9. You can add further streams to the *WaveView* window by selecting them from the streams list and dragging the selection into the *WaveView* window.

10. You can open new *WaveView* windows by making a selection of streams from the list and double-clicking on that selection.

11. To see the status information coming from each digitiser, right-click on the status stream (ending in "00"), and select **View** from the pop-up menu. A **Status** window will open containing all the text that has been received since power-up.



The first blocks will give the boot message from the digitiser, including its software revision and the data streams selected for downloading and triggering. Later blocks give information on visible GPS satellites, the location of the GPS antenna and time synchronization status. Also displayed are the baud rates currently used for each channel and for the data link.

The following chapters describe a selection of the features available in the Scream! 4 software provided with the DM24S12AMS. For full information on what you can do with Scream! please consult its own user guide or the extensive online help.

3 Using Scream!

3.1 Configuring digitisers

The DM24S12AMS unit contains two built-in 6-channel DM24 digitiser modules, one running the ports *CH 1 – 6*, and the other using ports *CH 7 – 12*. These may be configured from within Scream!, together with any external Güralp digital instruments attached to the DM24S12AMS's *DIGITAL A – F* connectors.

Scream! 4 distinguishes between *configuration* and *control* of digitisers. The most important difference is that a digitiser may be *controlled* through Scream! whilst in the process of acquiring data, whereas *configuring* a digitiser requires that it be rebooted (with consequent loss of data.)

To change the configuration of any attached digitiser, including the two 6-channel digitisers installed within the DM24S12AMS unit, right-click on the digitiser's entry in the list to the left of Scream!'s main window (*not* the **Local** or **Comxx** icons) and click **Configure...**. Scream! will then contact the digitiser and retrieve its current configuration, a process which will take a few seconds, after which the *Configuration setup* window will be displayed. Once you are happy with any changes you have made in the *Configuration Setup* window, click **UPLOAD** to send them to the digitiser and reboot. This will take a short while.

To control a digitiser whilst it is running, either right-click on the digitiser's entry in the list and click **Control...**, or double-click the entry. In either case Scream! will contact the digitiser to retrieve control information and display the *Control* window. The options you can control immediately are:

- The type of sensor you are using
- GPS power cycling options
- The short-term and long-term average values for triggering (but *not* which streams perform the trigger, or which are output by it) (see also “Triggering” in Section 3.1)

- The length of pre-trigger and post-trigger periods (see also “Triggering” in Section 3.1)
- Calibration signal options
- Mass control functions

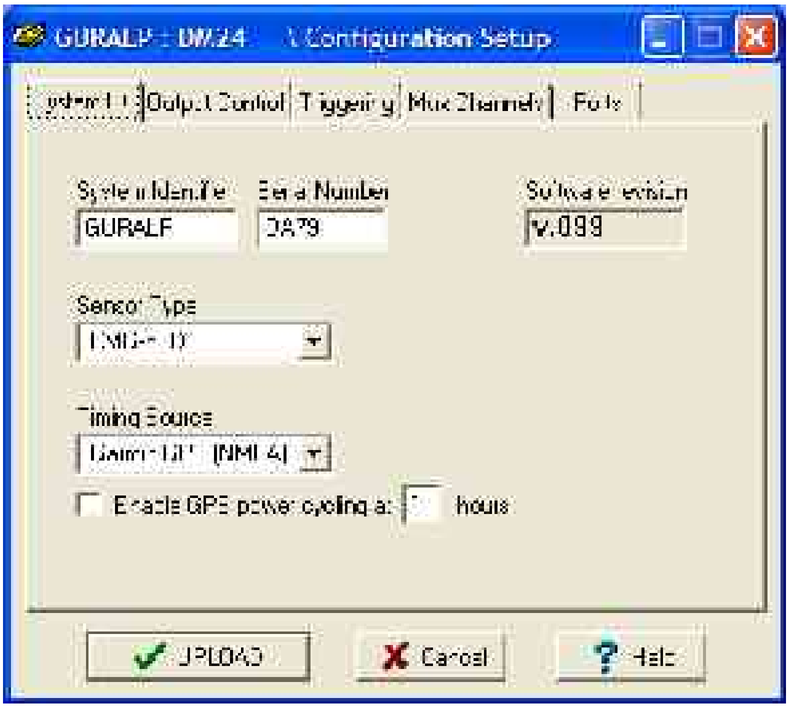
Some of these options can also be altered in the *Configuration setup* window. For more information on the *Control* window, see Section 3.2, “Controlling digitisers”.

If you need a more powerful interface to the digitiser modules, you can also issue commands to it directly using Scream!'s terminal mode. A terminal window is opened by right-clicking on the digitiser's entry in the list and selecting **Terminal...**. The digitiser will stop collecting data while you have a terminal window open. For more details on the DM24's terminal mode commands, please see its technical documentation (available from Güralp Systems.)

The remaining sections of this chapter describe in detail the configuration options available for the DM24S12AMS's in-built digitisers. Many of these options will also be available for other Güralp digitisers or digital sensors connected to the unit's *DIGITAL A – F* ports. For the most accurate information, you should consult the Operator's Guide for the digitiser or sensor you connect.

System ID

The *System ID* pane gives information about the digitiser and its internal software, and allows you to change GPS timing parameters.



System Identifier and **Serial Number:** The digitiser type is identified by its system identifier and serial number. Every data and status block generated by the digitiser includes these two fields at the beginning, so that the block's origin can be identified. On delivery from the factory, the system identifier and the serial number are set to the GSL works order number and the digitiser's serial number, but you can set either value to any combination of up to 6 letters A-Z and numbers, such as an abbreviation of your institution's name, etc.

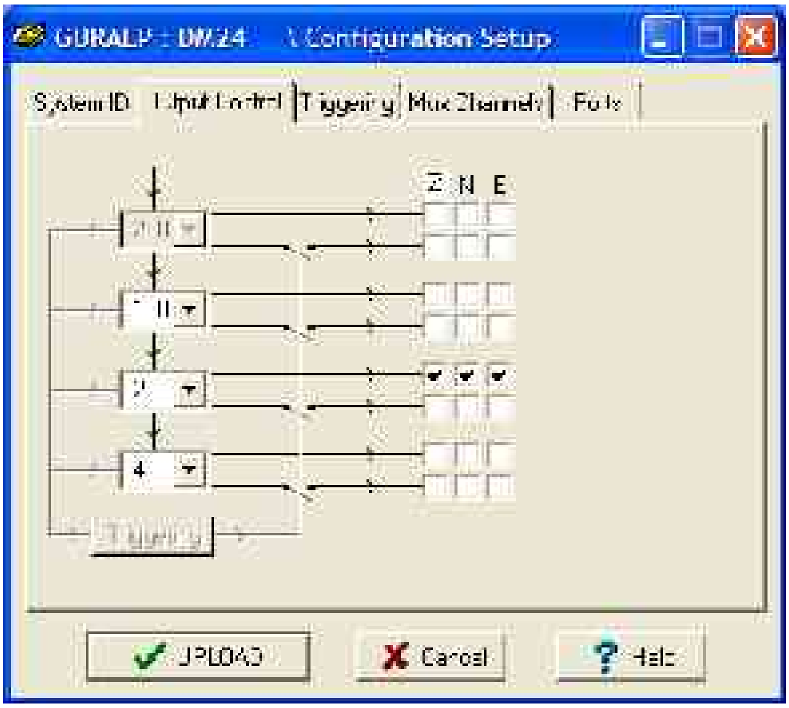
Sensor Type: If the sensor attached to the digitiser is a Güralp velocity sensor, useful seismometer functions (such as sensor locking, centring, and calibration) may be controlled through the digitiser. The type of sensor programmed with this option determines which functions will be available through the Scream! digitiser configuration set-up interface or through interactive commands. The in-built digitisers are already programmed to the proper sensor type for Güralp CMG-5U uniaxial sensors.

GPS Type: The digitiser needs to be able to time-stamp accurately all data that passes through it. It can set its clock either by receiving time signals from the GPS satellite network using an attached Garmin GPS unit, or by taking time information from a central site (*stream sync* mode). In *stream sync* mode, the digitiser expects to receive GCF packets from the central timing source (which may have its own GPS unit, or take signals from one of the radio time standards).

Enable GPS power cycling: If you are using a GPS unit to receive time signals, but do not experience significant drift in the system's clock (for example, in a stable-temperature environment), you can save power by selecting **Enable GPS power cycling.** With this option in use, the GPS time is only checked at intervals of a specified number of hours. Disabling this option keeps the GPS unit running constantly; if you have ample power, this will give the most accurate results. You can choose any whole number of hours for the interval.

Output control

The *Output control* tab allows you to configure which data streams are sent to Scream! from each digitiser.



Güralp instruments output data sampled at 2000 Hz, which is then filtered and reduced to a lower rate (*decimated*) using an on-board digital signal processing unit, or DSP. The DSP has four filtering-decimation stages, which run one after the other. The output of each stage is called a *tap*. The first filter stage, tap 0, is pre-set to reduce the data by a factor of 10 to 200 samples/second.

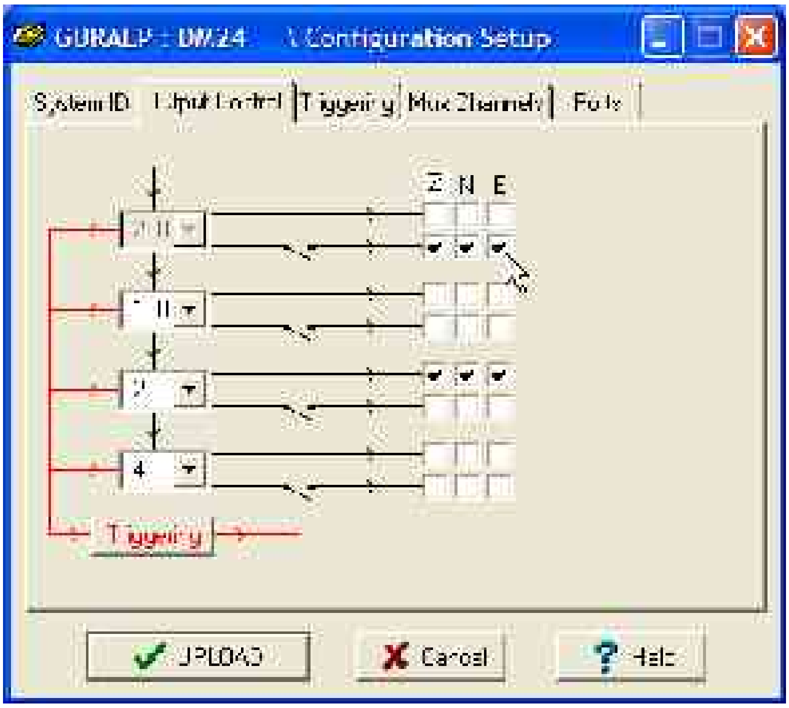
Each of the three remaining taps may be configured for a different decimation factor by choosing values from the drop-down menus on the left. Decimation factors of 2, 4, 5, 8, and 10 are available. The numbers visible in the drop-down menu of each tap are the data rates that each of the possible decimation factors will provide, given the settings of the taps above it. Only integer (Hz) data rates are allowed: thus, for example, if one tap emits data at 25 Hz, the only possible further decimation factor is 5.

To the right of each decimation factor menu is a grid of check-boxes. These boxes mark which streams of data to record at each sample rate. The screenshot above shows a possible configuration for a triaxial instrument (similar to a CMG-5TD connected to one of the ports *DIGITAL A – F*).

If you want to change the names used for the channels, click in the white box containing a Z in the above picture, and type a letter or number. It will name the channels with a sequence of letters or numbers beginning with the one you choose (*e.g.* A, B, C; 2, 3, 4; 9, A, B), unless you type Z in which case they will revert to Z, N, and E.

Each combination of channel and tap has two check-boxes. The upper check-box of each pair activates *continuous* output, whilst the lower activates *triggered* output. In the example above, the digitiser will output data continuously for all three channels at Tap 2, but never for any other taps. If you do not need all the streams to output at all rates, you should leave boxes unchecked to save communications capacity. You cannot check both continuous and triggered output for the same channel and tap.

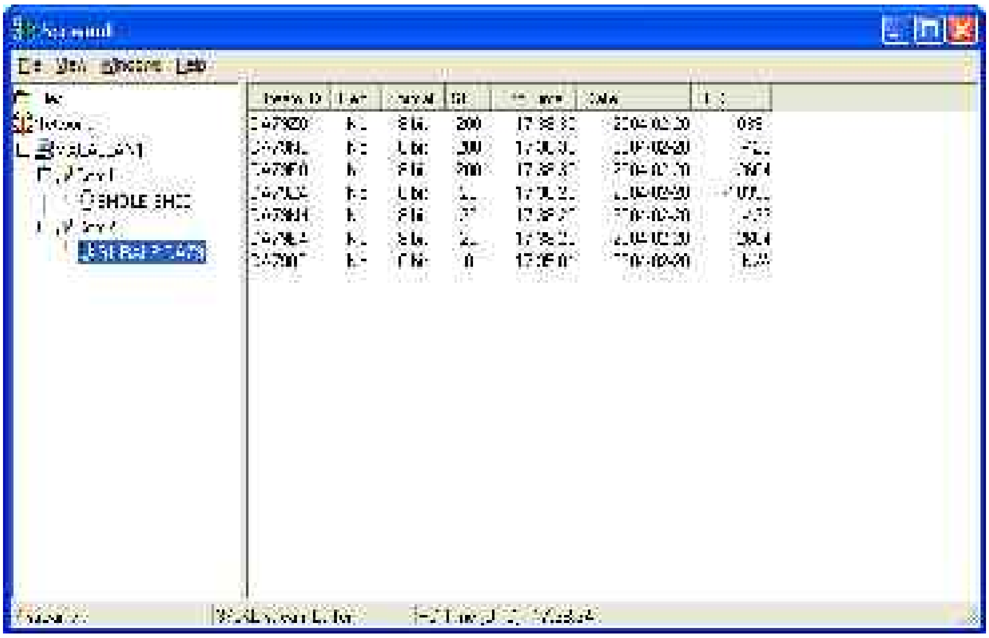
Triggered output causes the digitiser to output data only when a particular set of trigger criteria are met. This is shown diagrammatically as data passing through a switch. In the example above, we might want the more detailed data from Tap 0 to be recorded only when an event registers at some other tap. To do this, the *lower* check-boxes of Tap 0 should be ticked:



With this configuration uploaded, Tap 2 will continue to produce output at all times, but Tap 0 will also emit data whenever the trigger criteria are met. The *Triggering* button is now shown in red to remind you that the trigger is active.

Every checked box in this window will give rise to a data stream coming from the digitiser, which will be displayed in Scream!'s main window when Scream! first receives some data from it. Every stream is identified by a 6-character code, where the first four characters identify the digitiser, and the last two characters identify the individual stream.

Using the example above, there are three data streams, Z, N and E, which each output data at 20 samples/s (continuously) and 200 samples/s (occasionally). The streams appear in Scream!'s main window like this:



In this example:

- DA79 is the serial ID of the digitiser.
- Z0, N0, E0 correspond to input channels Z, N, and E, output through Tap 0.
- Z4, N4, E4 correspond to input channels Z, N, and E, output through Tap 2. A six-channel digitiser connected to two triaxial instruments will use Z0, N0, E0, Z1, N1, E1 for tap 0; Z2, N2, E2, Z3, N3, E3 for tap 1; Z4, N4, E4, Z5, N5, E5 for tap 2; and Z6, N6, E6, Z7, N7, E7 for tap 3. The digitiser in the example has only one triaxial instrument connected to it, so Z/N/E1, 3, 5 and 7 are unused.

  You can change these designations if you wish: see the Scream! manual or online help for more details.
- 00 is the digitiser status stream (notice: no sample rate),
- M8, M9, MA are slow-rate Mux channels reporting the sensor mass positions for the Z, N, and E components ("Mux Channels" in Section 3.1).
- ME is another Mux channel, here used for reporting the temperature.

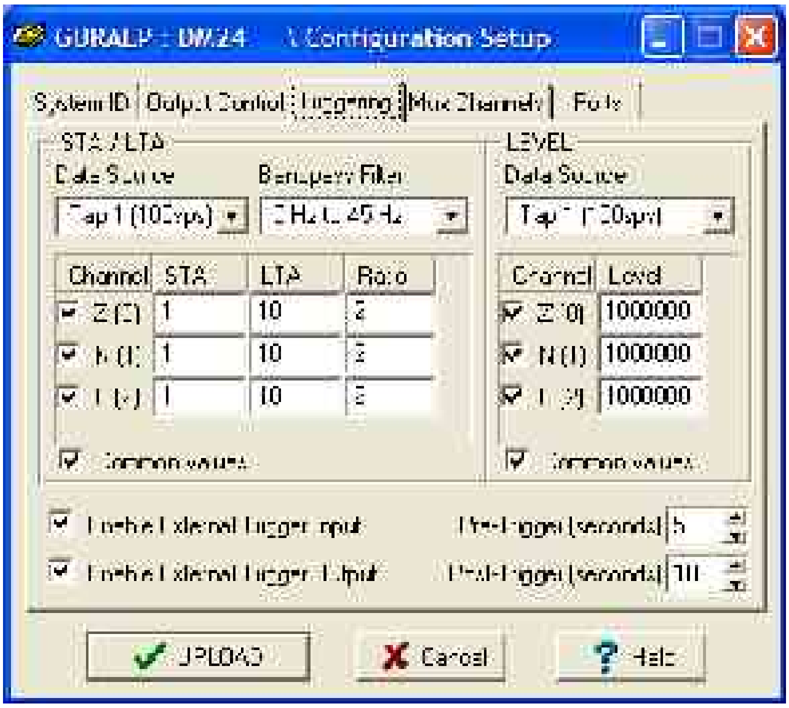
Triggering

In its standard configuration, the digitiser modules inside the DM24S12AMS output continuous data at a sample rate you specify. In addition to this, the digitiser can run a triggering algorithm on the data it acquires. This allows you to record data continuously at a relatively low sample rate, but record at a much higher sample rate during short periods when the trigger is active. The parameters controlling the triggering algorithm, and controlling the data output once the system is triggered, are all selectable by the user, permitting maximum flexibility of operation and the most efficient use of available storage space.

The digitiser modules inside the DM24S12AMS can be set up for triggered output, that is, to output certain data streams only when a particular trigger criterion is met. The trigger criterion can be tested with data from the same or some other stream. For example, you could use a later tap (with a lower sample rate) as a trigger for output from an earlier, more detailed tap. Scream! 4 also allows each digitiser to receive triggers from other digitisers.

To create a new stream with a trigger, open Scream!'s *Digitiser configuration* window for the relevant digitiser, and click on the *Output control* tab. In the *Output control* pane, a tap which gives rise to a triggered stream has a tick in the *lower* row of its grid of check-boxes. You cannot configure the trigger criteria until you have selected at least one stream to be affected by the trigger.

Once you have decided which streams should be output when the trigger is activated, you will be able to click on the **Triggering** button to describe the trigger condition. Alternatively, click on the **Triggering** tab at the top of the window. Either action will open the *Triggering* pane:



There are two triggering algorithms which Güralp digitisers can use. However, not all models can use both methods. Scream! will find out from the digitiser whether its on-board software supports each method.

STA/LTA

The *STA/LTA* algorithm applies a simple short-term average – long-term average calculation to the triggering stream. It works by identifying sections of an incoming data stream when the signal amplitude increases. The purpose of taking a short term average, rather than triggering on signal amplitude directly, is to make it less likely that spurious spikes will trigger the device. Averaging also introduces an element of frequency selectivity into the triggering process.

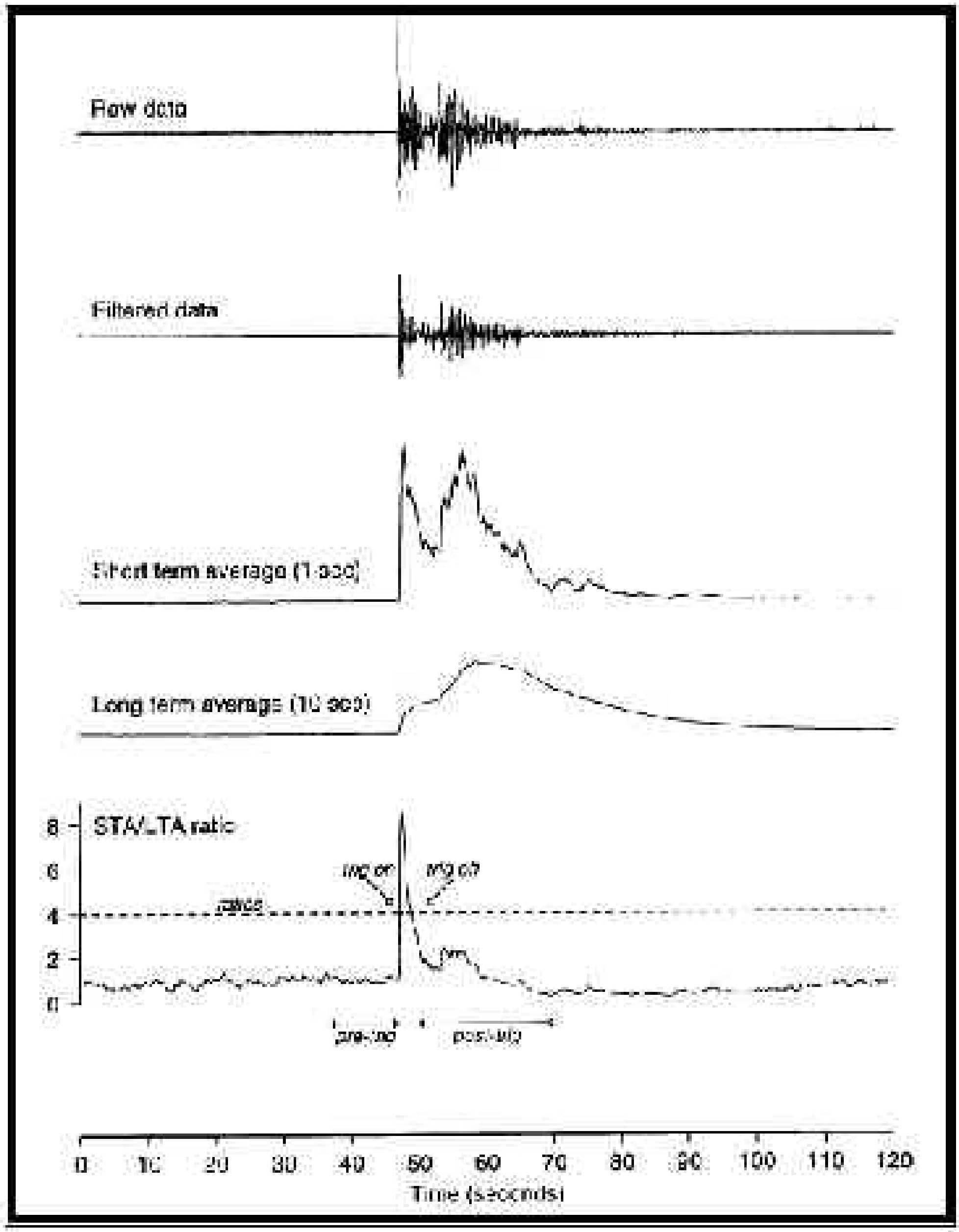
You can select which tap is tested for the trigger from the **Data source** drop-down menu. The tap does not have to output data to Scream! for you to be able to use it here.

Any or all of the channels available at that tap may be used to determine a trigger. You can select which channels are considered by checking the boxes in the **Channel** column of the table. If *any* of the checked channels passes the trigger condition, the trigger will activate, and will not detrigger until *all* of the checked channels have fallen below their respective ratio values.

The **STA** and **LTA** columns allow you to set the intervals over which the two averages are calculated, in seconds. Typically, the time interval for the short term average should be about as long as the signals you want to trigger on, while the long term average should be taken over a much longer interval. Both the STA and LTA values are recalculated continually, even during a trigger.

The **Ratio** column determines by what factor the STA and LTA must differ for the trigger to be passed. Finding the ratio most suited to your needs is best done by experiment. Too high a value will result in events being missed, while too low a value will result in spurious non-seismic noise triggering the system. Like the averages, their ratio is continuously recalculated for all components. Note that none of the boxes are allowed to be empty, and so you will need to enter the new value before removing the old one. Alternatively, you can use the up and down cursor keys to change the values.

For example, setting the **STA** to 1 second, the **LTA** to 10 seconds and the **Ratio** to 4 would give rise to the following trigger behaviour:



Usually, the values of the **STA** and **LTA** periods, and of the **Ratio**, will be the same for all checked channels. For convenience, Scream! will automatically fill in other values to match ones you enter. If you want to use different values for some channels, you should uncheck **Common values** before altering them.

Once you have enabled the *STA/LTA* triggering method on a particular channel, you can use the *Control* window to change the values of the **STA** and **LTA** periods, together with the **Ratio**, without restarting the digitiser (see Section 3.2, "Controlling digitisers".)

Since it is not generally advisable to trigger from broadband data, the digitiser provides a set of standard bandpass filters to apply to the data streams before they are tested for the trigger condition. This filtering serves to maximise sensitivity within a the frequency band of interest, and filter out noise outside this band. You can select which bandpass filter to use from the **Bandpass filter** drop-down menu. The corner frequencies of the pass band of the filter are determined by the Nyquist frequency, which is given by the sampling rate of the triggering data. The three filter options have pass bands between 10 % and 90 %, between 20 % and 90 % and between 50% and 90% of the data's Nyquist frequency, respectively.

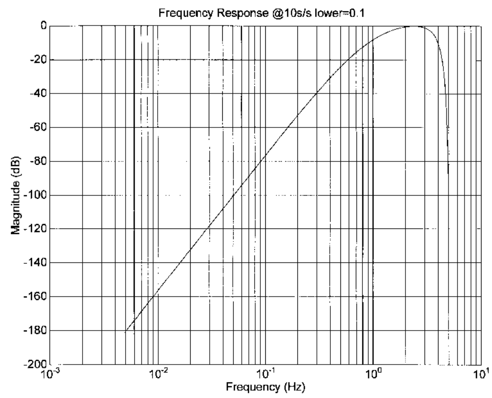
The possible filter configurations are shown in the following table:

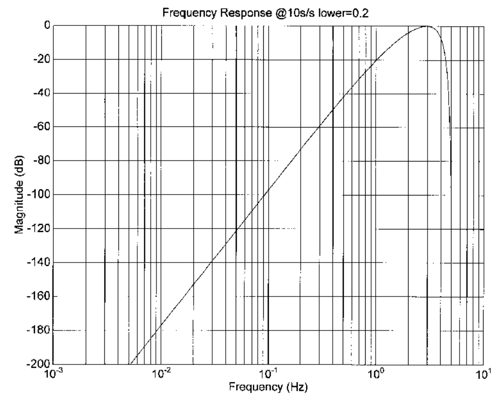
Tap #	Rate (samples/s)	Bandwidth 1 (Hz)	Bandwidth 2 (Hz)	Bandwidth 5 (Hz)
0	200	10 – 90	20 – 90	50 – 90
1	100	5 – 45	10 – 45	25 – 45
	50	2.5 – 22.5	5 – 22.5	12.5 – 22.5
	40	2 – 18	4 – 18	10 – 18
	25	1.25 – 11.25	2.5 – 11.25	6.25 – 11.25
	20	1 – 9	2 – 9	5 – 9
2	50	2.5 – 22.5	5 – 22.5	12.5 – 22.5
	25	1.25 – 11.25	2.5 – 11.25	6.25 – 11.25
	20	1 – 9	2 – 9	5 – 9
	10	0.5 – 4.5	1 – 4.5	2.5 – 4.5
	8	0.4 – 3.6	0.8 – 3.6	2 – 3.6
	5	0.25 – 2.25	0.5 – 2.25	1.25 – 2.25
	4	0.2 – 1.8	0.4 – 1.8	1 – 1.8
	2	0.1 – 0.9	0.2 – 0.9	0.5 – 0.9
3	25	1.25 – 11.25	12.5 – 11.25	6.25 – 11.25
	10	0.5 – 4.5	1 – 4.5	2.5 – 4.5
	5	0.25 – 2.25	0.5 – 2.25	1.25 – 2.25
	4	0.2 – 1.8	0.4 – 1.8	1 – 1.8

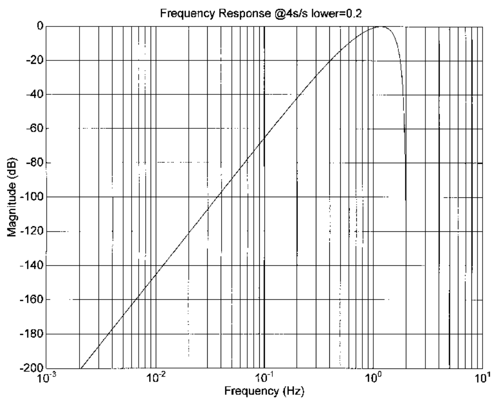
Tap #	Rate (samples/s)	Bandwidth 1 (Hz)	Bandwidth 2 (Hz)	Bandwidth 5 (Hz)
	2	0.1 – 0.9	0.2 – 0.9	0.5 – 0.9
	1	0.05 – 0.45	0.1 – 0.45	0.25 – 0.45

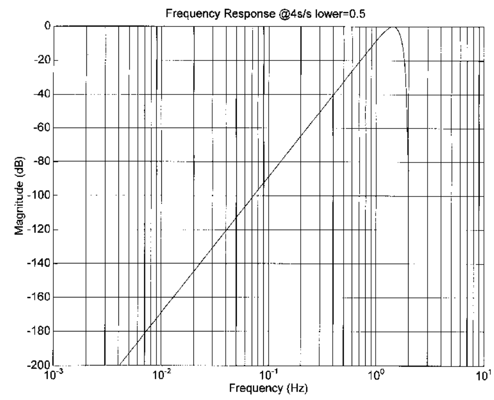
As can be seen, the filter you choose defines the set of permissible sample rates.

The spectral amplitudes for the various frequency responses available are shown in the following figures.









Level

Using the *Level* triggering method, a trigger is generated whenever one of the checked components reaches a certain level above the baseline. You can select which tap is monitored from the **Data source** drop-down menu, and the channel(s) to be considered from the **Channel** column of the table. The values in the **Level** column are the number of counts above the baseline that channel must reach before a trigger is generated. If you wish, you can apply a bandpass filter to the incoming data (see above) before checking whether it has reached the trigger level.

As with the *STA/LTA* method, the values of the **Level** will often be the same for all checked channels. If you want to use different values for some channels, you should uncheck **Common values** before altering them.

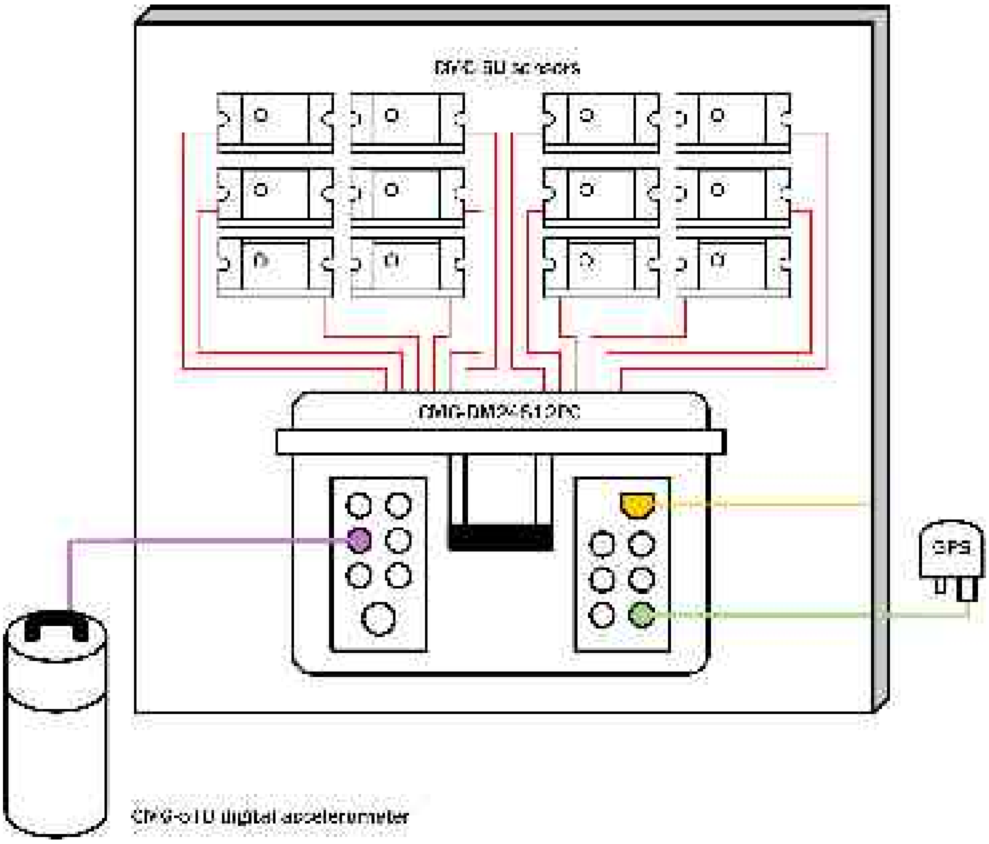
Once you have enabled the *Level* triggering method on a particular channel, you can use the *Control* window to change the level at which the system triggers without restarting the digitiser (see Section 3.2, "Controlling digitisers".)

External triggering

When a digitiser triggers, it sends the trigger itself to Scream! as well as any extra data that it has been configured to record. Scream! can then pass on the trigger to other connected digitisers. As an example, consider an installation similar to that depicted in the Introduction (overleaf).

Here, a ground sensor attached to one of the ports *DIGITAL A – F* is being used to monitor local seismic activity, whilst 12 uniaxial sensors distributed through a building are measuring its response to ground movements. These 12 sensors are attached to the analogue inputs *CH 1 – 12* on the DM24S12AMS unit.

When a seismic event occurs at the ground sensor, it will trigger. This trigger needs to be passed on to the CMG-5U sensors (*via* Scream!) so that the building's response can be measured accurately. Newer 5TD units and the DM24S12AMS's internal digitisers support this facility. To configure the above installation, you would carry out the following procedure:



1. Open the *Configuration setup* window for the digital sensor, and check **Enable External Trigger Output** to make it send triggers to Scream!.

2. **UPLOAD** the new configuration to the digital sensor.

3. Open the *Configuration setup* window for one of the DM24S12AMS's internal digitisers, and check **Enable External Trigger Input** to make it listen for triggers coming from the digital sensor *via* Scream!, and record data when it receives one (depending on its *Output control* configuration.)

4. **UPLOAD** the new configuration to the internal digitiser.

5. Repeat for the other internal digitiser.

If a digitiser has both **Enable External Trigger Output** and **Enable External Trigger Input** selected, it will record data when it receives a trigger from Scream! as if it had triggered itself, but it will *not* report that trigger back to Scream!. It will only send a trigger to Scream! if its *own* triggering criteria are satisfied.

Note that Scream! must be up and running for external triggering to work. If you shut down the internal PC, you will need a copy of Scream! running on a connected network to pass on trigger signals. Because this introduces a degree of latency, you should allow a reasonable pre-trigger period for high data-rate capture (see below).

Pre-trigger and post-trigger recording

In order to capture all of a seismic event, it is often useful to be able to record data immediately preceding the trigger. The DM24 has an internal buffer of some seconds which allows this data to be added to the triggered stream. Pre-trigger data is particularly useful for emergent-type signals, where the system does not trigger until one phase after the first arrival.

In addition, to ensure that the coda of each event is included, some seconds of data are recorded after the system detriggers. In the example diagram above, the system detriggers well before the event has finished, so a post-trigger value of 20 seconds is used to capture the remainder of the event. The example also uses a pre-trigger period of 10 seconds.

The two boxes at bottom right of the *Triggering* pane allow the user to set the pre-trigger and post-trigger data intervals, in seconds. These values determine the *minimum* length of time during which data will be saved before the trigger condition occurs, and after it has lapsed. Regardless of the intervals chosen, the data in the triggered streams will begin on an even second.

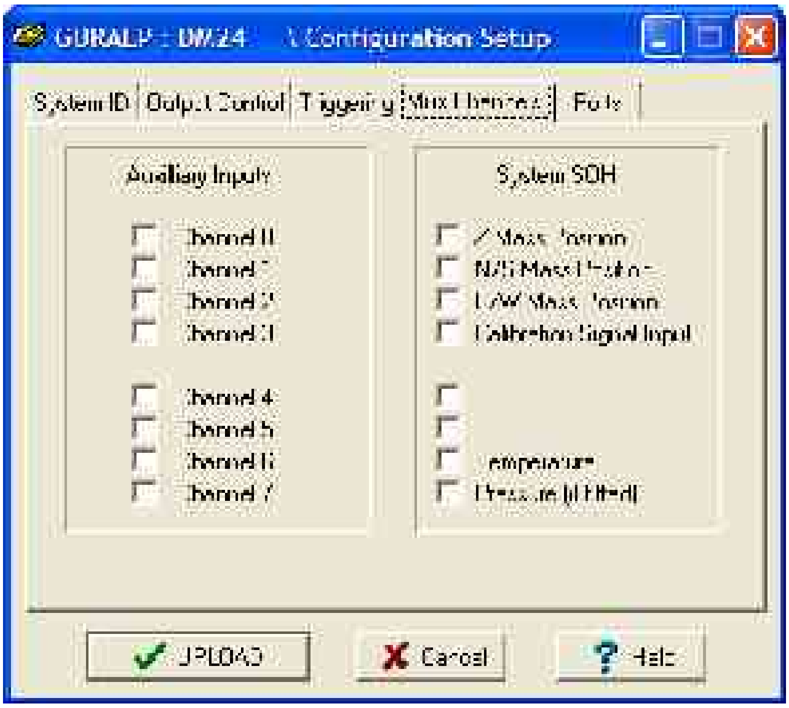
Mux Channels

Units based on the CMG-DM24 digitiser provide a range of 16-bit, 4 Hz auxiliary channels for reporting the system's state of health and other diagnostic information, known as multiplexed ("Mux") channels.

In the stand-alone configuration, three of these are used to report the sensor mass position, another for receiving calibration signals, and a fifth for measuring the internal temperature of the digitiser. There are a further three channels available at the time of manufacture for user-specified optional features, such as pressure monitoring, borehole orientation, etc., making eight factory-set Mux channels in all.

In addition to these, each digitiser provides eight Mux channels for the user's own purposes. Mux channels for both internal digitisers can be accessed through the DM24S12AMS's *AUXILIARY* port.

The collection and transmission of these environmental channels is controlled using the *Mux Channels* pane:

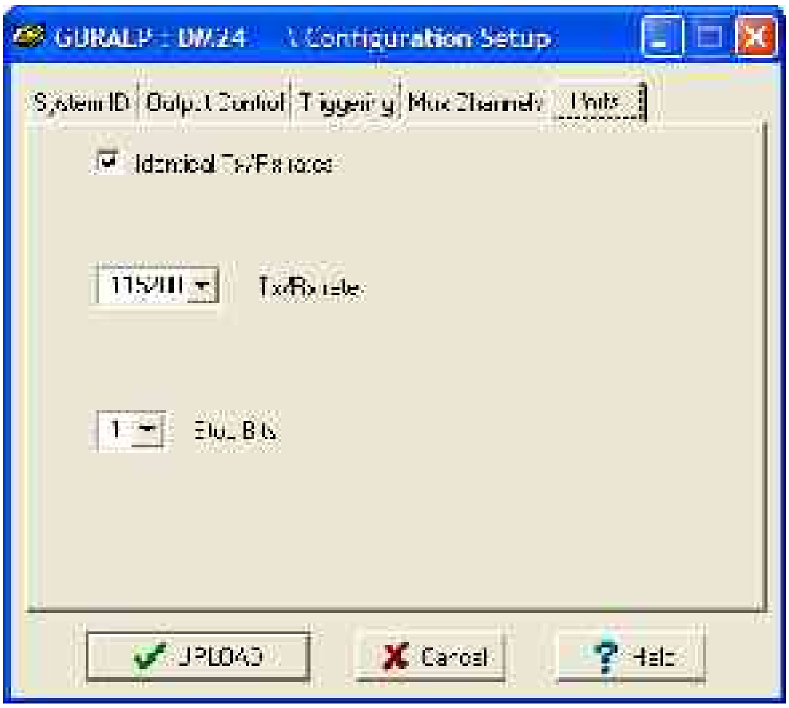


If a tick is placed in the box next to a channel, its data will be collected and transmitted as a data stream in GCF format, just as with the normal data channels. To indicate that the data comes from a Mux channel, the Stream ID will take the form `****M`x, where `M` stands for Mux and x is a hexadecimal integer (*i.e.* 0 – 9 and A – F for 10 through 15). If a Güralp digital instrument is attached to a *DIGITAL A – F* input, the **Z, N/S** and **E/W Mass Position** Mux channels appear as `M8`, `M9` and `MA` respectively. The unit's built-in DM24 digitisers do not report mass positions, although you can access the user-defined channels 0 – 7 for both through the *AUXILIARY* connector on the casing. Digitisers also monitor their internal temperature, which is reported on channel `ME`.

Ports

Scream! can normally auto-detect the settings it needs to communicate with any instruments you connect to the DM24S12AMS. However, if you connect a digitiser to the unit through a telemetry link or a Güralp Storage and Acquisition Module (SAM), you may need to set the baud rate and other COM port parameters to match those of the link or module you are using.

The *Baud Rates* pane of the *Configuration setup* window allows you to program the baud rate and stop bits for the digitiser's COM port.



The baud rate you choose must satisfy two conditions:

- It must be high enough to allow all the transmission of all data generated by the digitiser at the sampling rates you have chosen. For three streams of data at 100 Hz, for example, 9600 baud will usually be sufficient. If you wish to transmit 200 Hz data, however, the baud rate must be at least 19200.

- It must be low enough to fit within the operating range of the telemetry equipment you are using. While modern modems often offer transfer rates up to 56 kbaud, the telephone or transmission lines may not support these rates. The same holds true for radio telemetry.

Usually, the transmit and receive rates of the data port will be the same. If not, you may select different data rates by removing the check in the box marked **Identical TX/RX rates**.

The **Stop Bits** option allows you to choose whether the serial link uses 1 or 2 stop bits. In most cases this can be left at 1, although 2 may be required if you are sending data over ‘difficult’ transmission lines (for example, some types of radio link.) Using 2 stop bits will add a 10% overhead to the data.

You will also need to set the data rate for Scream's local Com port, as well as for the SAM/DCM or other communications device (if you are using one). In Scream!, you can configure a Com port by right-clicking on its icon (*not* that of the digitiser) and selecting **Configure...** from the pop-up menu: for more details, consult the online help or user guide for Scream!. If you are using an additional communications device, you should consult its documentation to learn how to set its baud rate.

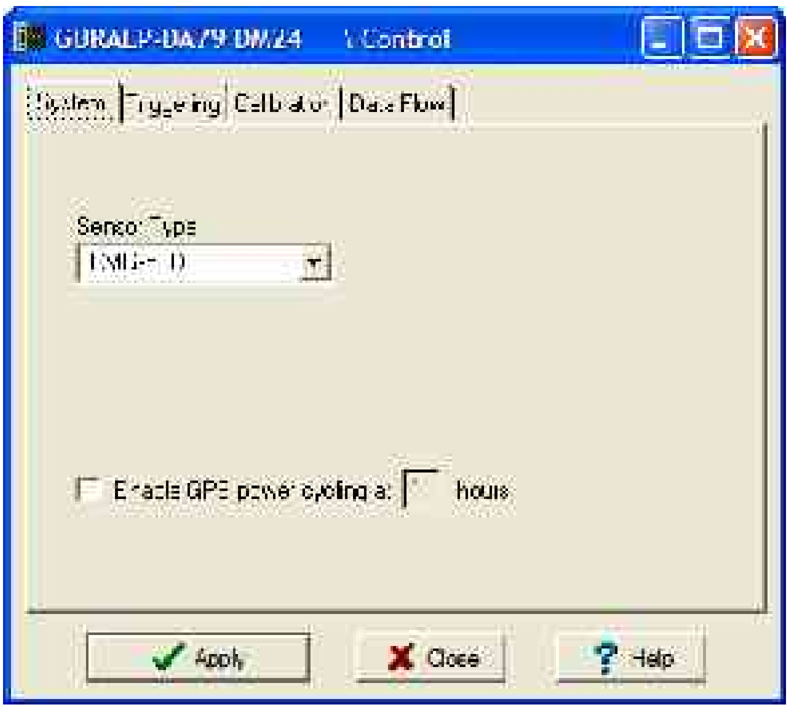
3.2 Controlling digitisers

To control a digitiser whilst it is running, either right-click on the digitiser's entry in the list to the left of Scream!'s main window (*not* the **Local** or **Com<u>xx</u>** icons) and click **Control...**, or simply double-click the entry. Scream! will then contact the digitiser and retrieve its current status, a process which will take a few seconds, after which the *Control* window will be displayed. Once you are happy with any changes you have made in the *Control* window, click **Apply** to send them to the digitiser, where they will take effect immediately.

This chapter describes the control options available to you for the DM24S12AMS's built-in digitisers. Many of these options will also be available for other Güralp digitisers or digital sensors connected to the unit's *DIGITAL A – F* ports. For the most accurate information, you should consult the Operator's Guide for the digitiser or sensor you connect.

System

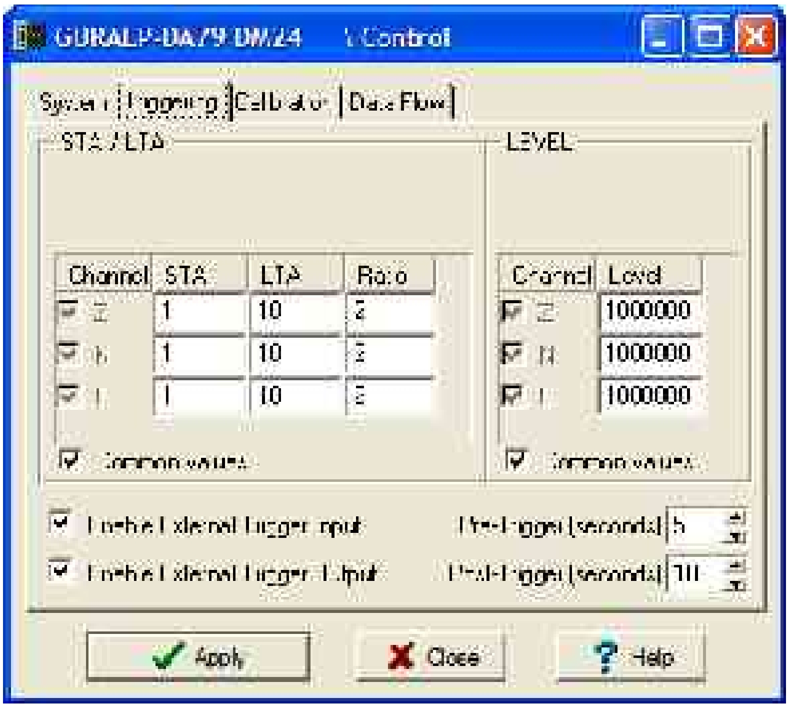
When the *Control* window is first opened, it will be showing the *System* pane.



Sensor Type: If the sensor attached to the digitiser is a Güralp velocity sensor, useful seismometer functions (such as sensor locking, centring, and calibration) may be controlled through the digitiser. The type of sensor programmed with this option determines which functions will be available through the **SCREAM** digitiser configuration set-up interface or through interactive commands. The in-built digitisers are already programmed to the proper sensor type for Güralp CMG-5U uniaxial sensors.

Enable GPS power cycling: If you are using a GPS unit to receive time signals, but do not experience significant drift in the system's clock (for example, in a stable-temperature environment), you can save power by selecting **Enable GPS power cycling.** With this option in use, the GPS time is only checked at intervals of a specified number of hours. You can enable or disable this feature at any time, but if you want to change the interval between time fixes, you will need to use the *Configuration setup* window (and reboot the digitiser.)

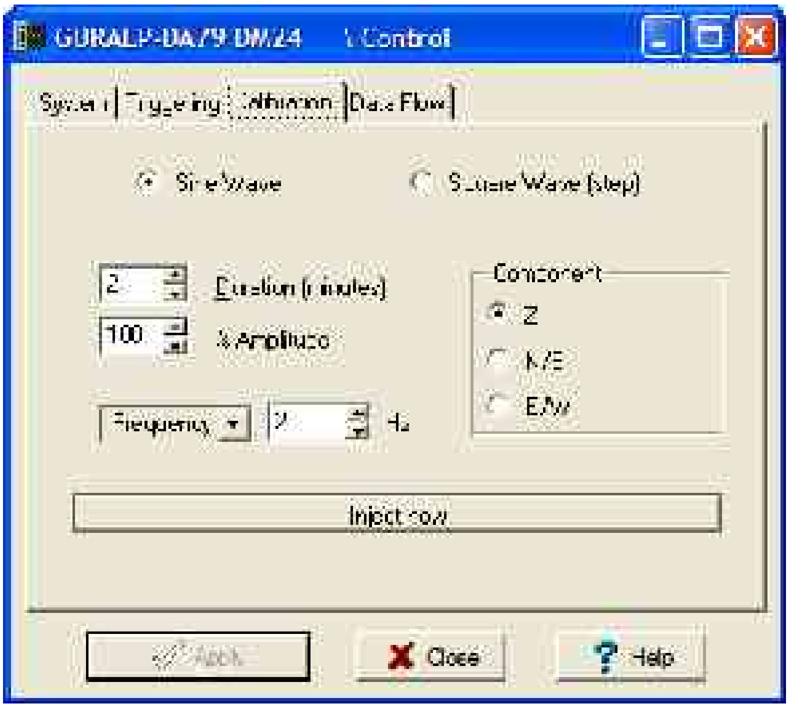
Triggering



The *Triggering* pane is very similar to the corresponding pane of the *Configuration setup* window, although not all options are available since some require rebooting the digitiser. See “Triggering” in Section 3.1 for more details.

Calibration

The analogue links between the DM24S12AMS and the sensors must be calibrated before you can use them, since the strength of the signal they output can vary. The *Calibration* pane allows you to do this once the sensors are installed.



Each channel **Z, N/S** and **E/W** can be calibrated separately. For triaxial digital instruments attached to the DM24S12AMS's *DIGITAL A – F* sockets, each channel calibrates the corresponding axis of the instrument; simply select one of the **Z, N/S** and **E/W check boxes** to calibrate that axis.

The DM24S12AMS's two internal digitisers can also be calibrated. For the first ("Digitiser A"), the **Z** channel sends calibration signals to both *CH 1* and *CH 2*, whilst **N/S** is connected to *CH 3* and *CH 4*, **E/W** being linked to *CH 5* and *CH 6*. For the second ("Digitiser B"), **Z** calibrates *CH 7* and *CH 8*, **N/S** calibrates *CH 9* and *CH 10*, and **E/W** calibrates *CH 11* and *CH 12*.

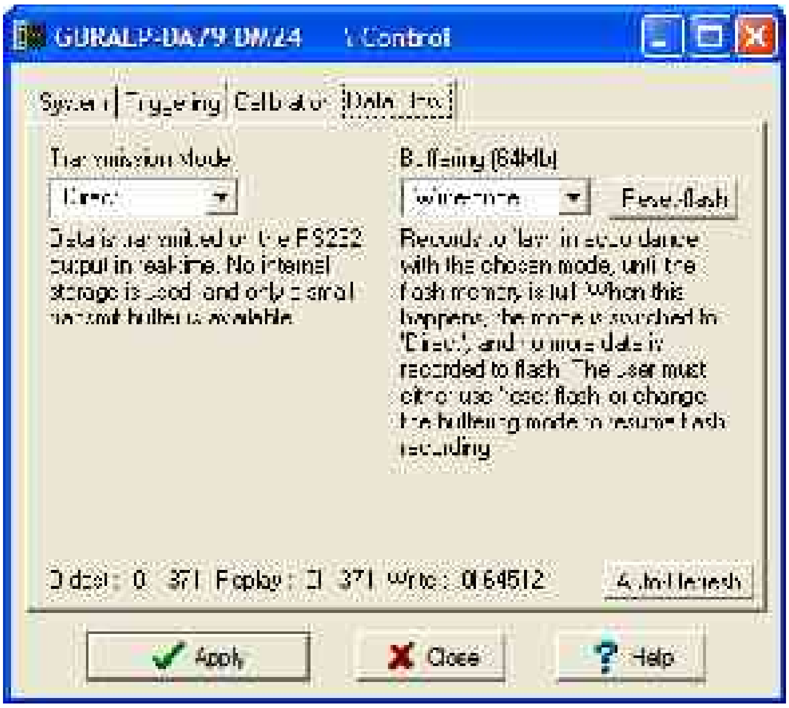
The sensors respond to calibration signals on the Mux channel `ME`.

The **Duration** box tells the digitiser how long to provide the calibration signal before disconnecting. This avoids the system being inadvertently left in calibration mode. The default is 2 minutes. If you change this setting, it will revert to the default value after one calibration stage.

The digitiser can produce either sine-wave or square-wave (step) calibration signals. The **Sine wave** calibration signal always starts and stops on the zero crossing. The frequency or period given by the boxes at bottom left. Only integers between 1 and 10 may be specified for either frequency or period, so to generate a 0.5 Hz signal you should select **Period** and set the time to 2 (seconds). Likewise, if you require a 0.25 second period you should select **Frequency** and set the rate to 4 (Hz). In this manner, you can select frequencies ranging from 0.1 to 10 Hz (10 to 0.1 s periods).

Alternatively, you can specify step calibration by selecting the **Square wave** button. The square wave consists of a positive step at the start of the next minute of the digitiser's internal clock, followed by a negative step after a specified number of minutes. After a further delay of the same number of minutes, the calibration signal is disconnected. The default is 2 minutes.

Data Flow



The *Data Flow* pane of the *Control* window allows you to instruct the digitiser what to do with data that it receives. Many Güralp digitisers contain internal Flash memory, which can be used to store incoming data if requested. The DM24S12AMS's internal digitisers do not contain internal Flash memory, since they are set up to transmit directly to the built-in laptop (which has a much greater storage capacity.) However, you may want to use these options if you have connected another Güralp digital instrument to one of the *DIGITAL A – F* ports. For more information, please consult the documentation for the instrument you connect.

3.3 Recording and filing data

Scream! allows you to record all incoming data and store it on the local hard disk. To do this, you should select the streams you want to record from Scream!'s main window, right-click, and choose **Start recording** from the pop-up menu. The streams will display `Yes` in the "Rec" column to indicate that they are recording.

By default, recorded data is placed in a `data` directory within the Scream 4 installation, in GCF format.

Scream! has a number of options which allow you to change the way data is recorded and filed. From the main window, select S**etup...** from the **File** menu to open the *Setup* window. Click on the **Recording** tab. (Scream!'s setup window also provides a number of other kinds of options. Consult Scream!'s documentation or online help for more details.)

Recording

The upper part of this pane allows you to instruct Scream! to record various streams automatically. Scream! will start recording all relevant streams immediately, but will also remember the settings for the next time it is started up.

Auto Record—Enable for Data Streams causes all local data streams to be saved automatically, whilst **Auto Record—Enable for Status Streams** does the same for digitiser status streams (those ending in "00".)

Auto Record uploaded streams tells Scream! to record streams it receives over the network. These are not normally counted with the streams above, since they may come from another Scream! which is already recording.

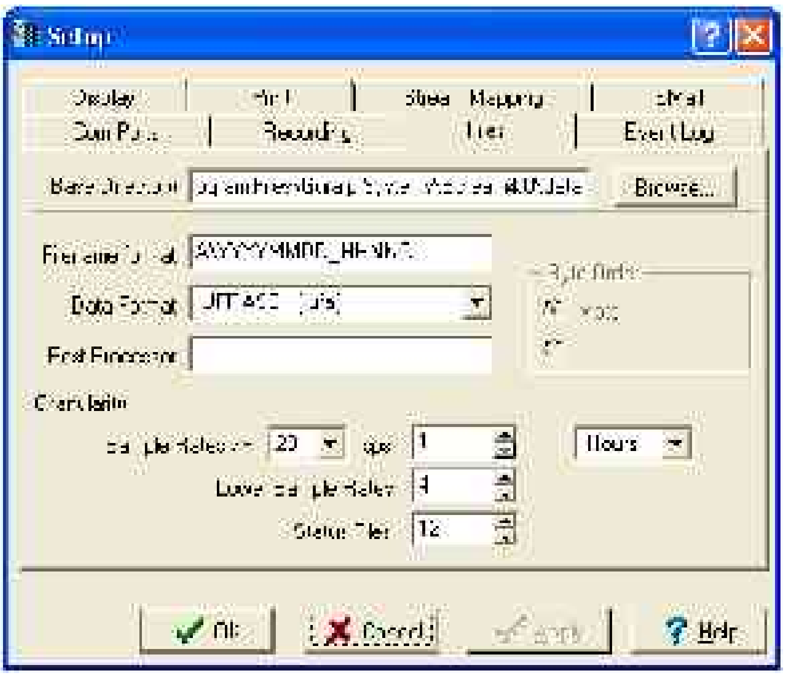
Auto-upload on heartbeat tells Scream! to attempt to fetch extra data from digitisers which are storing it in their own Flash memory whenever possible, so that it can fill in gaps in the data it is recording. The DM24S12AMS's built-in digitisers do not have any internal Flash memory, so this option will only have an effect for digital instruments connected to the *DIGITAL A – F* ports.

The lower section tells Scream! how to use its hard disk space. If **Stop on Disk Full** is selected, then Scream! will stop recording data once it runs out of space in its directory. This way, the data recorded will have a known starting point. If you select **Ring Buffer**, then Scream! will start deleting the oldest files in the data directory in order to make space for new data, so that you will always have access to the most recent recorded measurements. Note that Scream! does *not* check whether it created the files itself. If you put your own files in Scream!'s data directory, then they are at risk of being deleted.

If there is very little space on the disk, the PC's operating system can become slow or unstable. By default, Scream! will consider the disk "full" when only 50 Mb of space remains on it. You can change this amount by altering the value at bottom right.

Files

Another part of the *Setup* window allows you to alter the way Scream! files the data it receives. Click on the **Files** tab to open the following pane:



The options you can change are:

Base Directory: This specifies the root directory in which data files will be saved. Files for each stream are stored in sub-directories off this root. The sub-directory structure depends on the filename format.

Filename format: This allows you to describe how you want files to be named by entering a *format specifier*. The string you enter is used to construct the file names for all files. Among the specifiers you can use are:

YYYY the year number (*e.g.* 2003),

M the month number (1 – 12),

D the day of the month (1 – 31),

H the hour (0 – 23),

N the minute (0 – 59),

S the second (0 – 59),

R or **J** the day in the year (0 – 366),

X the date represented as an 8-digit hexadecimal number (this allows a complete date to fit in the DOS 8.3 format, for compatibility),

I the system ID (e.g. TEST),

T the stream ID (e.g. DMZ2),

C the component identifier (Z,N,E,M, etc.),

P the sample rate, in samples per second.

The specifiers **MM, DD, HH, NN, SS, RRR, JJJ, IIIIII** and **TTTTTT** are the same as their single-letter counterparts, but they are padded with zeros or underscores to a constant length. **YY** can also be used for a 2-digit abbreviation of the year (*e.g.* 03 for 2003.)

Any other letters (including small letters) in the filename will be left as they are, so you can add constant descriptions or field separators as you wish. Owing to operating system limitations, you cannot use any of the punctuation marks * ? " : < > | in filenames. You can create directory structures by using the \ character.

For example:

T\YYYY_MM_DD;HHhNNmSSs will give filenames like `dmz2\1997_10_05;07h35m20s`.

Data Format: Selects the format of the recorded data files. Options are GCF, SAC, MiniSEED, P-SEGy, PEPP, SUDs, GSE, UFF (ufa and ufb; see below), and CSS.

Byte Order: For SAC, SEG-y, UFB and CSS files, the byte order of the files can be specified. This can be used to match the byte order with the native order of the platform where you are going to perform analysis.

GCF and MiniSEED are defined to be in “Motorola or SPARC” byte order. PEPP and SUDs data is defined to be in “Intel” byte order. Byte order is not applicable to the ASCII-like GSE or UFA formats.

Granularity: Allows you to decide how large files are allowed to become before a new one is started, for three different types of stream (high sample rates, low sample rates and status streams.) The distinction between high and low sample rates is set by the number in the **Sample Rates >=** box. The remaining boxes give how many hours of data should be combined into a single file for each type of stream.

If you prefer to set a limit on a file's size, rather than its duration, choose **Kilobytes** from the drop-down menu (instead of **Hours**) and set as appropriate.

Post-processor: This option allows you to specify a program which Scream! will run every time it closes a file. The name of the file is passed as a parameter. You can use this feature to interface to other analysis or archival systems, for example:

- FTP or emailing files to remote data centres,
- format conversion using a third party utility,
- post-processing of file data headers to add site-specific information.

The UFF file format

The DM24S12AMS unit is specially configured to record files in the Universal File Format (UFF) in dataset 58 structure (Function at Nodal DOF). Two types of UFF format are supported: ASCII and binary, where the extension ".ufa" denotes the ASCII variant, and ".ufb" denotes the binary variant. The byte order used for the binary variant is specified in the *Recording* pane of the *Setup* window. ASCII does not have byte-ordering options. Details for the layout of the UFF format can be obtained from the University of Cincinnati at *http://sdrl.rhod.uc.edu/UFF2/*

Recording in UFF format

You can instruct Scream! to record incoming data directly in UFF format. To do this, open the *Files* pane of the *Setup* window as above and select either *UFF ASCII (.ufa)* or *UFF Binary (.ufb)* in the *Data format* drop-down menu. However, since UFF files tend to be large and do not contain all the data gathered by the sensor, it is recommended that you keep the initial recording in GCF format, and convert to UFF as required using the tools provided (see below).

Files in UFF format must represent a continuous period of time. If a discontinuity is detected in the incoming data stream, then the file which is currently recording will be closed, and a new file opened with a filename time stamp matching the start of the new file. This operation will take place whatever options you have specified for **Granularity**, although the **Granularity** options will still work. For example, if you specify files lasting one hour, a new file will be opened on the hour, every hour, whether or not a discontinuity occurred during the previous hour (which will have caused a new file to be opened at that point).

Converting between UFF and other file formats

On occasion, you may need to convert files between the various data formats supported by Scream!. For example, you may want Scream! to record data in GCF format and convert it to UFF later, to ensure that you retain all the data received from the sensors. The most convenient way to convert a GCF file into UFF format is using the command-line tool `gcf2asc`, available from Güralp Systems' website at http://www.guralp.com/. Once the program is installed, you can convert files from a command window (click on Windows **Start – Run...** and type `cmd`<*enter*>). The command to issue is

`gcf2asc your-gcf-file.gcf /uff` where `your-gcf-file.gcf` should be replaced with the correct filename.

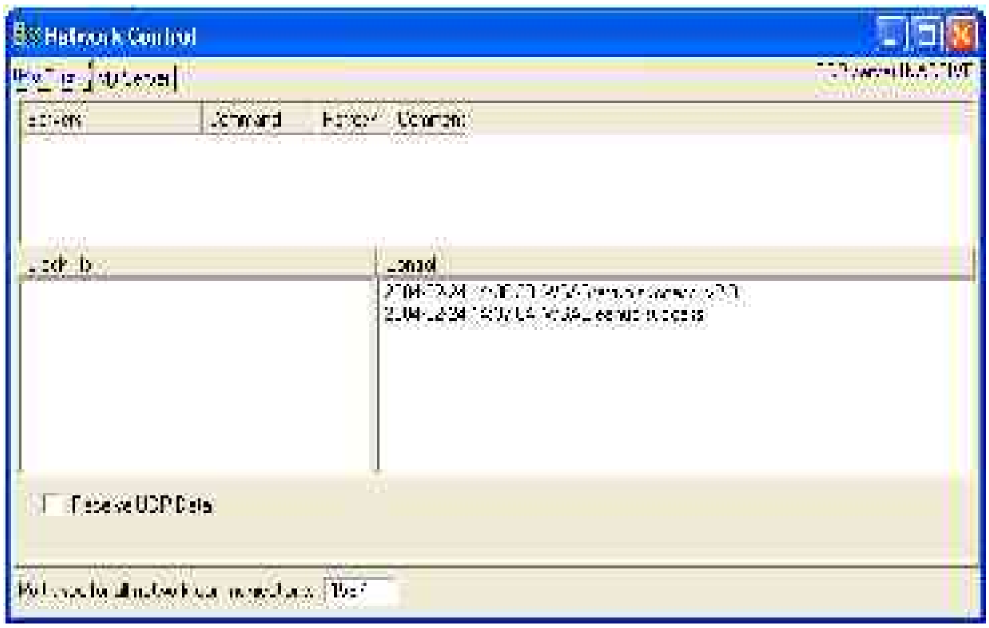
By default, `gcf2asc` will create a file with the same name as the original, but with a `.txt` extension; you may want to rename the file produced to have a `.uff` or `.ufa` extension. Any time periods missing from the GCF file are represented by values of –2147483647 (the lowest possible negative number in the GCF format).

You should ensure that you have enough space to create a UFF file before running `gcf2asc`. UFF ASCII files are typically around 10 times larger than the equivalent GCF file.

3.4 Networking

You can access the data coming from the DM24S12AMS from anywhere on a local or remote network through its on-board laptop PC. The *USB* and *NETWORK* ports on the casing connect directly to the laptop's USB and Ethernet interfaces, whilst the *TELEPHONE* socket is connected to an internal modem. Any of these can be configured through the Windows XP *Control Panel*.

Once a network connection is set up, Scream! can act as a server to provide data to other computers running Scream! or archival programs. To view the currently active Scream! network connections, select **Network Control** from the **Window** menu of the main window:



My Client

As a client, Scream! receives blocks of data inside UDP *packets*, which are shown in the *Block Rx* pane. UDP does not guarantee that data will be successfully received. If data is lost and subsequently recovered, a diagnostic message will appear in the *Control* pane. (Scream! is also able to open TCP connections, but these are designed for direct serial links, and will generally not allow two computers running Scream! to communicate.)

Scream! servers can be set to *push* data onto the network (*i.e.* to broadcast it to all listening clients), or to wait for data to be *pulled* from other Scream!s on the network. To receive data from a Scream! server that is *pushing* data, simply check the `Receive Data' box. No other action is necessary.

If you need to *pull* data from the server, you should use the following procedure:

1. If it is not already selected, check **Receive Data** to start Scream! listening.

2. Right-click anywhere in the **Servers** list box, and select **Add UDP Server...**. Enter the IP address and port number on which the server is waiting for requests, separated by a colon **:** (*e.g.* 192.168.42.98:1567)

3. Test communications by right-clicking on the newly-added server, and selecting **GCFPING**. A message appears in the *Control* pane logging the ping being sent. If communication is good, and the server is enabled for client requests, you will receive a *GCFACKN* message from the server which will also appear in the *Control* pane.

4. Request data by right-clicking on the server and selecting **GCFSEND:L** (or **GCFSEND:B**) from the pop-up menu.(**L** is used for little-endian and **B** for big-endian byte order, and are distinguished for compatibility.) Streams should soon begin to appear in Scream!'s main window.

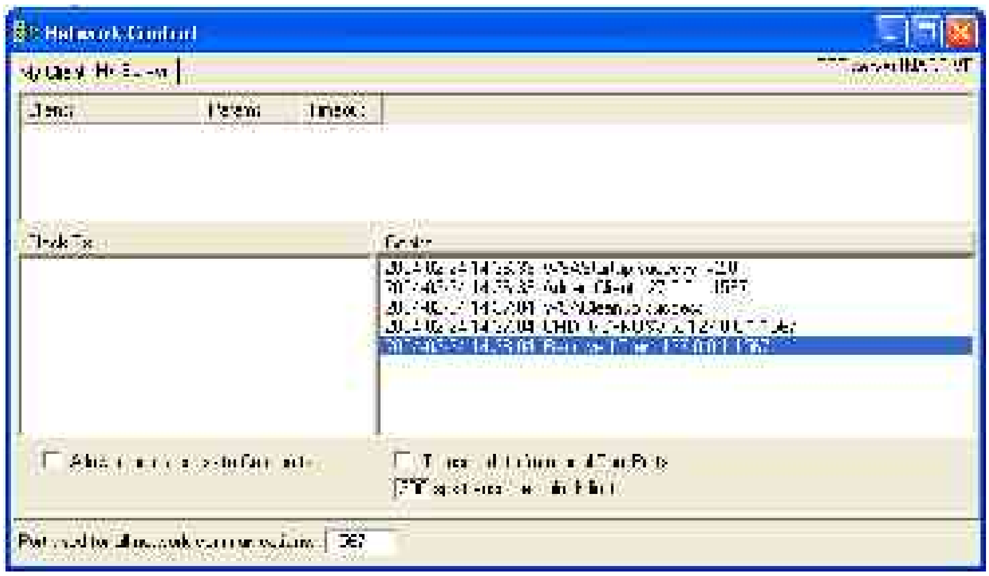
5. To stop the link, right-click as before and select **GCFSTOP** from

the pop-up menu. If you do not **GCFSTOP**, the server will continue to transmit to a client that is no longer listening. You should ensure that the server replies with a *GCFACKN* message If an acknowledgement does not appear in the *Control* pane, repeat the **GCFSTOP** command.

The steps above can be repeated as many times as necessary to pull data from several servers, but care should be taken to **GCFSTOP** each one before terminating the application.

My Server

Scream!'s server can transmit blocks of data acquired from local instruments over the network via UDP. The list of clients that are currently being sent data is shown in the *Clients* table at the top of the window. Block-by-block details of the data being transmitted are indicated in the *Block Tx* pane. Other server operations are logged by messages in the *Control* pane to its right.



Scream! can either *push* data to a network device or wait for it to be *pulled* off it. The server can behave in different ways for different clients. You can see which clients are using which method by looking in the **Timeout** column: pushed clients have a timeout value of 0, whilst pulling clients have some other timeout value (after which, if nothing is heard from them, they will be removed from the list.)

To start the server, check the **Transmit data from local Com Ports** box. This applies to both push and pull type data transfer.

You can add client to push data to by right-clicking in the *Clients* list box and selecting **Add**. Type in the IP address and port number of the destination, separated by a colon **:**. Many destinations or broadcasts may be added, and data will be sent to each one simultaneously.

You can broadcast data to all connected computers by using the IP address 255.255.255.255. To restrict broadcasts to a particular subnet, use 255 as a wild card: for example 192.168.255.255:1567 will broadcast data on port 1567 to all clients whose IP addresses begin with 192.168. To send data to another Scream! running on the same computer, use the IP address 127.0.0.1.

The ***x*** **sps transmitted block limit** sets a ceiling on the sample rate of data for transmission. This is useful if your network connection is slow or congested, since it limits the amount of data Scream! sends. The default value is 200 (effectively, all data). As an example, if a digitiser is configured to generate 4 samples/sec and 100 samples/sec continuous data, you could monitor the data remotely over a low-bandwidth network, whilst still recording the 100 samples/s data, by setting this value somewhere between 4 and 100. Setting this value to zero suppresses all data, but still transmits status information.

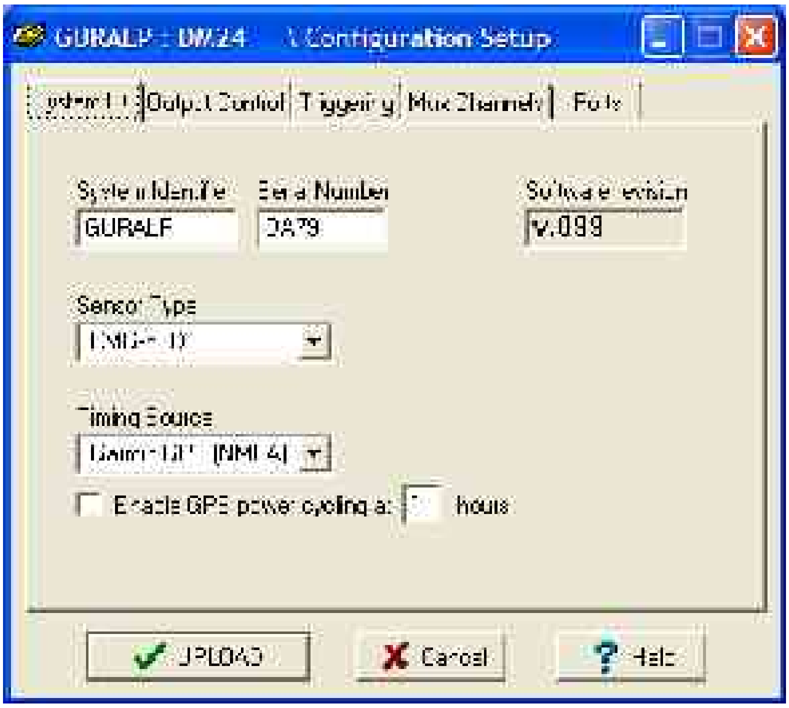
Scream! can act as a conduit from a network connection to any device connected to a local serial port. To enable this, select **Allow remote access to Com Ports**. If you wish to change the configuration of the equipment remotely, you should enable this option. If you are concerned about security, or there are potential problems from outside interference, disable this option.

3.5 Upgrading firmware

The built-in digitisers of the DM24S12AMS carry their on-board software in Flash memory, so that the user can upgrade it as new versions become available. These are posted from time to time on the Güralp Systems website and announced on the Scream! users' mailing list. To subscribe, send an email to `listserver@guralp.com` with the single line in the body:

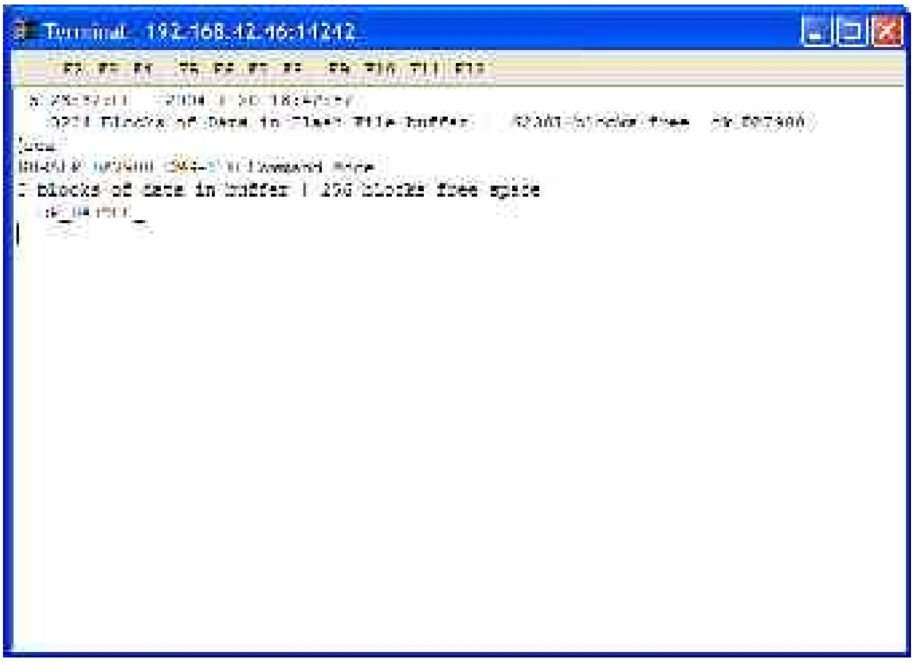
```
subscribe screamusers
```

To find out what software version you are currently using, right-click on the digitiser's icon (*not* the **Local** or the **Com**<u>**xx**</u> icons) in Scream!'s main window and select **Configure** from the pop-up menu. This will open the *Configuration setup* window.

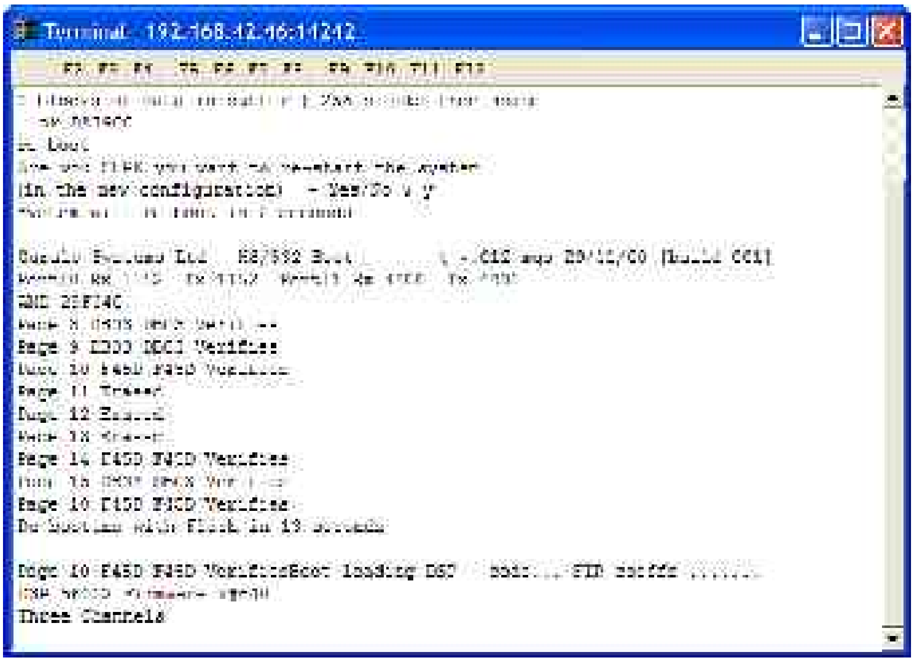


If you are running an older version of the digitiser software, and wish to upgrade, you should first obtain the latest software from Güralp Systems, then proceed as follows.

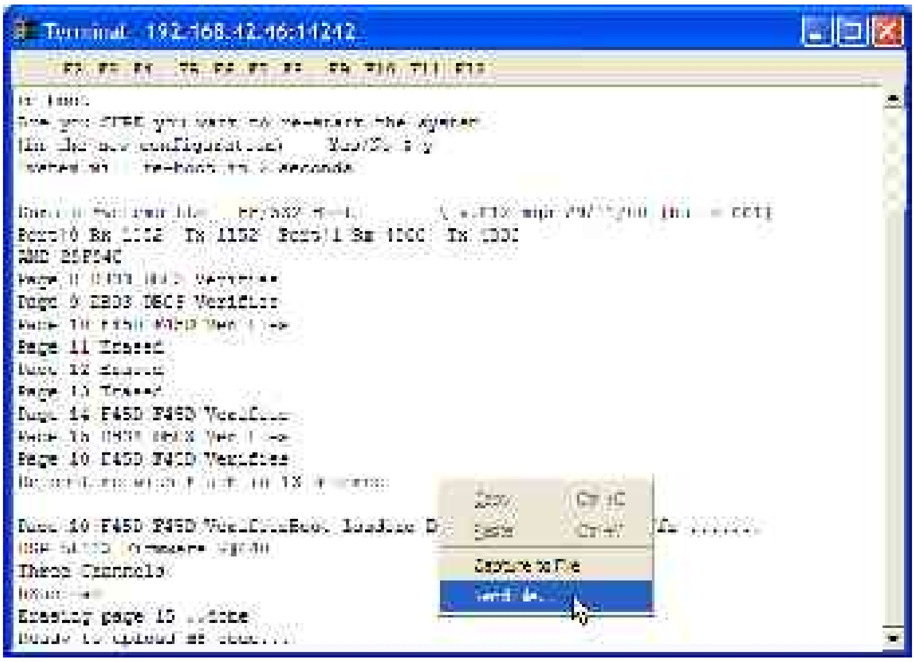
In Scream!'s main window, right-click on the digitiser's icon and select **Terminal** from the pop-up menu to open a terminal window. Check that there is two-way communication with the digitiser by pressing Enter. The digitiser should reply with `ok` on a new line.



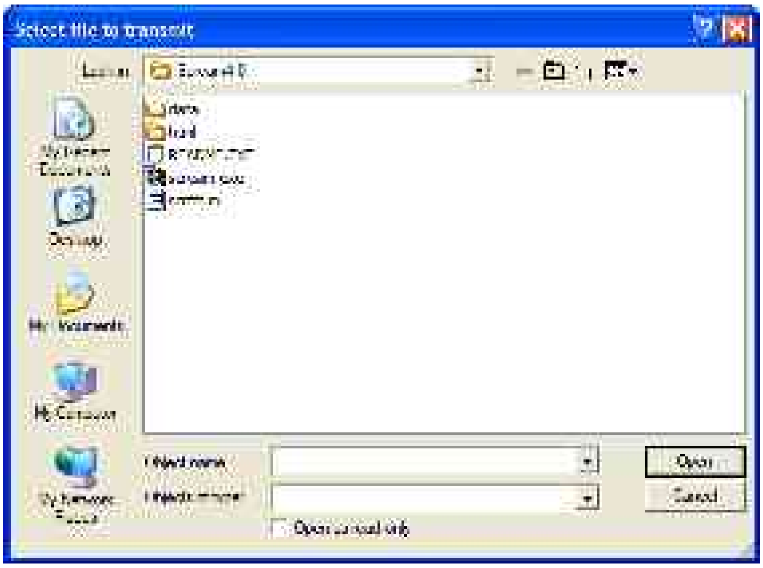
Type `re-boot` to reinitialize the digitiser, and confirm with `y`. The initial boot-up information will be displayed, similar to that shown in the picture below. After a short while, the digitiser will pause. If you do not enter a command in the next 13 seconds, the digitiser will continue booting up normally.



To update the firmware, type `h8upload` during the pause and press Enter. Once the message Ready to upload has appeared, right click anywhere on the terminal window and select **Send file** from the menu:



Navigate through the directories on your computer and select the file to be uploaded, or type in its full path and file name. Click **Open**.



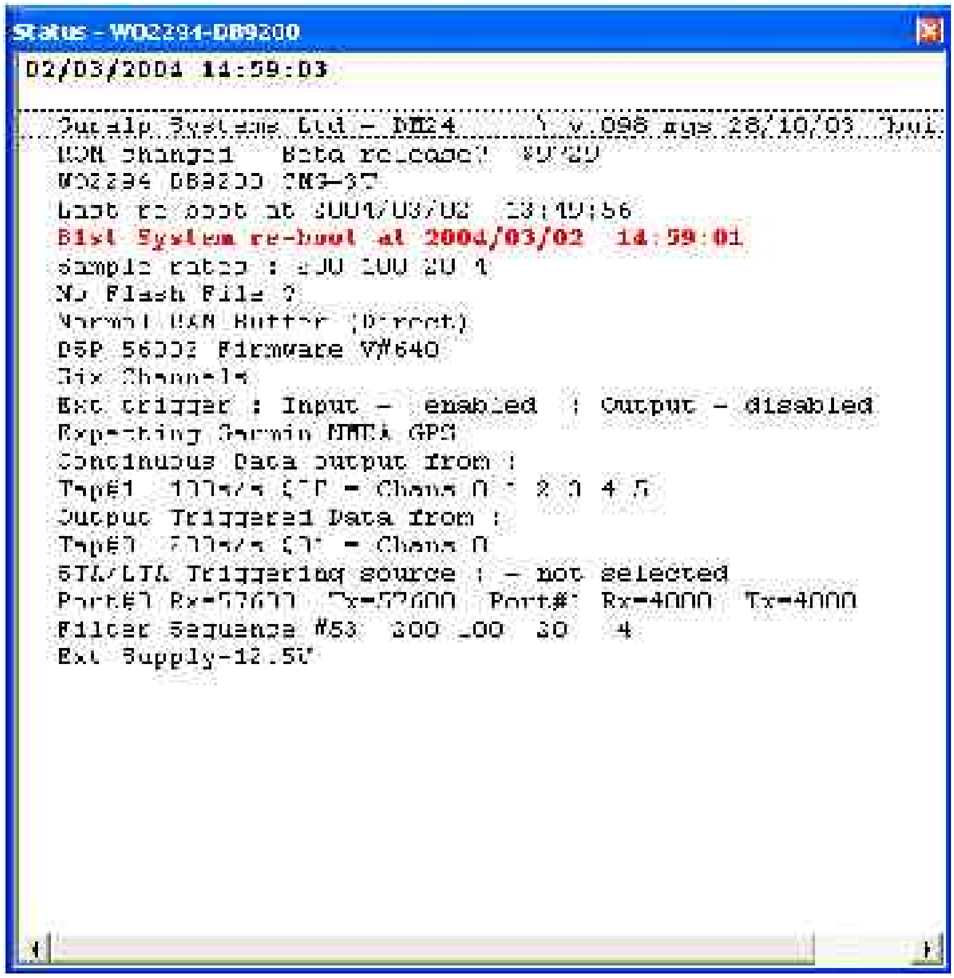
Whilst the file is loading, a progress window will be displayed. Once the software is fully transferred, the old installation will be backed up and the new one put in place. This will take a couple of minutes, after which you should type `re-boot` to restart the digitiser with the new firmware.

3.6 GPS

All Güralp digitisers have a separate stream for reporting information about the system, such as their GPS and time synchronization status. This status information is in plain ASCII text format.

To see a **Status** window for any digitiser, right-click on the **Stream ID** **xxxx00**, (where xxxx is the ID of the digitiser). In the example below this is `102600`. This is the only stream with a reported rate of 0 samples/s.

During boot-up each unit reports its model type, firmware revision number, the system ID and serial number. This information is followed by the number of resets that have occurred and the time of the latest reboot from its internal clock. The following lines report the current configuration of the unit's sample rates, output taps, and baud rates. A typical digitiser re-boot status message looks like this:



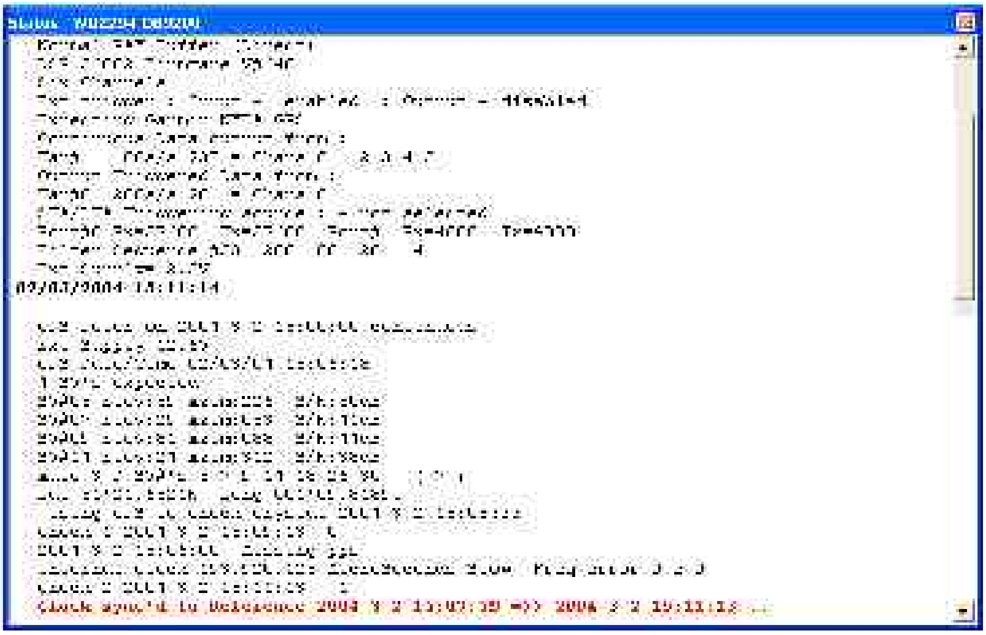
The system will produce this status message whenever it is powered up. If this status is reported at other times it indicates that the system has been reset by the built-in watchdog monitor. This will occur if the system has suffered corruption as a result of external noise or power dips.

If the digitiser does not have a GPS unit connected for time synchronisation no further status reports are produced.

If a GPS unit is fitted, its operational status is reported on reboot and the behaviour of the time synchronisation software will also be shown.

From a cold start, GPS will initially report `No GPS time` together with its last position (taken from the internal backup.) All messages from the GPS that involve a change of its status are automatically reported. Repeated status messages are not shown to avoid unnecessary clutter.

The initial GPS status report will look like this:



If the GPS receiver is having difficulty locating satellites, there may be a delay of several minutes before a new message is displayed, but if the system has not been moved from its previous location it should report the acquisition of one or more satellites and GPS time fairly quickly. The report will also show the satellite numbers and their corresponding signal strengths.

The internal time synchronisation and control software will wait for the GPS unit to report a good position fix (this requires 3 satellites) before beginning. (The system actually waits for good reception of 6 consecutive messages, which normally occur every 10 to 20 seconds.)

If the GPS unit maintains a good fix from the satellites available, the system will then switch on the control process and set the internal clock. It will also re-synchronise the Analogue to Digital Converters so that the data is accurately time-stamped to the new reference. Any data transmitted up to this point will be stamped with the time from the internal backup clock, which is set to the new accurate time at the end of this process. The re-synchronisation will result in a discontinuity in the data received.

From this point, the control process will continually attempt to keep the internal time-base synchronised to the GPS 1 pulse per second output by adjusting its voltage-controlled crystal oscillator. The control algorithm has two stages: initially it compares its internal 1 Hz timebase with the GPS signal and adjusts the voltage control to minimise the error. Once this has been achieved it then controls the crystal to minimise both the 'phase error' (*i.e.* the offset between its internal 1 Hz signal and the GPS) and the drift (frequency error relative to GPS.) During the control process the system reports the measured errors and the control signal applied, as a PWM (Pulse Width Modulation) value.

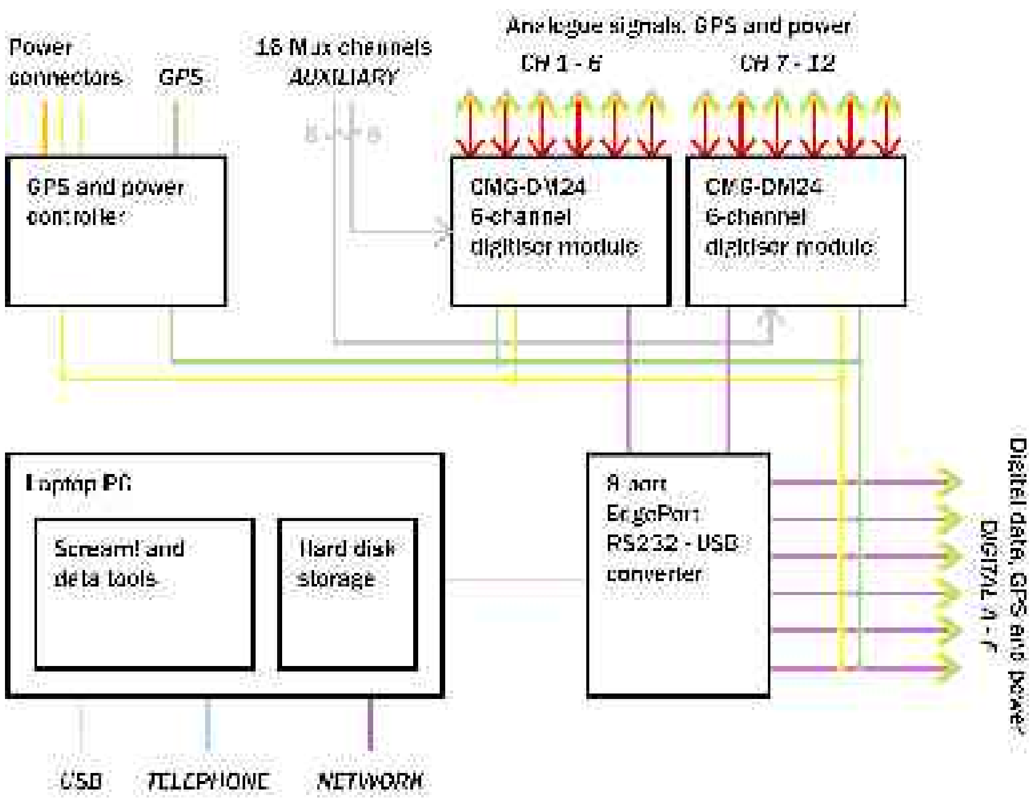
During the initial, coarse adjustment stage only the coarse voltage control is used and no drift calculation is made. If the system is operating in a similar environment to that when the system was last powered (most importantly, the same temperature) the saved control parameters will be appropriate and the system should rapidly switch to the 'fine' control mode. The system reports its control status and parameters each minute, with error measurements given in nominal timebase units. In a stable temperature environment the system should soon settle down showing an offset error of only a few thousand (average error < 100 microseconds) and a drift rate under 100 counts (< 1 in 10^{-6}).

4 Inside the DM24S12AMS

4.1 DM24S12AMS module

The DM24S12AMS is a complete data acquisition and monitoring system, with a modular design. The casing contains two independent CMG-DM24 6-channel digitisers, each of which processes data from six of the twelve analogue input channels. A separate GPS controller provides timing information to both digitisers and to any additional instruments connected to the *DIGITAL A – F* sockets.

Once in digital (GCF) form, the data is relayed to the built-in laptop PC where it is received by Scream! and can be recorded or passed on to other devices as necessary, either through a local network or USB connection or over a telephone line.



Power

The power module can convert power supplied from several sources into a supply suitable for running the system. The same power supply is normally used for running the DM24S12AMS, the GPS unit, and any sensors attached to the module. If you prefer, however, you can attach separate 12 V DC power supplies to any external unit.

Whilst sufficient mains (110 – 230 V) or 12 V DC power is supplied to the DM24S12AMS, you can also trickle-charge a battery connected to the *BATTERY/UPS* socket. To do this, you will need to use a cable which connects *both* positive and charging pins of the socket to the same terminal of the battery (see the Appendices for more details.) For example, you might want to connect the *DC INPUT* socket to a solar array or other intermittent power source, whilst keeping a rechargeable battery attached to the *BATTERY/UPS* socket to use when power is unavailable.

GPS

The CMG-GPS2 Receiver Unit comprises an antenna, the GPS receiver electronics, wide range input isolated DC power supply and output line drivers.

The antenna and all the associated electronics above are housed inside a specially-designed enclosure. The enclosure is sealed with O-rings and manufactured from a hard rigid resin. It is a stand-alone unit requiring only one cable connection to the DM24S12AMS, which carries both signals and power.

GPS data, including position, date/time and device status, is output in NMEA format at 4800 baud once per second. A time synchronisation pulse of 100 ms duration is output at 1 pps (pulse per second). Both outputs use RS232 (or, optionally, RS422) line drivers, enabling you to use cables up to 100 metres long.

For information on how to set up a GPS receiver, see Section 3.6, "GPS".

USB to RS232 converter

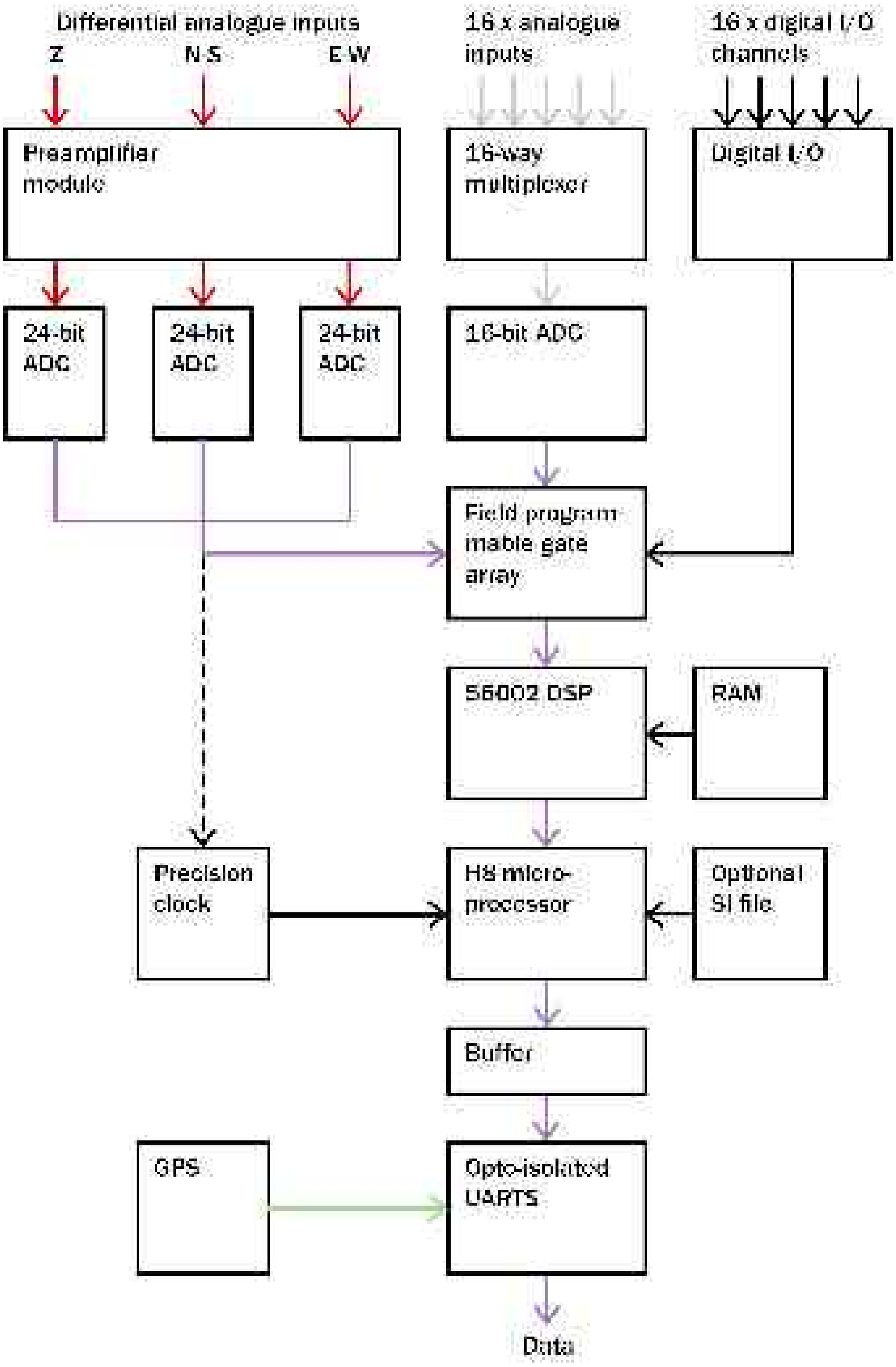
Digital channels within the DM24S12AMS (the digital outputs of the two internal digitisers, and the six *DIGITAL A − F* are carried over RS232 links to an 8-port EdgePort module, which allows the serial ports to be emulated over USB. The PC is configured so that the external *DIGITAL A − F* ports appear as if they were directly attached, together with two Com ports for the internal digitisers.

If your installation requires some other setup of the PC's Com ports, you can configure the EdgePort device using the driver software provided. Further information can be obtained at the EdgePort documentation website, http://www.ionetworks.com/support/epdocs.html

4.2 Inside the DM24

Internally, all DM24 digitisers are structured as shown in the diagram overleaf, where each box represents a separate printed circuit board within the module. There are two of these modules in the DM24S12AMS unit, which operate separately.

The system is designed around a low power, high performance Hitachi H8/500 microprocessor. This is a 16-bit processor with a large address space for data storage and manipulation—1Mb in sixteen 64k pages. It also includes many integrated functions such as multiple timers and serial I/O ports. In addition, the system contains a Crystal Semiconductor CS5321/2 chipset and Motorola 56002 DSP. The CS5321/2 provides data at 2,000 samples per second, triggered by the H8 timing system, to the 56002 DSP. The DSP can control from 1 to 3 ADCs and process the data.



The modular design of the system takes advantage of the processor's paged structure: each module is designed to occupy its own separate page, with a dedicated I/O function. Thus any module can simply be added to the system at any available page when it is required. Each module includes 32k of RAM which is used for data buffering and workspace for the module’s software.

An important feature of the system design is its ability to synchronise the sampling of the analogue to digital converter to an external time reference. This way, data samples are accurately time stamped at source. To keep sampling accurately in step with UTC, you can synchronise the microprocessor's time-base to an external reference such as GPS, or in larger arrays to a centrally-transmitted time reference. Transmitting a time reference avoids the cost and power consumption of multiple GPS receivers, and since it only involves sending 2 characters per second it can utilise a low band-width, even half-duplex link.

To achieve the high degree of timing precision required for a 24 bit digitiser system, the microprocessor time-base is run from a precision voltage controlled oscillator. On-board software keeps this oscillator tuned to the external reference so that its frequency is accurately set and maintained through changes in temperature or ageing. Once the system has stabilised, the control is sufficiently accurate to maintain precision sampling for several hours without an external reference. The system also automatically compensates for the pure time delay introduced by the digital filtering/decimation processes in the DSP.

The main microprocessor board incorporates a battery-backed real-time clock and RAM which is used to set the system's internal software clock at start-up independent of the availability of the external time reference. The RAM is used to store system parameters such as the optimum control voltage setting for the system time-base and the system configuration.

The microprocessor module includes the (multi-tasking) system operating software in 64K EPROM. This module also has 512k of static RAM for system workspace and data buffering depending on the system requirements (number of data channels and sample rates).

The microprocessor serial port (19,200 Baud) provides an interactive interface for system setup and configuration. This port is known as the terminal port. Unlike the GPS serial port or the data port, the terminal port is not optically coupled to the outside world. Care should be taken not to run a terminal over very long RS232 cables.

The DSP software consists of 4 cascaded programmable filter/decimation stages, which allow you to select multiple data output rates simultaneously. The first stage is set to decimate the data by 10 resulting in a data output rate of 200 samples/sec. The following 3 stages can be set individually for decimation factors of 2, 4, 5, 8, and 10 allowing data to be output at lower rates requiring less storage and transmission bandwidth. For example, a system can be configured to provide data at 200, 50, and 10 samples/sec covering the whole of the seismological broad band range.

The configuration of the DSP is programmable (in the field) via the host H8 microprocessor. The H8 communicates with the DSP via its high speed 8-bit 'host port', which allows the operating mode/configuration to be altered and the resulting processed/filtered data to be acquired.

The primary digital interface for the systems is the multiple serial port card. Each card can contain 1 or 2 dual UARTs (Universal Asynchronous Receiver Transmitters) and up to 2 cards can be fitted to a SAM/DM unit. This allows a system with up to 8 serial ports to be configured.

On a DM unit with analogue inputs a serial port is usually configured to send the data packets to a (local) SAM unit for storage/acquisition or via a modem or radio link to the central recording station. The second serial port is available for use with a local GPS receiver for time synchronisation, or alternatively the first (data) port is used for time synchronisation from the central station.

The multiple serial port card is usually configured as several data inputs for a SAM unit allowing it to collect data from up to 8 other SAM or DM units located locally, using RS232 or RS422 links, or more remotely using radio links or telephone modems.

Each of the serial ports on a module can be configured for a wide range of standard baud rates (with different settings available for transmit and receive channels), allowing a wide range of data links to be used depending on the required data rates.

The first dual UART supports full modem interface on one port and hardware handshake on the second. The second dual UART is configured for data line interface only, supporting software handshake. Each dual UART is optically isolated to avoid ground loops that could degrade the performance of the ADC's. The serial port module includes 32k of RAM for data buffering and formatting by the transmission/reception process.

5 Using CMG-5U sensors

5.1 The CMG-5U accelerometer

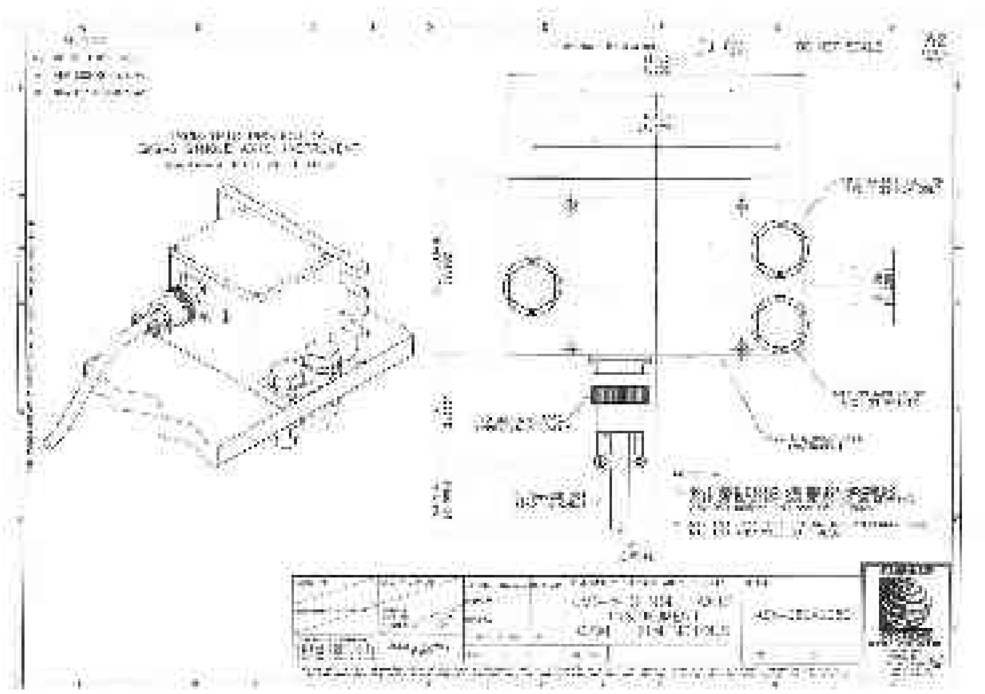
The CMG-5U sensor is a single-axis strong-motion force-feedback accelerometer in a sealed case, which can be used in either vertical or horizontal orientations. The sensor system is self-contained except for its 10 – 12V power supply, which can be provided through the same cable as the analogue data. An internal DC–DC converter ensures that the sensor is completely isolated.

The 5U system combines low-noise components with high feedback loop gain to provide a linear, precision transducer with a very large dynamic range. In order to exploit the whole dynamic range two separate outputs are provided, with high and low gain. Nominally the high gain outputs are set to output a signal 10 times stronger than the low gain outputs.

The 5U sensor outputs are all differential with an output impedance of 47 Ω. A single signal ground line is provided as a return line for all the sensor outputs.

Full-scale low-gain sensitivity is available from 4.0*g* down to 0.1*g*. The standard frequency pass band is flat to acceleration from DC to 100 Hz (although other low pass corners from 50 Hz to 100 Hz can be ordered.) A high frequency option provides flat acceleration from DC to 200 Hz.

Each seismometer is delivered with a calibration sheet showing its serial number and measured frequency response in both the long period and the short period sections of the seismic spectrum.



5.2 Installing CMG-5U sensors

Unpacking and packing

The 5U accelerometer is delivered in a single cardboard box with foam rubber lining. The packaging is specifically designed for the 5U and should be reused whenever you need to transport the sensor. Please note any damage to the packaging when you receive the equipment, and unpack on a clean surface. The package should contain:

- the accelerometer
- a signal connection cable (if ordered)
- a suitable connector.

The sensor serial number label can be found on the lid of the sensor. If you need to request the sensor production history, you will need to quote either the serial number of the sensor or the works order number, which is also provided on the calibration sheet.

Initial testing

To test the 5U before installation, you will need a power source which can deliver 100 mA at 10 to 12 V and a digital voltmeter (DVM) with 1 and 10 V ranges. You should *never* supply more than 12.5 V to the 5U unit. Also ensure that the supplied cable is connected with the correct polarity (see the Appendices).

To make it easier to measure the output from the sensor, you can use the 5U handheld control unit or a compromised interface box, which can be manufactured from a screw clamp connector block. This will simplify the connections to the appropriate connector pin outputs.

1. Place the 5U sensor on a flat surface with the *POSITIVE ACCELERATION* arrow horizontal.

2. Switch on the power supply.

3. Connect the voltmeter to pins J and K of the output connector (corresponding to the low gain vertical component.) Measure the output of the low gain vertical component. The steady output voltage should be about zero (± 10 mV).

4. Now turn the sensor on its side, so that the *POSITIVE ACCELERATION* arrow points upwards.

5. The low gain vertical component should now read about –5 V, corresponding to –1*g*.

If the performance so far has been as expected, the instrument may be assumed to be in working order and you may proceed to install for trial recording tests. Most likely, however, you will need to adjust the mass deflection offset.

Installing the sensor

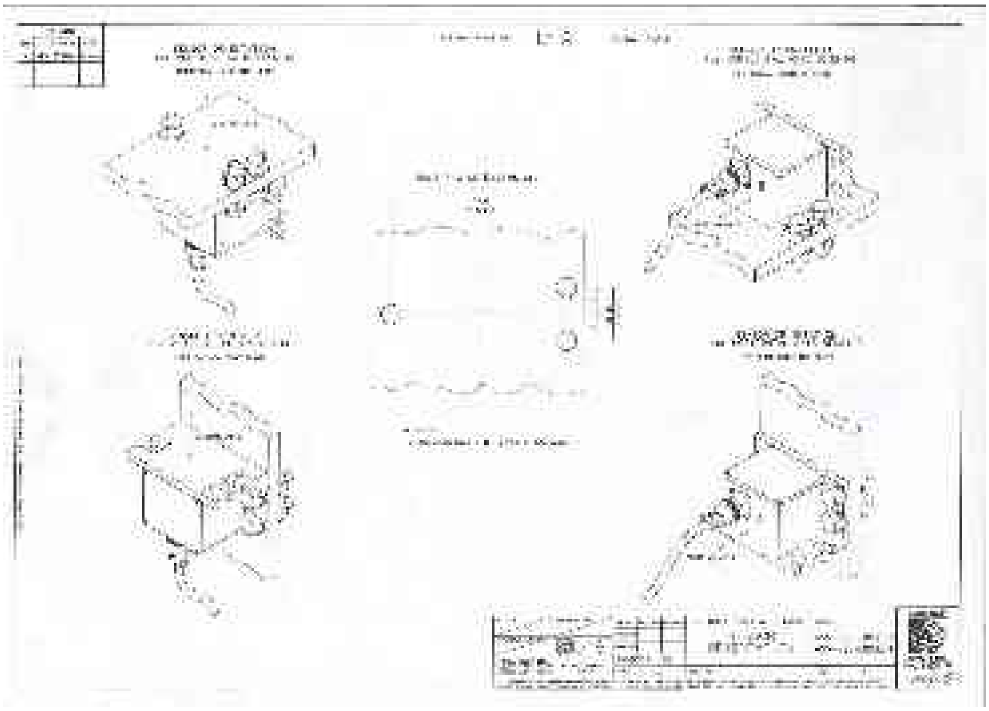
NOTE: If you are in any doubt about how to install the sensor, you should contact Güralp Systems.

1. The sensor can be fixed on to any surface either with three M10 or M12 hexagonal bolt screws and washers (to protect the anodised surface), or with an appropriate fixing clamp. The three holes used to fix the sensor are shown in the mechanical drawing of the sensor base, above. You may find it useful to copy the footprint of the sensor base onto a metal sheet as a template to drill fixing holes into the surface where you want to fix the sensor.

2. Fix the sensor to the mounting surface, with the *POSITIVE ACCELERATION* arrow pointing in the correct direction. The accelerometer has no levelling feet, but can use internal simulated level adjustment to compensate as long as it is fixed to a hard, clean surface within 1 degree of the horizontal.

   The sensitive direction of the sensor is marked on the outside of the unit, with the arrow pointing towards the positive sensor output orientation. If this arrow is horizontal, the sensor will be responsive to horizontal signals; likewise, if the arrow points upwards, the sensor will respond to vertical ground acceleration (with positive output corresponding to an upwards ground movement.)

Although converting a sensor from horizontal to vertical response involves compensating for the acceleration due to gravity, you do not have to zero the sensor manually. The sensor output offset adjustment is carried out electronically by emulating the shift in mass position. You can then calibrate the offset using a potentiometer within the unit, without any loss of dynamic range.



1. If required, make a screening box for the sensor, to shield it from draughts and sharp changes of temperature. A suitable box can be constructed from expanded polystyrene slabs (*e.g.* 5 cm building insulation slabs) with sealed joints between them and a hole drilled for the connector. You can then use high-grade glass fibre sealing tape to fix the leads in position, and fasten the box to the mounting surface. Commercial duct sealing tape is ideal.

2. Connect the sensor to one of the*CH 1 – 12* analogue inputs of the DM24S12AMS using the cable provided, or one made up as described in "Electrical connections" in Section 5.2.

Centring the 5U

Once installed, you should centre the instrument ready for use. The offset can be as much as the entire output range of the accelerometer, which corresponds to around 1 degree from the horizontal or vertical.

1. Turn on the DM24S12AMS unit, and find the data stream produced by the 5U sensor.

2. Remove the pressure release cap and insert a thin screwdriver or pot-adjuster into the hole.

3. Locate the small potentiometer screw head just inside, and turn it in one direction or another until the output voltage is reading zero.

4. Replace the pressure cap to keep the instrument's electronics protected from water and dust.

After the cover is installed, the accelerometer outputs may drift until the system establishes temperature equilibrium with its environment and the sensor settles down in its position. If required, the offset adjustment can be repeated to achieve a better output offset. With experience, it should be possible to reduce the output level to less than ± 1 mV.

Electrical connections

The CMG-5U sensor has two separate outputs, with low gain and high gain. The straight-through cable provided will connect the low gain outputs to the digitiser input (see Appendices). To make use of the high-gain signal, you will need to make up a cable connecting the high-gain pins (C and G) of the sensor to the digitiser input pins (J and K). The sensor outputs have an output impedance of 47 Ω, which is low compared to the input impedance (1 MΩ) of the digitiser.

The low and high gain output lines are differential outputs balanced about signal ground so that either differential drive or single-ended drives of opposite polarity (phase) are available. For a single-ended drive, the signal ground must be used as the signal return path. You must *not* ground any of the active output lines, as this would allow damaging currents to flow through the output circuits. Also, if single-ended outputs are used, the positive acceleration outputs must be interfaced to the recorder.

If you have two analogue ports available, you could make up a three-way cable which connects both high and low gain outputs to the DM24S12AMS. You should *not* attempt to connect both outputs of the 5U to the same digitiser input port.

The sensor is normally powered directly from the digitiser through the 10-way connector, although you can use a separate 10 – 36 V DC power supply if you wish (again, a custom cable will be required.) The current consumption from a 12 V supply is about 53 mA. An isolated DC–DC converter installed inside the sensor housing forms the main part of the

5U unit's power supply; its filtered outputs provide the ±12 V required to operate the sensor electronics. The DC–DC converter is protected against polarity reversal.

The calibration signal and calibration enable inputs are referenced to the signal ground. These lines can be connected directly to the DM24S12AMS's calibration lines.

5.3 Calibrating CMG-5U sensors

The 5U accelerometer is supplied with a comprehensive calibration document, and it should not normally be necessary to calibrate it yourself. However, you may need to check that the response and output signal levels of the sensor are consistent with the values given in the calibration document.

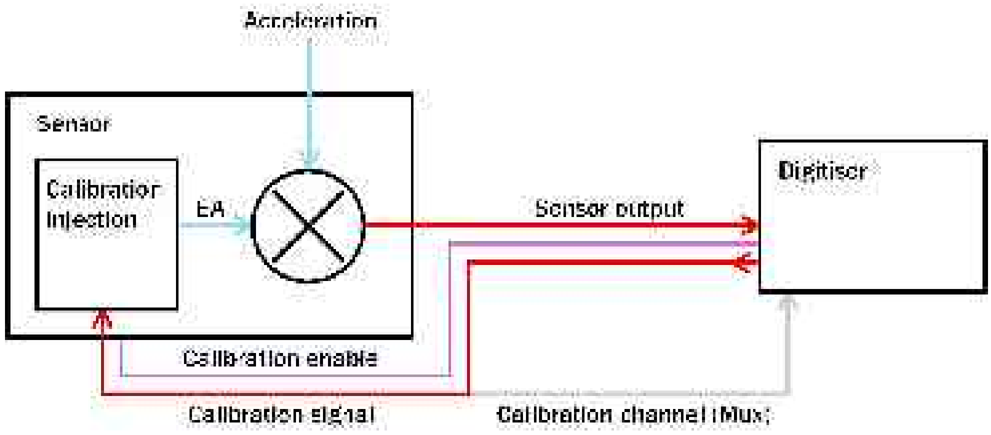
Absolute calibration

The sensor's response (in $V/m/s^2$) is measured at the production stage by tilting the sensor through 90 ° and measuring the acceleration due to gravity. Local *g* at the Güralp Systems production facility is known to an accuracy of 5 digits.

Relative calibration

In addition to the response of the sensor, several other variables are calibrated at the production stage. Using these values, you can convert directly from counts (as measured in Scream!) to acceleration values and back. You can check any of these values by performing calibration experiments.

Güralp sensors are calibrated as follows:



In the diagram above, a Güralp digitiser is being used to inject a calibration signal into the sensor. This can be either a sine wave or step function, depending on your requirements. As well as going into the sensor, the calibration signal is returned to the digitiser on one of the 4 Hz auxiliary (Mux) channels. The calibration signals and sensor output all travel down the same cable from the sensor to an analogue input port on the digitiser.

The signal injected into the sensor gives rise to an *equivalent acceleration* (EA on the above diagram) which is added to the measured acceleration to provide the sensor output. Because the injection circuitry can be a source of noise, a *Calibration enable* line from the digitiser is provided which can disconnect the calibration circuit when it is not required. Depending on the factory settings, the *Calibration enable* line must be held either high (+5 to +10 V) or low during calibration: this is given on the sensor's calibration sheet.

The equivalent acceleration corresponding to 1 V of signal at the calibration input is measured at the factory, and can be found on the 5U calibration sheet. The calibration sheet for the digitiser documents the number of counts corresponding to 1 V of signal at each input port. The sensor transmits the signal differentially, over two separate lines, and the digitiser subtracts one from the other to improve the signal-to-noise ratio by increasing common mode rejection. As a result of this, the sensor output should be halved to give the true acceleration.

All sensors are tuned at the factory to produce 1 V of output for 1 V input on the calibration channel. For example, a sensor with an acceleration response of 0.25 V/m/s^2 should produce 1 V output given a 1 V calibration signal, corresponding to 1/0.25 = 4 m/s^2 = 0.408*g* of equivalent acceleration.

The following section explains how to calibrate 5U sensors using a DM24 series digitiser and a computer running Güralp Systems Scream! software.

Using a DM24 series digitiser for calibration

The *CH 1 – 12* ports on the are connected to two separate internal 6-channel digitisers. To calibrate uniaxial sensors attached to these:

1. In Scream!'s main window, right-click on the digitiser's icon and select **Control...**. Open the *Calibration* pane.

2. The **Z** calibration channel is connected to ports *CH1* and *CH2.* Select this channel, make any other choices you require (see "Calibration" in Section 3.2 for more details), and click **Inject now**. A Mux stream ending `MB` should appear in Scream!'s main window containing the returned calibration signal.

3. Open a WaveView window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the WaveView using the scaling icons at the top left of the window or the cursor keys.

4. If you need to scale one, but not another, of the traces, right-click on the trace and select **Scale...**. You can then type in a suitable scale factor for that trace.

5. Click on **Ampl Cursors** in the top right hand corner of the window. A white square will appear inside the WaveView at the top left. This is in fact two superimposed cursors.

6. Drag one cursor down to be level with the lowest point of the signal trace.

7. Drag the other down to be level with the highest point. In the following example, a step function of 1 minute duration has been applied to the `Z3` stream. Note that ground movements continue to be observed, superimposed on the returning calibration signal.

The **Ampl Cursors** button will now be displaying a value, which is the strength of the returning signal in counts (doubled, if using a sine wave). Measure the other two signal strengths in this manner.

Note that if you have used the **Scale...** option described above, you will need to take the scale factor into account to produce the correct number of counts. In the example, the MB (calibration input) signal has been scaled by a factor of 40, so the signal strength as measured by the **Ampl Cursors** must be *divided* by 40 to yield the correct value.

8. Convert to volts using the *µV/Bit* values given on the digitiser's calibration sheet for the various input ports, and compare the returned signal with the input calibration signal (`MB`).

9. In the example, the following data is now known:

Input calibration signal strength (`MB`)	9856 counts
Returning signal strength (`Z3`)	704512 counts

The calibration sheets provide us with the remaining values needed to calibrate the sensor:

Sensor acceleration response	0.254 $V/m/s^2$
Equivalent accel. from 1V calibration	1.968 m/s^2
Digitiser input port sensitivity	3.507212 μV/Bit
Mux channel sensitivity	255.9253 μV/Bit

From these we know that the calibration signal is producing 9856 × 247 = 2434432 μV (2.434 V). This corresponds to an equivalent input acceleration of 2.434 × 1.968 = 4.791 m/s^2.

The sensor's acceleration response is given as 0.254 $V/m/s^2$, so that an acceleration of 4.791 m/s^2 will produce an output of 0.254 × 4.791 = 1.217 V (1216904 μV), which corresponds to a count number at the digitiser's input port of 1216904 / 3.5 = 347687 counts.

Because the signal is transmitted differentially, the count number observed at the digitiser should be double this: 695373 counts. The actual signal at the digitiser of 704512 counts is within 1.5% of this value, indicating that the sensor is adequately calibrated.

10. If you know the local value of *g*, you can also perform absolute calibration by tilting the sensor by 90 ° and varying the calibration signal until it precisely compensates for the signal generated due to gravity.

11. Calibrate ports *CH3* and *CH4* in the same way, but with the **N/S** calibration channel selected. You must wait for the previous calibration to finish before doing this: clicking **Inject now** has no effect whilst the *Calibration enable* relay is open.

12. Calibrate ports *CH5* and *CH6* in the same way, but with the **E/W** calibration channel selected.

13. Close the window and right-click on the second internal digitiser's icon. Select **Control...** and open the *Calibration* pane.

14. Repeat steps 2 – 11 to calibrate ports *CH7 – 12* in pairs: *CH7* and *CH8* on the **Z** channel, *CH9* and *CH10* on the **N/S** channel, and *CH11* and *CH12* on the **E/W** channel.

If you prefer, you can inject your own signals into the system at any point (together with a *Calibration enable* signal, if required) to provide independent measurements, and to check that the voltages around the calibration loop are consistent. For reference, a DM24-series digitiser will generate a calibration signal of around 16000 counts / 4 V when set to 100% (sine-wave or step), and around 10000 counts / 2.5 V when set to 50%.

Appendix A: Connectors and cables

Appendix A.1: DM24S12AMS connectors

Data ports

DIGITAL A – F ports

These are standard 10-pin mil-spec sockets (02E-12-10S).

Pin	Function
A	Power 0 V
B	Power +10 – +36 V
C	GPS data
D	GPS 1pps signal
E	RS232 receive (pin 2 internally)
F	RS232 transmit (pin 3 internally)
G	Data ground
H	Trigger out, common
J	Trigger out, normally-open
K	Trigger in

The trigger lines H, J and K are referenced to 0 V at pin A, so that the triggering system is isolated.

CH 1 – 12 ports

These are standard 10-pin mil-spec sockets (02E-12-10S).

Pin	Function
A	Power 0 V
B	Power +12 V
D	Calibration signal

E	Signal ground
F	Calibration enable
J	Data in +ve
K	Data in –ve

AUXILIARY port

The port is a standard 19-pin mil-spec plug (02E-14-19P).

Pin	Function
A	Internal digitiser A channel 0
B	Internal digitiser A channel 1
C	Internal digitiser A channel 2
D	Internal digitiser A channel 3
E	Internal digitiser A channel 4
F	Internal digitiser A channel 5
G	Internal digitiser A channel 6
H	Internal digitiser A channel 7
J	Internal digitiser B channel 0
K	Internal digitiser B channel 1
L	Internal digitiser B channel 2
M	Internal digitiser B channel 3
N	Ground
P	Internal digitiser B channel 4
R	Internal digitiser B channel 5
S	Internal digitiser B channel 6
T	Internal digitiser B channel 7

GPS port

This is a standard 10-pin mil-spec plug (02E-12-10P).

Pin	Function
A	Power 0 V
B	Power +12 V
C	1Hz reference (RS232 level isolated)
G	Data ground
J	Data transmit
K	Data receive

Power ports

BATTERY / UPS connector

This is a standard 10-pin mil-spec plug (02E-12-10P).

Pin	Function
A	0V
B	Battery +ve
C	Charge output

If pins B and C are connected to each other, an attached rechargeable battery will be trickle-charged whenever there is enough additional power from the mains or *DC POWER* socket. If mains power is used, the battery will never draw more than 1 A of current for charging.

DC POWER connector

This is a standard 10-pin mil-spec plug (02E-12-10P).

Pin	Function
A	0V
B	Battery +ve

PC ports

The remaining connectors are wired directly to the DM24S12PC's built-in laptop PC.

USB connector

This is a standard 6-pin mil-spec socket (02E-10-06S).

Pin	Function
A	+5 V DC (USB Type A pin 1)
B	Data +ve (USB Type A pin 3)
C	Data –ve (USB Type A pin 2)
D	0 V (USB Type A pin 4)
E	Shielding

NETWORK connector

This is a standard 6-pin mil-spec plug (02E-10-06P).

Pin	Function
B	Data transmit +ve (pin 1)
C	Data receive +ve (pin 3)
E	Data transmit –ve (pin 2)
F	Data transmit –ve (pin 6)

TELEPHONE connector

This is a standard 6-pin mil-spec socket (02E-10-06S).

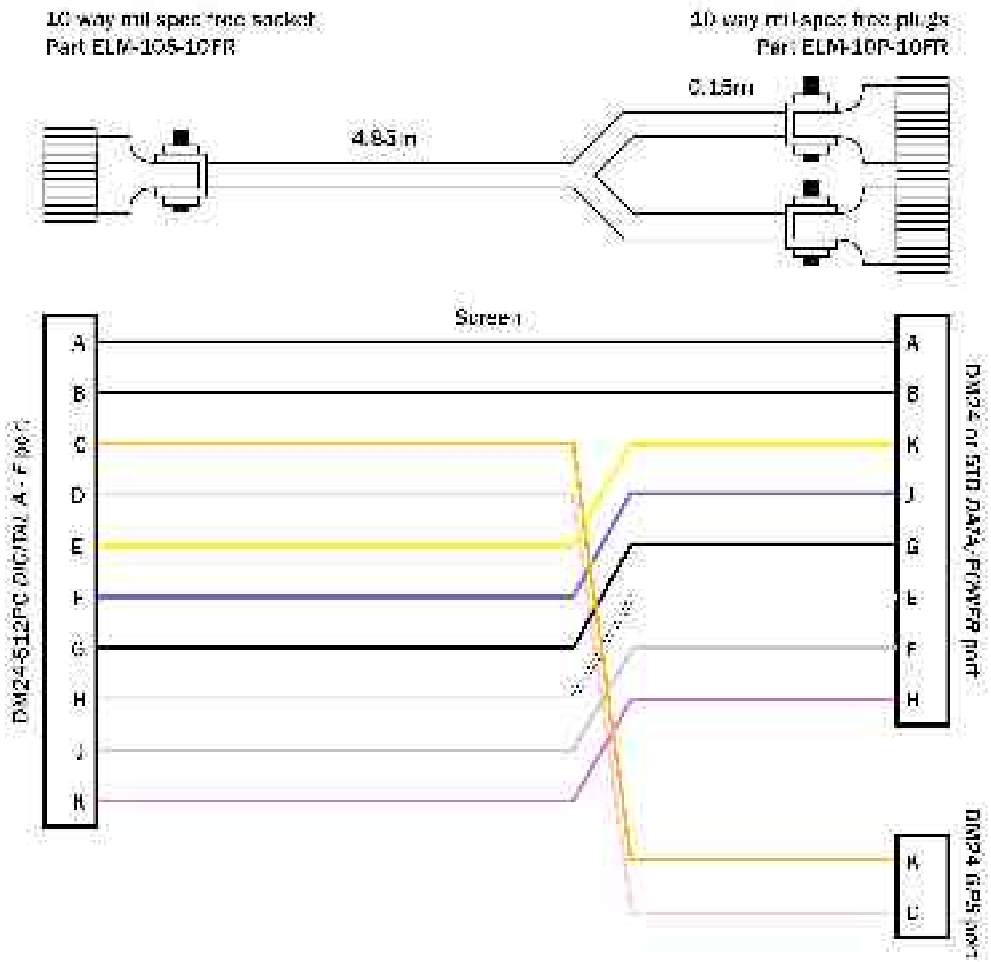
Pin	Function
E	Data receive (pin 3)
F	Data transmit (pin 4)

Appendix A.2: 5U connectors

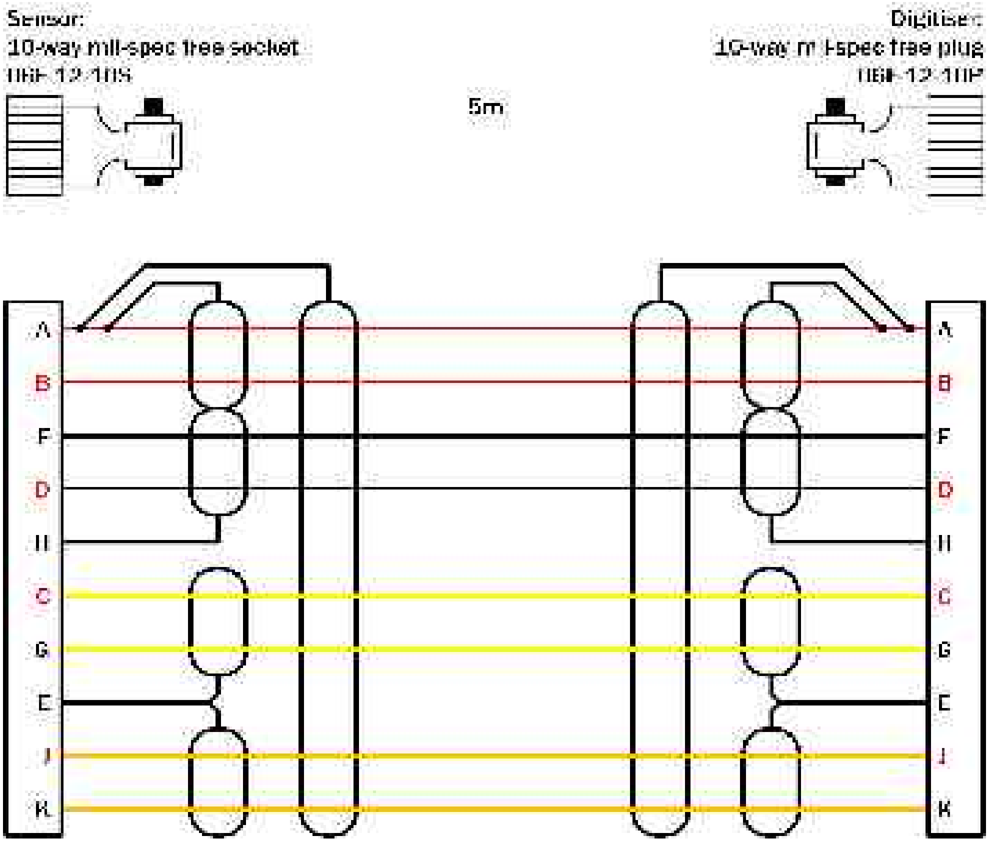
The 5U sensor has a single 10-pin mil-spec connector (02E-12-10P) for both power and acceleration transmission.

Pin	Function
A	Power 0 V
B	Power +12 V
C	High gain acceleration +ve
D	Calibration signal
E	Signal ground
F	Calibration enable
G	High gain acceleration –ve
H	Motor control
J	Low gain acceleration +ve
K	Low gain acceleration –ve

Appendix A.3: Cable from DM24 or 5TD DATA/POWER and GPS to DM24S12AMS *DIGITAL A – F*



Appendix A.4: Cable from 5U sensor to DM24S12 series CH 1 – 12



Appendix B: Specifications

Output	Low gain output options	2*g*, 1*g*, 0.5*g*, 0.1*g*
	Corresponding high gain outputs	0.2*g*, 0.1*g*, 0.05*g*, 0.01*g*
	Dynamic range at 2 g	standard
	Dynamic range, 0.005 – 0.05 Hz	< 140 dB
	Dynamic range, 3 – 30 Hz	< 127 dB
	Standard frequency band	DC – 100 Hz (–3dB point)
	Optional low-pass corner	50, 100 or 200 Hz
	Linearity	0.1 % of full scale
	Cross-axis rejection	0.001*g* / *g*
Calibration controls	Open-loop response	pin on connector
	Closed-loop response	pin on connector
	Step function response	may be added to open- and closed-loop calibrations
	External inputs	Sine-wave, step, or pseudo-random
Physical	Lowest spurious resonance	450 Hz
	Operating temperature range	–20 to +70 °C
	Pressure jacket material	hard anodised aluminium
	Power / signal connector	Mil-spec connector on sensor housing (02E-14-19P)
	Dimensions	75 × 75 × 125 mm
	Weight	908 g
Power	Current at 12 V DC	8 mA