



CMG-DM16R8

Broadband Digitizer

Operator's guide

Part No. MAN-D16-0001

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1 Introduction

The DM16-R8 is a 16 bit, 8 input-channel digitizer, configured in a standard 1U 19inch rack unit. The primary purpose of the instrument is for use in a seismic data collection station with multiple telemetric input channels.

The eight individual differential input channels are accessed via isolated BNC plugs on the front panel, labelled from A to H. Alternatively, all eight inputs are provided at the rear of the 19inch unit via a single 25pin 'D' plug (see pin-outs in appendices).

Other features include

- A built-in Digital Signal Processor (Motorola 56002), providing simultaneous multiple sample rate data streams at user selectable rates. Up to 3 streams of data for each component are available at sample rates from 200 samples/second down to 2 sps.
- Accurate time synchronisation to external GPS or serial time code.
- A single GPS can be cascaded down multiple DM16 digitizers.
- Precision microprocessor controlled time-base synchronises Analogue to Digital Converters and DSP, and time-stamps data blocks.
- Control microprocessor (Hitachi H8) formats and buffers data in on-board 512k RAM ring buffer.
- Compressed data format (Güralp Compressed Format) for efficient storage and transmission.
- Serial data output RS232 or RS422 at user selectable baud-rates.
- Low system power consumption, typically 210-220mA.
- Differential high input impedance pre-amplifiers of 1M Ω
- Common mode rejection ratio exceeding 90dB

The input stages of all the differential amplifiers are protected against excessive input voltages and limited to $\pm 10V$. Each input is furnished with an inductor and capacitor network to filter out the high frequency signals and enable a minimum of 100dB of common mode rejection.

To minimise ground loops the differential power supply is isolated. Two sets of dedicated dc-dc converters ensure low noise dc supply voltages to the input stages and the digitizer electronics.

1.1 Options

Güralp Systems also manufacture a 16-channel DM16 unit, the DM16R16. This is a 2U rack-mount module containing two 8-channel digitizers with cascaded output. A single GPS unit can synchronize both digitizers to the same time base.

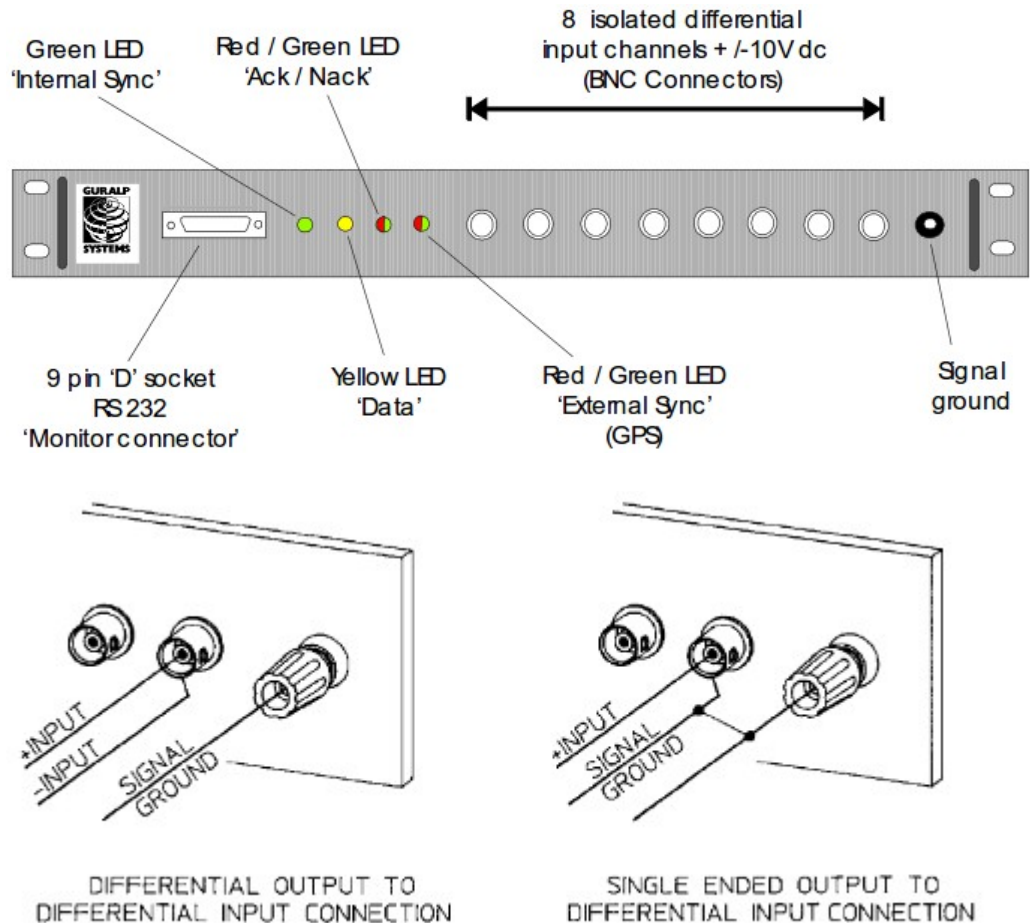


The DM16R16 can optionally be supplied with an internal CMG-DCM data communications module. The DCM is a low-power network device running a full Linux operating system, providing a cost-effective way to connect multiple analogue data sources to a modern TCP/IP network. The DM16R16DCM also fits within a 2U rack space.

2 Using the DM16

2.1 Connections

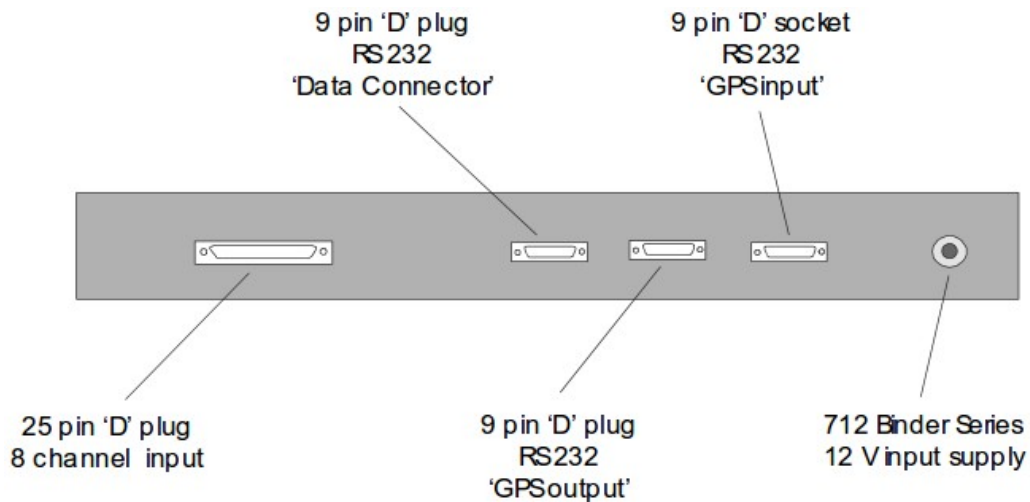
Front panel



Rear panel

Power Connection : Connect supply power (+12 Vdc and 0 Vdc) to the rear connector (Binder series 712) using the cable provided. The pinouts for this cable and connector are given at the back of this guide.

RS-232 Connections : Normally the rear Data connector is duplex, and the front Monitor connector is simplex. For normal operations, connect the rear Data port to the modem, radio, phone line, etc. over which data will be sent, and, if using a



duplex link, over which the digitizer can be remotely configured. To monitor the digitizer's output locally, connect a laptop PC to the Monitor connector and run SCREAM. To configure the digitizer locally, connect the laptop PC to the front Monitor connector using a specially-wired (pin 4 to pin 1; see pinouts) 9-way male serial plug. Use of the specially-wired plug temporarily disables the rear Data connector, and converts the front Monitor connector to duplex, allowing digitizer configuration and monitoring.

Analog Inputs : Analog inputs (+/- 10Vdc) can be connected to the digitizer via the front BNC connectors or via the rear 25-way connector (see pinouts attached).

Terminate unused input ports on the front panel with a 50 Ω BNC terminator cap, *unless* the 25 way rear connector is used for signal inputs into the digitizer. If you use the 25-way connector for an input, then the corresponding BNC input on the front must not be terminated.

GPS Receiver : Use the cable provided to connect the GPS receiver (Garmin antenna) to the rear GPS In connector. The DM16/R8 is designed to allow a single GPS receiver to synchronize multiple digitizers. The first digitizer in the chain must have the GPS receiver connected directly to the rear GPS In connector. Subsequent digitizers can be daisy-chained together, using the rear GPS Out and GPS In connectors. Note that each digitizer in the line adds 5.5 microseconds delay to the actual GPS time stamp.

Front panel LEDs

Int Sync (Internal synchronization) : This LED flashes GREEN whenever the digitizer's internal oscillator generates a timing pulse. Should always flash as long as the digitizer is powered.

Data (Data transmission) : This LED flashes YELLOW when a GCF block is sent from the digitizer. The rate of flashing for this LED depends on the configured sampling rate(s). No activity indicates that data is not being sent.

Ack/Nack (Acknowledge/No Acknowledge) : Indicates whether data blocks are being acknowledged by SCREAM (requires duplex link, via serial port).

- If LED is off, SCREAM is not attached, or the link to SCREAM is simplex.
- GREEN : SCREAM is attached and acknowledging blocks (the LED blinks momentarily for each block received).
- RED : a block(s) was not acknowledged.

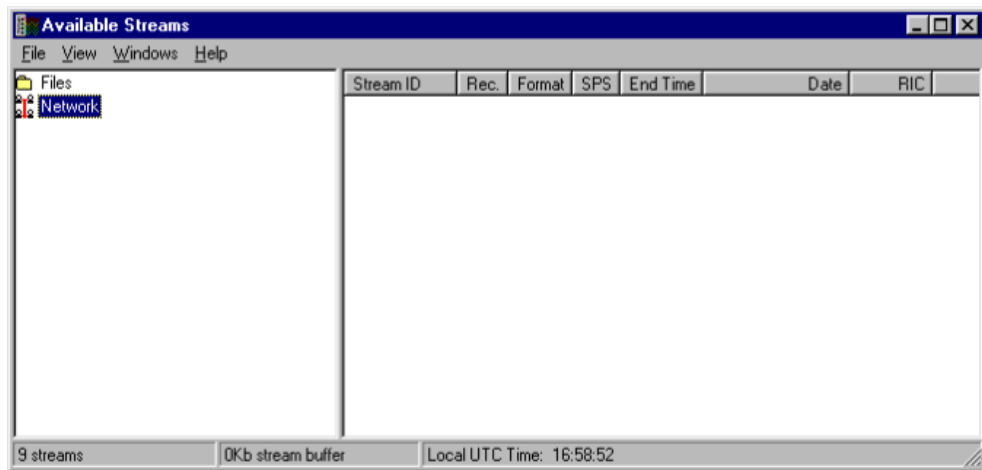
ExtSync (External synchronization) : The timing pulse from the GPS receiver.

- No activity indicates that the GPS receiver is not attached or is inoperative.
- RED blink :- indicates GPS is attached and operating, but has not yet obtained a fix.
- GREEN blink : at one second intervals, indicates GPS has obtained a fix.
- GREEN blink synchronized with IntSync LED: indicates GPS has obtained a fix and the internal oscillator is synchronized to it.

2.2 Quick start

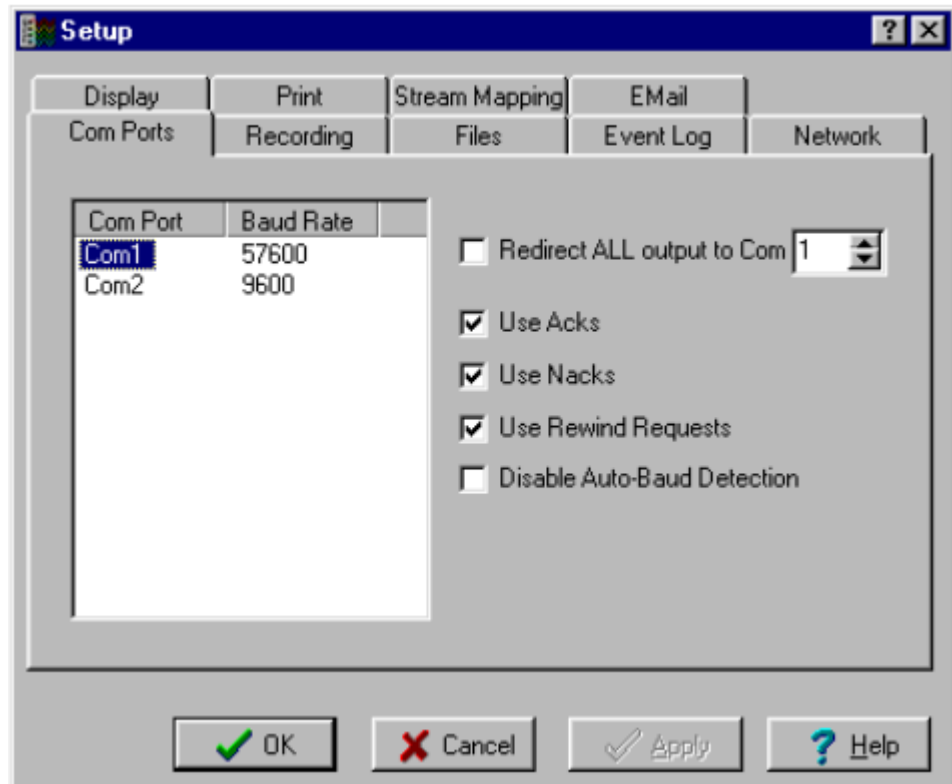
1. Connect the GPS cable to the digitizer's plug marked 'GPS Input' (GPS is not essential for initial test setup).
2. Connect the cable from the plug marked 'Data Output' to the COM port of a PC.

3. Install SCREAM software (see later chapter) on your PC and run.
4. Connect a 12V DC power supply to the DM16-R8 plug marked 'Power'. (the DM16-R8 will operate from 10 to 36 V DC). At 12 V, the DM16-R8 draws 210-220mA, or 310-320mA with one GPS2 connected
5. To configure the COM port connected to the digitizer, start from the main window in SCREAM



6. Click on the 'File' button , select 'Setup'

7. Select the 'Com Ports' tab.



Click on the COM port to which the digitizer is connected.

8. Select **Autodetect** from the *Baud Rate* drop-down menu.

SCREAM will detect, then display the baud rate that the digitizers output is currently set at.

9. Click **OK** to return to the main Available Streams window.

10. In the Available Streams window the identifier of the digitizer will appear in the left hand frame. The data streams will appear in the righthand frame.

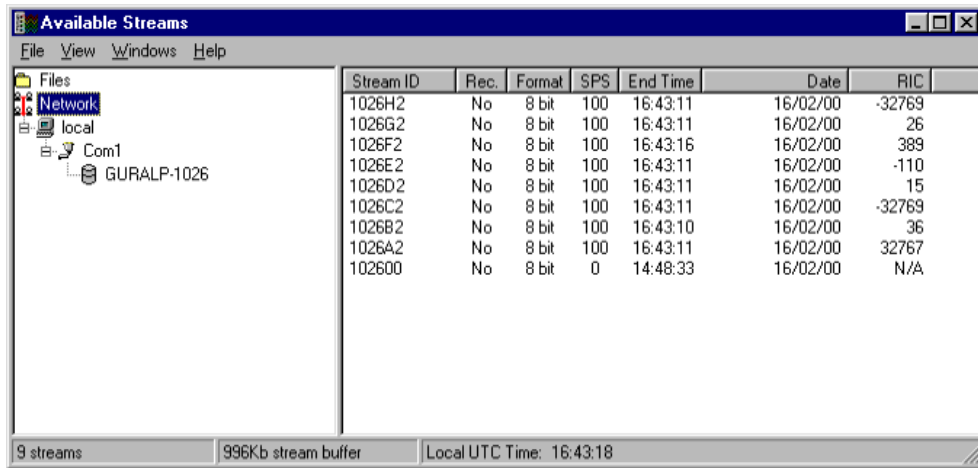
The Stream ID's are six character strings uniquely identifying each instrument, component and sample rate. (There may be upto three different sample rates per channel)

The stream ending in '00' contains status information from the digitizer.

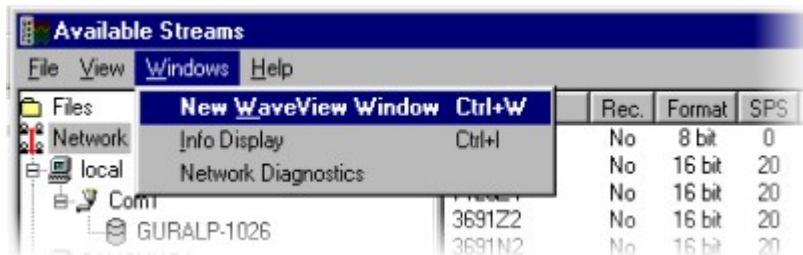
11. Analogue signals can now be connected to any of the eight individual differential inputs on the front of the

digitizer or via the 25 pin 'D'plug on the rear of the unit.

- From the main 'Available Streams' window, choose **Windows - New WaveView Window**.



- Select the data streams and drag them into the *WaveView* window.



- To see status information coming from the digitizer, right click on the status stream, from the pop-up menu select 'View'. A new window, 'Status' should open containing text. The first blocks will give the boot message from the DM. Later blocks give information on the expected GPS satellites, the location of the GPS antenna, time synchronization status and transmit and receive baud rates for each channel and the data link.

3 Digitizer status information

The digitizer outputs various status information to report the system operation such as GPS and time synchronisation status. This status information is in plain ASCII text packaged in the same block structure as the channel data. There are usually 12 lines of information in a block.

To access a Status window right click on the Stream ID '****00', (where **** is the digitizer). In the example below this is 102600

Notice this is the only stream with '0'samples per second

During boot-up the units report their module type, firmware revision number, the system-id and serial number. This information is followed by the count of resets that have occurred and the time of this re-boot from the internal back-up clock. The following lines report the configuration of the unit sample rates, output taps selected, and the baud-rates of the serial ports.

Typical digitizer re-boot status message:

The screenshot shows a status window titled "Status - DM16X8 MGS100". The text inside is as follows:

```

Guralp Systems Ltd - DM16-8 \ v.075 mgs 11/01/00 (B037)
ROM changed - Beta release? $68C7
DM16X8 MGS100
Last re-boot at 2000/02/28 16:35:35
241st System (re-)Boot at 2000/02/28 16:47:10
Sample rates : 200 20 1
DSP 56002 Firmware V#4864
Eight Channels
Expecting Garmin NMEA GPS
Continuous Data output from :
Tap#0 200s/s $FF = Chans 0 1 2 3 4 5 6 7
Tap#1 20s/s $FF = Chans 0 1 2 3 4 5 6 7
Tap#2 1s/s $FF = Chans 0 1 2 3 4 5 6 7
No Triggered outputs selected
No Triggering source specified

Port#0 Rx=38400 Tx=38400 Port#1 Rx=4800 Tx=4800
  
```

Red annotations point to the following fields:

- System type:** DM16-8
- Firmware revision:** v.075 mgs 11/01/00
- System ID & serial number:** DM16X8 MGS100
- Internal clock:** 16:47:10
- Sample rates:** 200 20 1
- DSP filter version:** V#4864
- Selected tap, sample rate and channel:** Tap#0 200s/s \$FF = Chans 0 1 2 3 4 5 6 7, Tap#1 20s/s \$FF = Chans 0 1 2 3 4 5 6 7, Tap#2 1s/s \$FF = Chans 0 1 2 3 4 5 6 7
- Data port baud rate:** Port#0 Rx=38400 Tx=38400
- GPS port baud rate:** Port#1 Rx=4800 Tx=4800

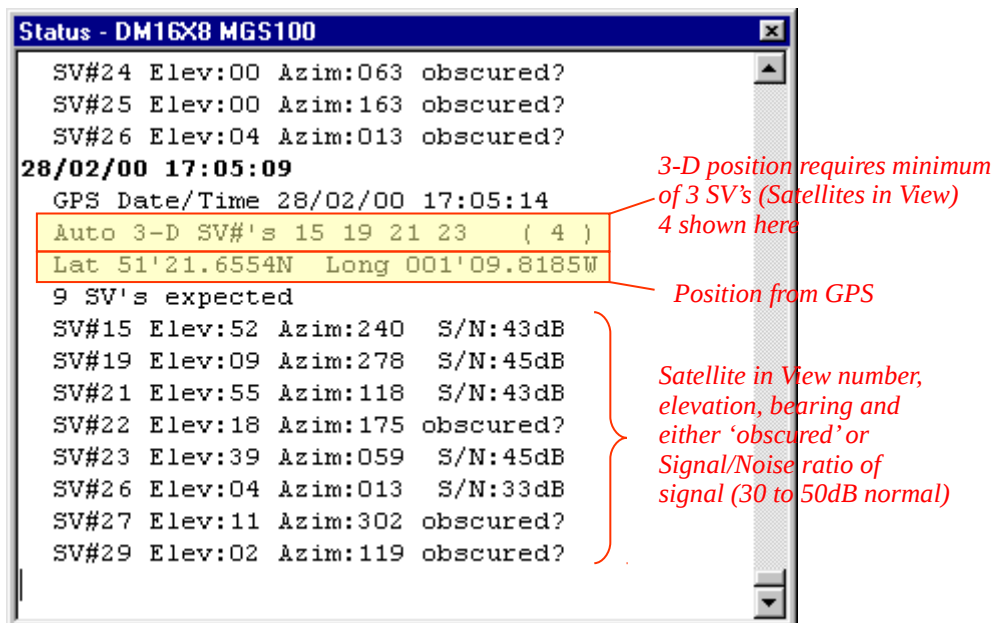
The system will produce this status message whenever it is powered up. If this status is reported at other times it indicates that the system has been reset by the built-in 'watchdog' monitor, which will occur if the system has suffered a corruption due to external noise or power dips.

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

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

From a 'cold' start GPS will initially report 'No GPS time' and its last position from the internally backed up status. All messages from GPS which involve a change of its status are automatically reported, repeated status messages are not shown to avoid unnecessary accumulation of the same information.

Initial GPS status report will be like this :



If GPS is having difficulty in acquiring satellites there can be a delay of several minutes before a new message is displayed, but normally if the system has not been moved from its previous location it should report acquisition of 1 or more satellites and GPS time in a very short time. 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 (requires 3 satellites) before starting operation. The system actually waits 6 consecutive 'good' messages, which normally occur every 10 to 20 seconds.

If GPS maintains a good fix from the satellites available, the system will then switch on the control process and set the internal clock as shown by the status messages over the page.

The system jam-sets its internal clock at this point to be synchronised to GPS time and will also re-synchronise the Analog to Digital Converters so that the data is accurately time-stamped to this new reference. The data transmitted upto this point will be stamped with the time from the internal back-up 'Real-Time Clock' ; this is also now reset to this accurate time. Re-synchronisation will also result in the received data showing a discontinuity.

The control process will now attempt to keep the internal time-base synchronised to the GPS 1 pulse per second output by adjusting the voltage controlled crystal oscillator. The control algorithm has two stages - initially it compares its internal 1 Hz timebase with the GPS 1pps 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' (offset between its internal 1 Hz and 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' value - Pulse Width Modulation - digital to analog conversion.

```

Status - DM16X8 MGS100
28/02/00 17:10:33
SV#08 Elev:12 Azim:315 obscured?
SV#15 Elev:52 Azim:240 S/N:37dB
SV#17 Elev:03 Azim:060 S/N:30dB
SV#19 Elev:09 Azim:278 S/N:44dB
SV#21 Elev:55 Azim:118 S/N:45dB
SV#22 Elev:17 Azim:175 S/N:35dB
SV#23 Elev:39 Azim:059 S/N:46dB
SV#26 Elev:04 Azim:013 S/N:30dB
GPS Date/Time 28/02/00 17:06:18
Using GPS to Control Crystal 2000 2 28 17:10:08
Clock sync'd to GPS 2000 2 28 17:10:30 ==>> 2000 2 28 17:10:32 0
Auto 3-D SV#'s 3 8 15 19 21 23 31 ( 7 )
28/02/00 17:13:56
Lat 51'21.6635N Long 001'09.8150W
GPS Date/Time 28/02/00 17:10:32
2000 2 28 17:11:00 Missing pps
2000 2 28 17:13:00 o/s= 22257 drift= 0 pwm= 7484
10 SV's expected
SV#03 Elev:70 Azim:122 S/N:45dB
SV#08 Elev:12 Azim:312 S/N:41dB
SV#11 Elev:22 Azim:247 obscured?
SV#15 Elev:56 Azim:243 S/N:40dB
SV#19 Elev:07 Azim:276 S/N:45dB
SV#21 Elev:56 Azim:113 S/N:32dB
    
```

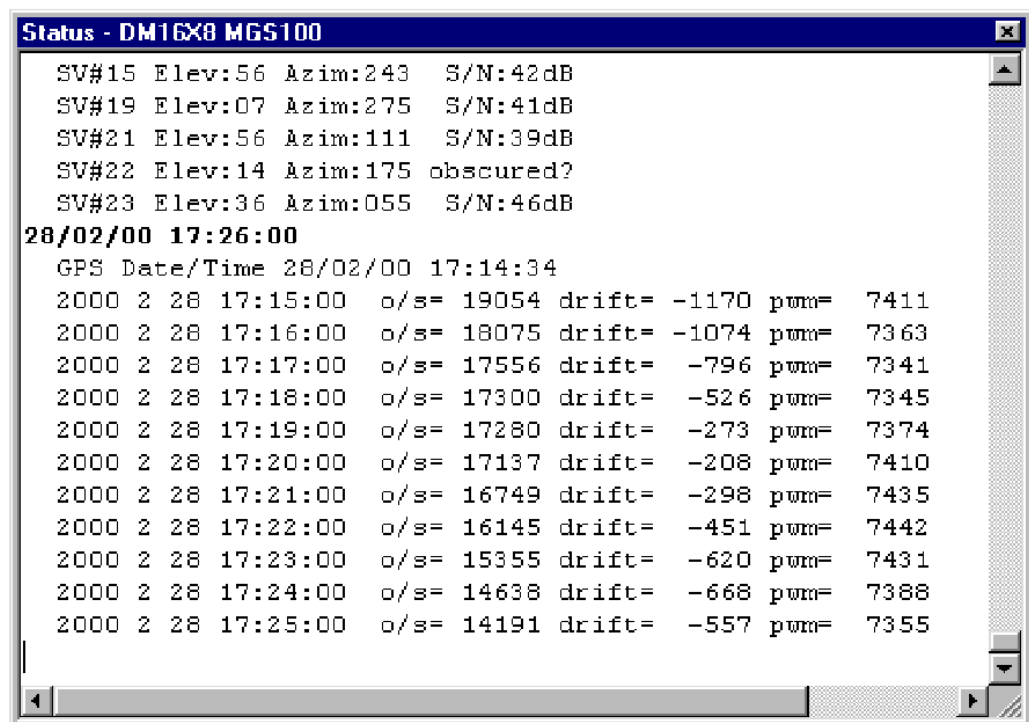
Synchronisation process commenced

*Internal clock synchronised to GPS
Notice time shift of 2 seconds from 17:10:30 to 17:10:32 in this example*

Synchronisation control parameters.(zero 'drift' in the first instance during coarse adjustment. 'pwm' is a saved parameter)

During the initial 'coarse' adjustment 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 (i.e. same temperature) the saved control parameters will be appropriate and the system should rapidly switch to the 'fine' control mode.

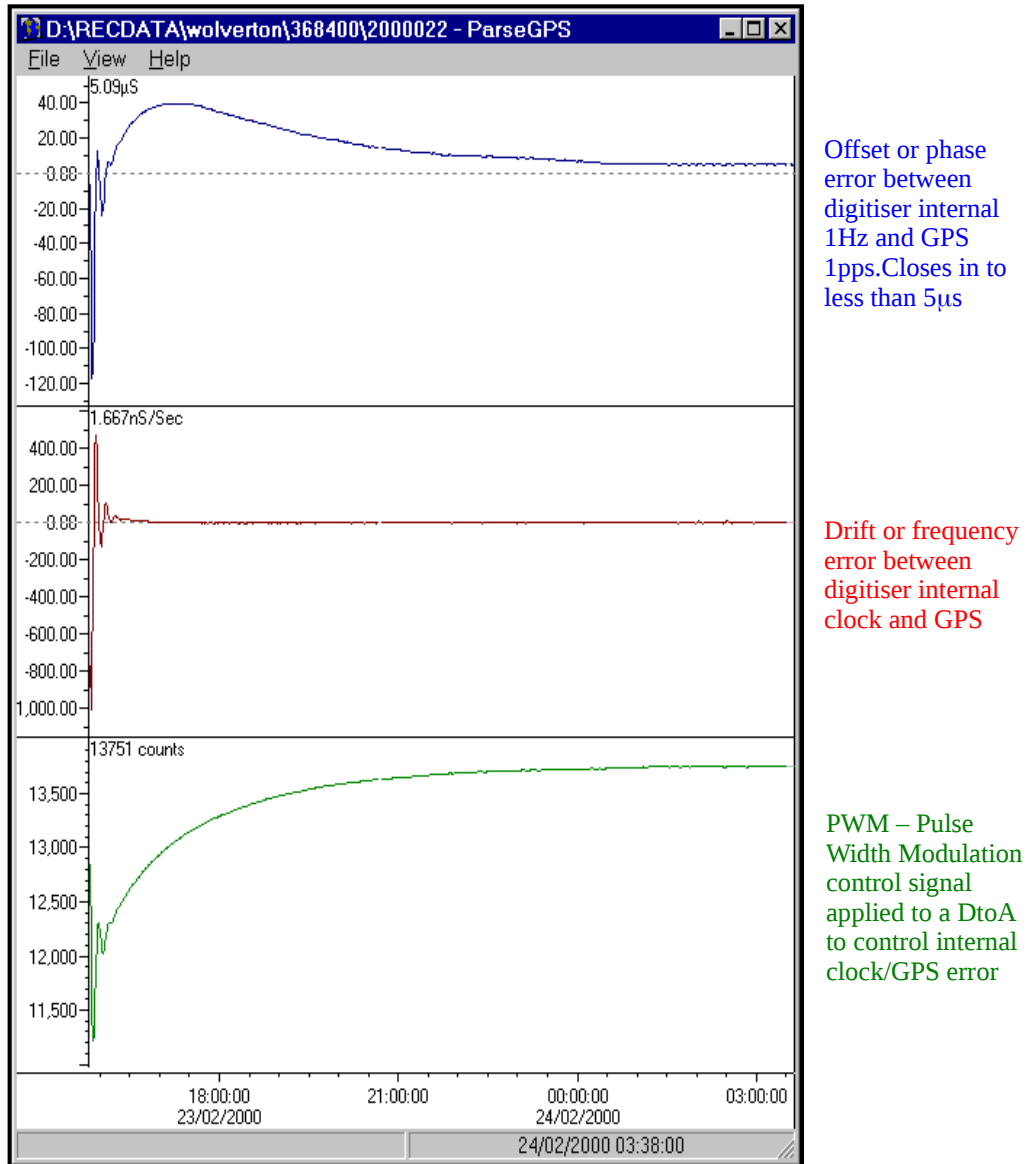
The system reports its control status and parameters each minute as shown below:



```
Status - DM16X8 MGS100
SV#15 Elev:56 Azim:243 S/N:42dB
SV#19 Elev:07 Azim:275 S/N:41dB
SV#21 Elev:56 Azim:111 S/N:39dB
SV#22 Elev:14 Azim:175 obscured?
SV#23 Elev:36 Azim:055 S/N:46dB
28/02/00 17:26:00
GPS Date/Time 28/02/00 17:14:34
2000 2 28 17:15:00 o/s= 19054 drift= -1170 pwr= 7411
2000 2 28 17:16:00 o/s= 18075 drift= -1074 pwr= 7363
2000 2 28 17:17:00 o/s= 17556 drift= -796 pwr= 7341
2000 2 28 17:18:00 o/s= 17300 drift= -526 pwr= 7345
2000 2 28 17:19:00 o/s= 17280 drift= -273 pwr= 7374
2000 2 28 17:20:00 o/s= 17137 drift= -208 pwr= 7410
2000 2 28 17:21:00 o/s= 16749 drift= -298 pwr= 7435
2000 2 28 17:22:00 o/s= 16145 drift= -451 pwr= 7442
2000 2 28 17:23:00 o/s= 15355 drift= -620 pwr= 7431
2000 2 28 17:24:00 o/s= 14638 drift= -668 pwr= 7388
2000 2 28 17:25:00 o/s= 14191 drift= -557 pwr= 7355
```

The offset and drift figures are the total accumulated error measurements during the previous minute in time-base units (nominally 0.5 μ sec). To convert the figures to time, divide by 120 (=60 \times 2) to give micro-seconds. In a stable temperature environment the system should soon settle down showing an offset error of only a few thousand (average error < 100 μ sec) and a drift rate under 100 counts (< 1 in 10⁻⁶).

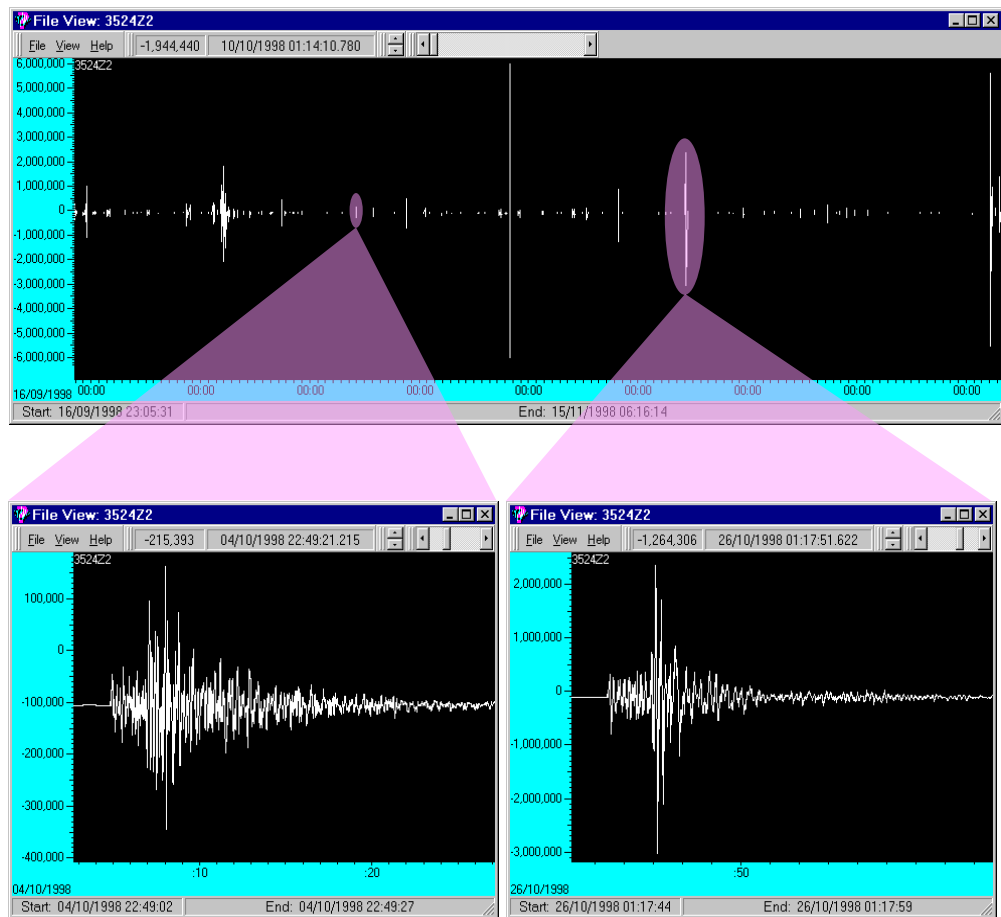
The screen shot below shows, from the top graph down, the offset, drift and pwm of a digitizer internal clock tracking and homing-in on a GPS clock pulse over approximately a twelve hour period.



The above graphical image was printed from a Guralp plot module to demonstrate the effectiveness of digitizer clock synchronisation and subsequently time stamped data.

4 STA/LTA triggering

In its standard configuration the digitizer outputs continuous data at a user-selectable sample rate. An additional powerful feature of the digitizer is the ability to simultaneously run a STA/LTA event triggering algorithm in parallel with the continuous acquisition. This permits the system to record continuously at a relatively low sample rate, and record at a much higher sample rate during short periods when triggered. Parameters controlling the triggering algorithm, and controlling the data output once the system is triggered, are all selectable by the user, permitting the maximum flexibility of operation and the most efficient use of available storage space.



Shown above in the upper window, is an example of a data stream recording over a two month period. Two seismic events are shown highlighted in the two lower windows which, given suitable triggering parameters, can be recorded in greater detail at a higher sampling rate of upto 200 samples per second.

Triggering of all three components from vertical channel 100Hz tap, filter from 5 to 45 Hz

Sta = 1, Lta = 50, Sta/Lta = 10, pre-trigger = 40, post-trigger = 70

This section describes the triggering algorithm and gives several examples of typical system configurations that may be used. It is intended to be read along with the digitizer Configuration Section of the Operator's Guide.

4.1 Using the triggering system

The digitizer Configuration Section of the Operator's Guide describes in detail how to configure the system to output continuously at up to 3 different sample rates, selectable within certain constraints by the user. Typically, you may only wish to record one sample rate as continuous data, but it may be useful to record selected time periods at a higher sample rate

The triggering algorithm used is a standard STA/LTA ratio test on a bandpass filtered signal. An individual channel, corresponding to an individual seismometer component can be defined as the trigger channel, or triggers can be permitted on any channel. Details of the various parameters related to the triggering process are given in the following sections.

Pre-trigger bandpass filtering

As the digitizer is normally used with a Güralp Systems Limited broadband seismometer the raw data is very broadband. To enhance the performance of the triggering algorithm, the raw input data is bandpass filtered prior to running it through the triggering system. This filtering serves to maximise sensitivity within a specific frequency band of interest, and to reject noise outside this band, for example from oceanic microseisms. The system is provided with a choice of 3 inbuilt generic bandpass filters (wide, medium and narrow) which are slaved to the defined tap output sample rates defined using the samples/sec command. The filters all have a low pass corner at 90% of the Nyquist frequency of the selected tap, and the wide, medium and narrow filters have high pass corner frequencies at 10%, 20% and 50% of the Nyquist frequency respectively. For example, if we consider the 100 samples/sec tap defined above (Tap#1) the low pass corner for each filter will be at 45Hz, and the high pass corners will be at 5Hz, 10Hz and 25Hz.

The possible filter configurations are shown in the following table:

Tap #	Samples /sec	Bandwidth 1		Bandwidth 2		Bandwidth 5	
		Hz	Hz	Hz	Hz	Hz	Hz
0	200	10 -	90	20 -	90	50 -	90
	100	5 -	45	10 -	45	25 -	45
1	50	2.5-	22.5	5-	22.5	12.5	22.5
	40	2 -	18	4 -	18	10 -	18
2	25	1.25	11.2	2.5-	11.2	6.25	11.2
	20	-	5	-	5	-	5
2	20	1-	9	2-	9	5-	9
	50	2.5 -	22.5	5 -	22.5	12.5	22.5
2	25	1.25	11.2	2.5-	11.2	6.25	11.2
	10	-	5	-	5	-	5
2	20	1 -	9	2 -	9	5 -	9
	10	0.5-	4.5	1-	4.5	2.5-	4.5
2	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
2	4	-	1.8	-	1.8	-	1.8
	2	0.1-	0.9	0.2-	0.9	0.5-	0.9

As can be seen from the list, the choice of required filter will tend to define the set of permissible sample rates required. The filter combination is set using the bandpass command, which takes the tap number (0-2) and bandwidth factor (1, 2 or 5) as arguments. For example:

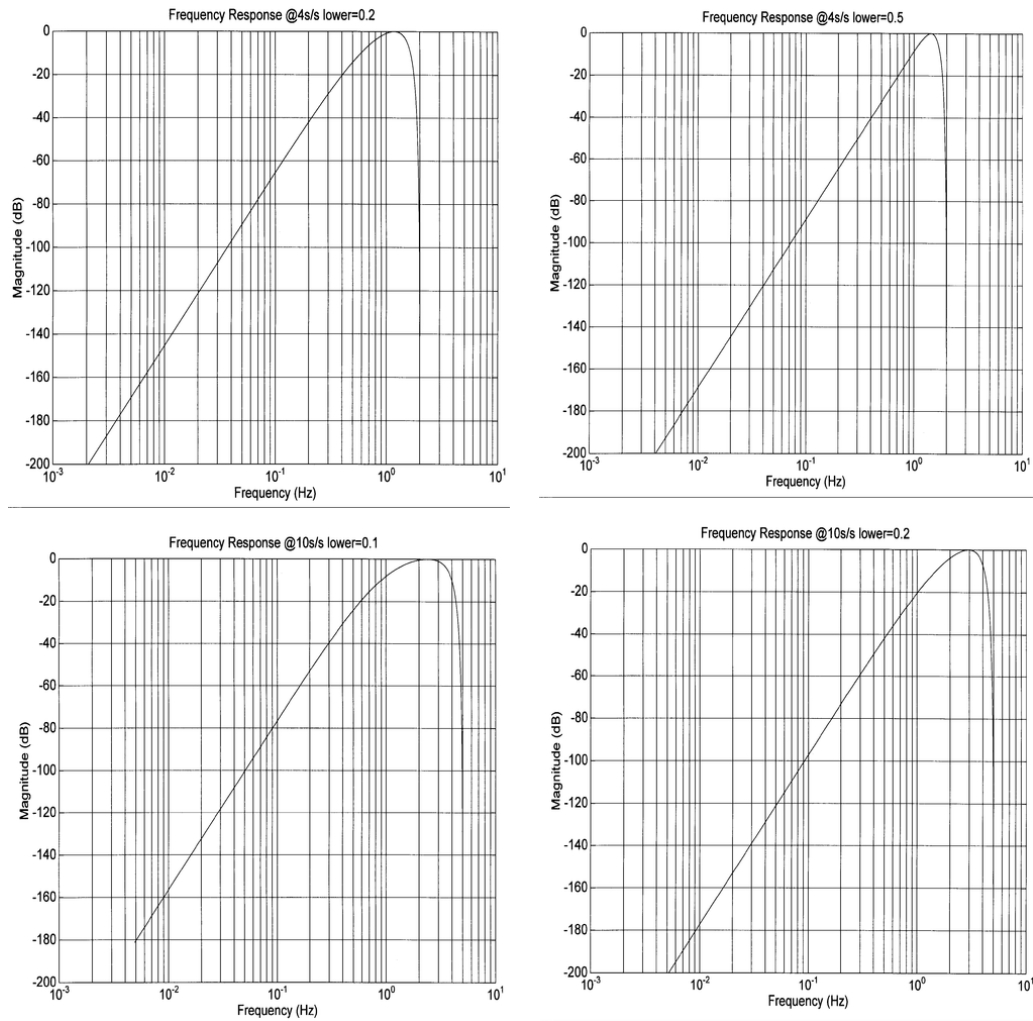
```
2 5 bandpass
```

defines the narrowest filter on the output from tap #2, the 20 samples/sec tap in our example, corresponding to a filter with corners at 5.0Hz (50% Nyquist) and 9.0Hz (90% Nyquist). The system response to the above command would be:

```
Tap#2 20 s/s Bandpass: 5.0->9.0Hz
```

The spectral amplitudes for the various frequency responses

available are shown in the figures below.



4.2 Triggering algorithm

The triggering algorithm applied to the bandpass filtered data is a standard STA/LTA ratio test. Averages of the modulus of signal amplitude are computed over two user defined time periods, a short time average (STA) and a long time average (LTA), and the ratio of the two at each sample point is computed (STA/LTA). If this ratio exceeds a user-defined threshold, then a trigger is declared, and the system remains in a triggered state until the ratio falls below the defined threshold. The trigger 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 reduce the

probability of triggering on spurious spikes or short duration transients, and to introduce some element of frequency selectivity into the triggering process. As a rule of thumb, the short term average should be set to the dominant frequency of the events the trigger is designed to catch. The purpose of the long term average is to provide a measure of the variation in the background seismic noise, so it should be set to some value longer than the period of the lowest frequency seismic signal of interest. Obviously there is some element of trade-off in setting a value for the trigger ratio. 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 producing false alarms. Determining an appropriate value in any given situation which maximises the number of seismic events detected while minimising the number of false alarms is a matter of experiment.

In order to capture all of a seismic event, some seconds of buffered data from before the trigger is declared are recorded. This facility is particularly useful for emergent type signals where the system triggers on a phase after the first arrival. Furthermore, some seconds of data after the system stops triggering are also recorded to ensure the coda of an event is not missed.

There are 5 parameters directly associated with the STA/LTA trigger algorithm:

sta defines the length of the Short Term Average window in seconds. Takes 3 arguments which are the values to use for each of the three seismometer components (Z, N/S, E/W)

Example: 1 1 1 sta

lta defines the length of the Long Term Average window in seconds. Takes 3 arguments which are the values to use for each of the three seismometer components (Z, N/S, E/W)

Example: 1 1 1 lta

ratios defines the STA/LTA ratio above which the system will declare an event. Takes 3 arguments which are the values to use for each of the three seismometer components (Z, N/S, E/W)

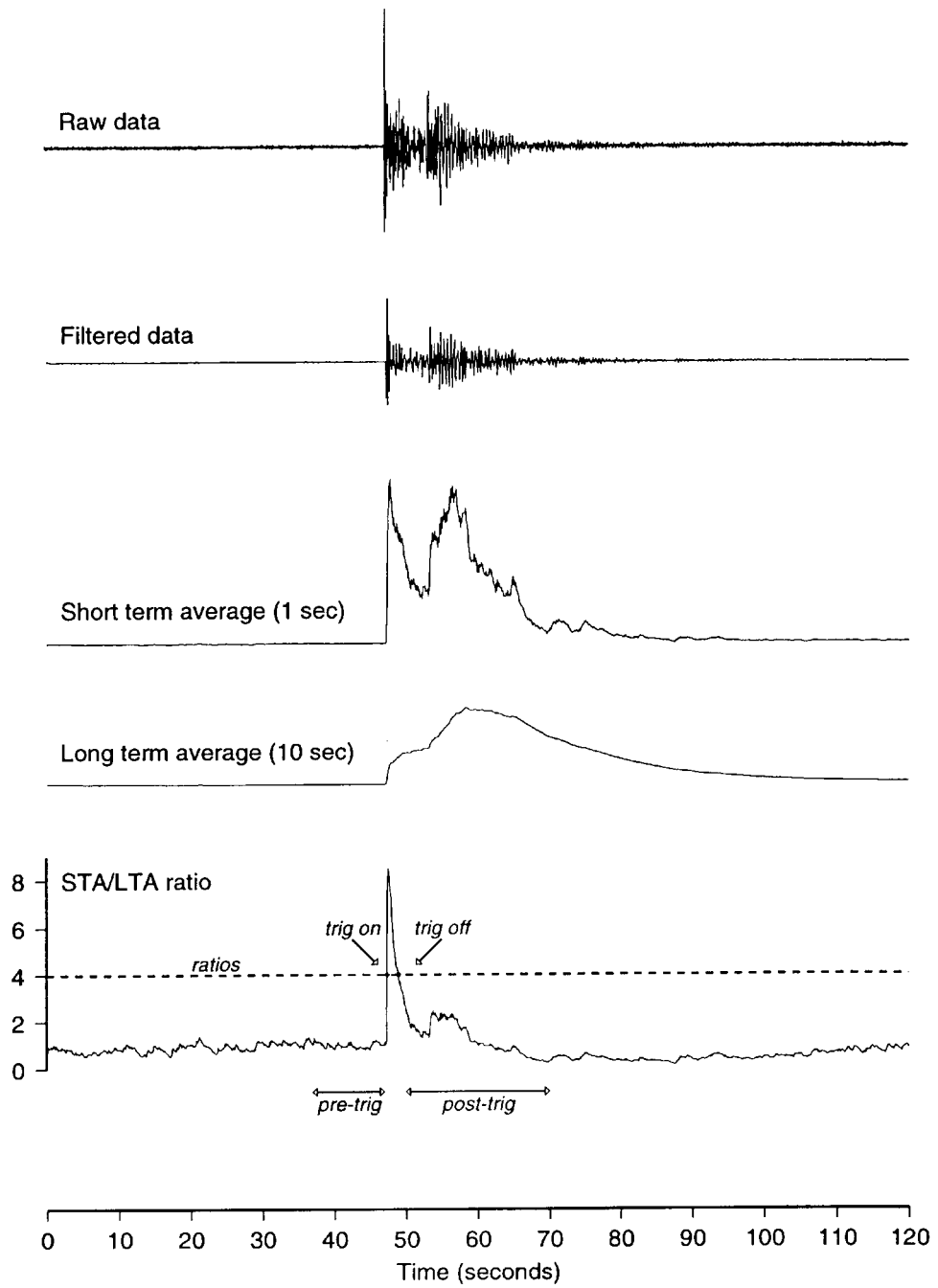
Example: 4 4 4 ratios

pre-trig specifies the amount of time in seconds for which data prior to the trigger will be retrieved from the buffer and output with the triggered data. Because of the block nature of the data format and compression algorithm this time is only approximate.

Example: 20 pre-trig

post-trig defines the amount of time in seconds after the trigger has ceased during which triggered data will continue to be output. Because of the block nature of the data format and compression algorithm this time is only approximate.

Example: 40 post-trig



4.3 Setting the channels running the trigger algorithm

The filtering and triggering can be carried out on 1, 2 or 3 channels, usually corresponding to the 3 components of a seismometer. The channels to be used are specified using the command **TRIGGERS**. A trigger on any defined channel will cause the system as a whole to declare a trigger. The argument for the **TRIGGERS** command is an integer specifying with its binary bits which components to enable: 1 (001) for the first component (channel 0, vertical), 2 (010) for the second component (channel 1, N/S) and 4 (100) for the third component (channel 2, E/W). So, for example, to enable triggering on all three components:

```
001+010+100 = 111 = 7
```

The command is:

```
7 triggers
```

This returns the configuration report:

```
Triggering on Data from:
  Tap#2 20s/s 70 = Chans 4 5 6
  Tap#2 20 s/s BandPass: 2.0->9.0Hz
```

(Note: Channels 4, 5 and 6 correspond to the bandpassed versions of data on Channels 0, 1 and 2)

The trigger operating mode can be disabled simply by sending the command:

```
0 triggers
```

4.4 Setting the triggered output channels

When a trigger is declared, the channels to be output are defined using the **TRIGGERED** command. This takes 2 arguments, the tap number (0-3) and the components (an integer defined from the bit values as for **TRIGGERS** defined above). For example:

```
0 7 triggered
```

will cause all three components to be output at 200 s/s on

triggering. The configuration report will be:

Output Triggered Data from:
Tap#0 200s/s 07 = Chans 0 1 2

5 Configuring the DM16

Scream! is a versatile seismic data visualisation program for Güralp instruments, and is available for free download from Güralp Systems, or may have been supplied with your equipment.

You can use Scream! to change the configuration of your digitizer through an easy-to-use graphical interface. All of the configuration options of the DM16 are supported by Scream!, including output control and triggering.

5.1 Configuring with Scream!

Scream! 4 distinguishes between *configuration* and *control* of digitizers. The most important difference is that a digitizer may be *controlled* through Scream! at any time whilst it is acquiring data, whereas *configuration* options only take effect after a reboot (with consequent loss of data.)

To change the configuration of any connected digitizer:

1. Locate the digitizer you want to configure. All connected digitizers have an entry in the tree on the left of Scream!'s main window. If the digitizer is transmitting data through a remote server or DCM, you may need to "unroll" the entry for that server (by clicking on the icon) to see the digitizers connected to it.
2. Right-click on the digitizer's entry (*not* the icon for the server or any **Comxx** icon). Digitizers are shown with icons depicting a coloured cylinder.
3. Click **Configure...** Scream! will then contact the digitizer and retrieve its current configuration, a process which will take a few seconds. This done, the *Configuration setup* window will be displayed.
4. Once you are happy with any changes you have made in the *Configuration Setup* window, click **UPLOAD** to send them to the digitizer and reboot. This will take a short while.

To control a digitizer whilst it is running, either right-click on the digitizer's entry in the list and click **Control...**, or double-click the entry. In either case Scream! will contact the digitizer 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)
- the length of pre-trigger and post-trigger periods,
- calibration signal options, and
- mass control functions.

Some of these options can also be altered in the *Configuration setup* window.

For more information on how to use Scream! to configure your digitizer, please see the Scream! user guide or the on-line help.

If you need a more powerful interface to the DM16, you can also issue commands to it directly using Scream!'s terminal mode. A terminal window is opened by right-clicking on the digitizer's entry in the list and selecting **Terminal....**

The digitizer will stop transmitting data while you have a terminal window open. Data collected whilst the terminal is active will be stored for transmission later, memory space permitting.

5.2 Terminal commands

You can connect to the internal software of the DM16 over its output serial port and communicate with it.

To enter command mode from Scream!, right-click on the digitizer's icon and select **Terminal...** from the menu that pops up. A window will open, and once the digitizer and computer are communicating properly you will see the prompt

ok

If you prefer, you can use a terminal program on your computer (such as `minicom` on Linux, or `hypertrm` on Microsoft Windows)

to connect to the DM16.

Whilst you are in terminal mode, data transfer will be interrupted; the digitizer may use any Flash memory as a temporary store, depending on how you have configured it. Some commands, such as SET-TAPS, require a reboot to take effect.

Güralp DCM and AM modules also allow you to send commands direct to the digitizer using the command-line tool `gccli`. For more information, please see the manual for your data module.

If you have problems connecting to the digitizer's console, you should check that the serial port's options and baud rate are set correctly in `Scream!` or your terminal program. As supplied, the DM16 expects connections at 38400 baud, with 8 data bits, no parity bit and 1 stop bit. No flow control is used.

FORTH

The DM16 uses FORTH to implement its features. To issue a command in FORTH, you must supply the arguments *before* the command, for example:

```
3 SENSOR-TYPE
```

In FORTH, anything you enter is termed a *word*. New words (case insensitive) are placed on a stack. Some words are known to the system, and may represent commands; if a command finds itself at the top of the stack (*e.g.* because it is the last thing you typed), they will execute, remove themselves from the stack, and then remove further items from the stack to use as arguments. Thus, in the command

```
3 SENSOR-TYPE
```

the 3 has no immediate effect, so stays on the stack; `SENSOR-TYPE` takes itself and the previous item (here 3) off the stack, then performs its action on the 3 (here, setting the configured sensor type to 3, representing a CMG-3T sensor.)

If a command completes with nothing remaining on the stack, the digitizer will show the prompt `ok`. Otherwise, the prompt will remind you that the digitizer is waiting for you to complete the command. Some commands, such as `SAMPLES/SEC`, clear the stack automatically after they execute.

Some commands are *interactive*, and will ask you to provide extra information after you execute them. In the following sections, interactive commands are shown as example sessions, where information you enter is given in medium and messages returning from the DM16 are given in **bold**.

5.3 Getting help

HELP

Syntax: HELP

Displays help about the DM16's terminal commands.

5.4 General configuration

SET-ID

Syntax: SET-ID (interactive)

Sets the system identifier and serial number of the DM16 to values you supply.

SET-ID

System Identifier ? (e.g. ALPHA,) DM16, Serial # ? (e.g. 1234,00)
4507,00

The system identifier you supply may contain up to 5 alphanumeric (0-9A-Z) characters, and must have a comma after it.

The serial number you supply must contain exactly 6 alphanumeric (0-9A-Z) characters, and must include a comma after the fourth character.

SENSOR-TYPE

Syntax: *type* SENSOR-TYPE

Tells the DM16 which kind of sensor is attached to it. This affects whether or not the digitizer exposes commands such as locking and centring.

type can be one of

- 1, for CMG-40T sensors,

- 2, for CMG-3ESP sensors,
- 3, for CMG-3T analogue sensors, or
- 4, for CMG-3TD sensors.

GPS-TYPE

Syntax: type GPS-TYPE

Tells the DM16 which kind of GPS is attached to it.

type can be one of

- 0, if no GPS is available, or
- 2, for attached GPS equipment using the NMEA protocol.

SET-CLOCK

Syntax: SET-CLOCK (interactive)

Sets the internal clock.

```
SET-CLOCK
Enter Date & Time -
YYYY MM DD HH MM SS
2006 02 01 12 53 25  Clock set to 2006  2  1 12:53:27 ok_SBHY
```

The time should be entered in the form year month day hour minute second, padding each field with zeroes so that they line up with the guide above.

If the DM16 does not recognize the time format you have used, it will output the message Invalid Time Entry.

This setting will be overridden when the GPS system next synchronizes the clock.

TIME?

Syntax: TIME?

Displays the current date and time.

LEAPSECOND

Syntax: yyyy mm dd LEAPSECOND

Manually notify the digitizer of an upcoming leap second. This command is not normally necessary, since GPS already has support for leap seconds. However, some units do not properly interpret the GPS signals. See SQPATCH, below.

The leap second is taken to be at the end of the day yyyy-mm-dd.

SQPATCH

Syntax: SQPATCH ENABLE or SQPATCH DISABLE

Enables or disables the internal patch for older GPS receivers based on Trimble Lassen SQ units. These units misinterpret the GPS system's advance notification of a leap second, and consequently run one second slow until the leap second occurs.

With SQPATCH enabled, the time reported by the digitizer is offset by 1 second to counteract this problem. If you have set LEAPSECOND, above, SQPATCH will automatically be disabled when the leap second occurs, and the digitizer will then run normally.

GPS receivers with the latest firmware do not suffer from this problem.

To find out whether SQPATCH is currently enabled, issue the command

```
.SQPATCH
```

BAUD

Syntax: port baud-rate BAUD

Sets the baud rate for one of the serial ports on the DM16, in bytes per second. port can be

- 0, for the *DATA OUT* port, or
- 1, for the *GPS* port.

For example,

0 38400 BAUD
1 4800 BAUD

This will reset a standard DM16 to its default configuration.

The allowable values for *baud-rate* are 4800, 7200, 9600, 14400, 19200, 38400, 57600 and 115200. For compatibility reasons, 1152 is also accepted, setting the baud rate to 115200.

GPS inputs should always be set to 4800 baud.

RE-BOOT

Syntax: RE-B00T (interactive)

Causes the DM24 to reset after a delay of 2 s.

```
RE-B00T
Confirm with 'y' ? y
```

Responding to the confirmation message with anything other than y will abort the reset.

5.5 Output configuration

SAMPLES/SEC

Syntax: *tap-0 tap-1 tap-2 tap-3* samples/sec

The DSP software on the DM16 supports up to 7 cascaded filter/decimation stages. At each stage, the sample rate can be decimated by a factor of 2, 4 or 5. The ADC within the unit outputs data at 2000 samples/sec, so decimated data streams are available from 1,000, 500 and 400 samples/sec down to 1 sample/sec.

You can specify the sample rate to use at four of these stages, known as *taps*. You can also take output from any of these four stages. The DM16 will arrange the remaining stages according to your settings.

The arguments *tap-0* to *tap-3* are the sample rates at each tap in turn, starting with the highest. You must ensure that each rate is lower than the previous one by a factor of 2, 4, 5, 8 (= 2 then 4), 10 (= 2 then 5) or 16 (= 4 then 4). Non-integer values are not allowed.

For example:

```
1000 125 25 5 samples/sec
1000 500 100 10 samples/sec
500 100 20 4 samples/sec
400 40 10 5 samples/sec
```

As long as you specify the initial taps, you can omit later ones. The command fills in the value of the missing taps, using a decimation factor of 2 where possible. Thus, the following commands are equivalent:

```
400 40 20 10 samples/sec
400 40 samples/sec
```

Currently the DM software does not support the new GCF format for higher sample rates. It also does not properly support 250 samples/s, nor rates below 1 sample/s.

CONTINUOUS

Syntax: *tap components* CONTINUOUS

Sets which components are output under normal conditions, and at which tap(s).

tap is the tap number at which to output the triggered stream. You can set which taps output which sample rate using the SAMPLES/SEC command, described above.

components is an integer below 16, whose binary bits represent the *Z* (1), *N* (2), *E* (4) and auxiliary (8) components respectively. Thus, for example,

- 0 1 CONTINUOUS will output the *Z* component only (1) at the first tap;
- 0 2 CONTINUOUS will output the *N* component only (2);
- 0 4 CONTINUOUS will output the *E* component only (4);
- 0 7 CONTINUOUS will output all three directional components (1 + 2 + 4 = 7);
- 0 12 CONTINUOUS will output the *E* component and the auxiliary component (4 + 8 = 12);

- 0 0 CONTINUOUS will output nothing at this tap.

To set triggered output streams, you should use the TRIGGERED command detailed below.

5.6 Triggering

TRIGGERS

Syntax: components TRIGGERS

Selects which component or components can generate an STA/LTA trigger. Only these components will be examined by the triggering algorithm.

components is an integer below 16, whose binary bits represent the *Z* (1), *N* (2), *E* (4) and auxiliary (8) components respectively as described above. Issuing 0 TRIGGERS will disable the triggering system.

TRIGGERED

Syntax: tap components TRIGGERED

Selects which component or components will be *output* when a trigger is generated, and at which tap (sample rate).

tap is the tap number at which to output the triggered stream. You can set which taps output which sample rate using the SAMPLES/SEC command, described above.

components is an integer below 16, which represents which components to output in the same fashion as in the CONTINUOUS command, above.

(This command and the previous one have similar names; remember that a component TRIGGERS the system, whilst taps and components are TRIGGERED.)

STA

Syntax: Z-secs N-secs E-secs X-secs STA

Sets the length of the “short-term” averaging period in the STA/LTA triggering algorithm.

Z-secs, N-secs, E-secs and X-secs are the time period over which to calculate the average for the *Z*, *N*, *E*, and auxiliary components respectively. If a component is not considered by the triggering algorithm (see TRIGGERS, above), the value you specify here will be ignored.

For example, 1 1 2 2 STA will calculate short-term averages over 1 s for the *Z* and *N* components, and over 2 s for the *E* and auxiliary components.

If you issue STA with only one argument, it is used for all four components. For example, 5 STA will calculate averages over 5 s of all components.

LTA

Syntax: Z-secs N-secs E-secs X-secs LTA

Sets the length of the “long-term” averaging period in the *STA/LTA* triggering algorithm.

Z-secs, N-secs, E-secs and X-secs are the time period over which to calculate the average for the *Z*, *N*, *E*, and auxiliary components respectively. If a component is not considered by the triggering algorithm (see TRIGGERS, above), the value you specify here will be ignored.

For example, 15 20 20 20 STA will calculate long-term averages over 15 s for the *Z* component, and over 20 s for the *N*, *E* and auxiliary components.

If you issue STA with only one argument, it is used for all four components. For example, 5 STA will calculate averages over 5 s of all components.

RATIOS

Syntax: Z-ratio N-ratio E-ratio X-ratio RATIOS

Sets the ratio of STA to LTA above which a trigger will be declared in the *STA/LTA* triggering algorithm.

Z-ratio, N-ratio, E-ratio and X-ratio are the time period over which to calculate the average for the *Z*, *N*, *E*, and auxiliary components respectively. If a component is not considered by the triggering algorithm (see TRIGGERS, above),

the value you specify here will be ignored.

For example, 4 10 10 10 RATIOS will cause the DM16 to trigger if the STA/LTA ratio is above 4 for the Z component, *or* above 10 for the remaining components.

BANDPASS

Syntax: tap filter BANDPASS

Instructs the DM16 to pass the stream(s) which generate *STA/LTA* triggers through a band-pass filter before examining them. The corner frequency of the band-pass filter is determined from tap and filter:

- filter = 1 creates a filter with a corner at 10 % of the Nyquist frequency for tap tap (*i.e.* 5 % of its sample rate)
- filter = 2 creates a filter with a corner at 20 % of the Nyquist frequency for tap tap (*i.e.* 15 % of its sample rate)
- filter = 5 creates a filter with a corner at 50 % of the Nyquist frequency for tap tap (*i.e.* 25 % of its sample rate)

When *LOWLATENCY* is active, this command is used to set the tap used as the source of low-latency data. Data from this tap is decimated inside the DSP, and output on a separate stream at a rate 10 times slower than the configured rate.

MICROG

Syntax: level MICROG

Sets the output level above which a trigger will be declared in the *LEVEL* triggering algorithm. level is measured in counts.

HIGHPASS

Syntax: filter HIGHPASS

Instructs the DM16 to pass the stream(s) which generate *LEVEL* triggers through a high-pass filter before examining them. filter can be

- 1, for a 100 s high pass filter,
- 2, for a 300 s filter,
- 3, for a 1000 s filter, or
- 0, to disable the high pass filter.

PRE-TRIG

Syntax: time PRE-TRIG

Sets the pre-trigger recording time. time is the number of seconds of data to output from *before* a trigger is declared.

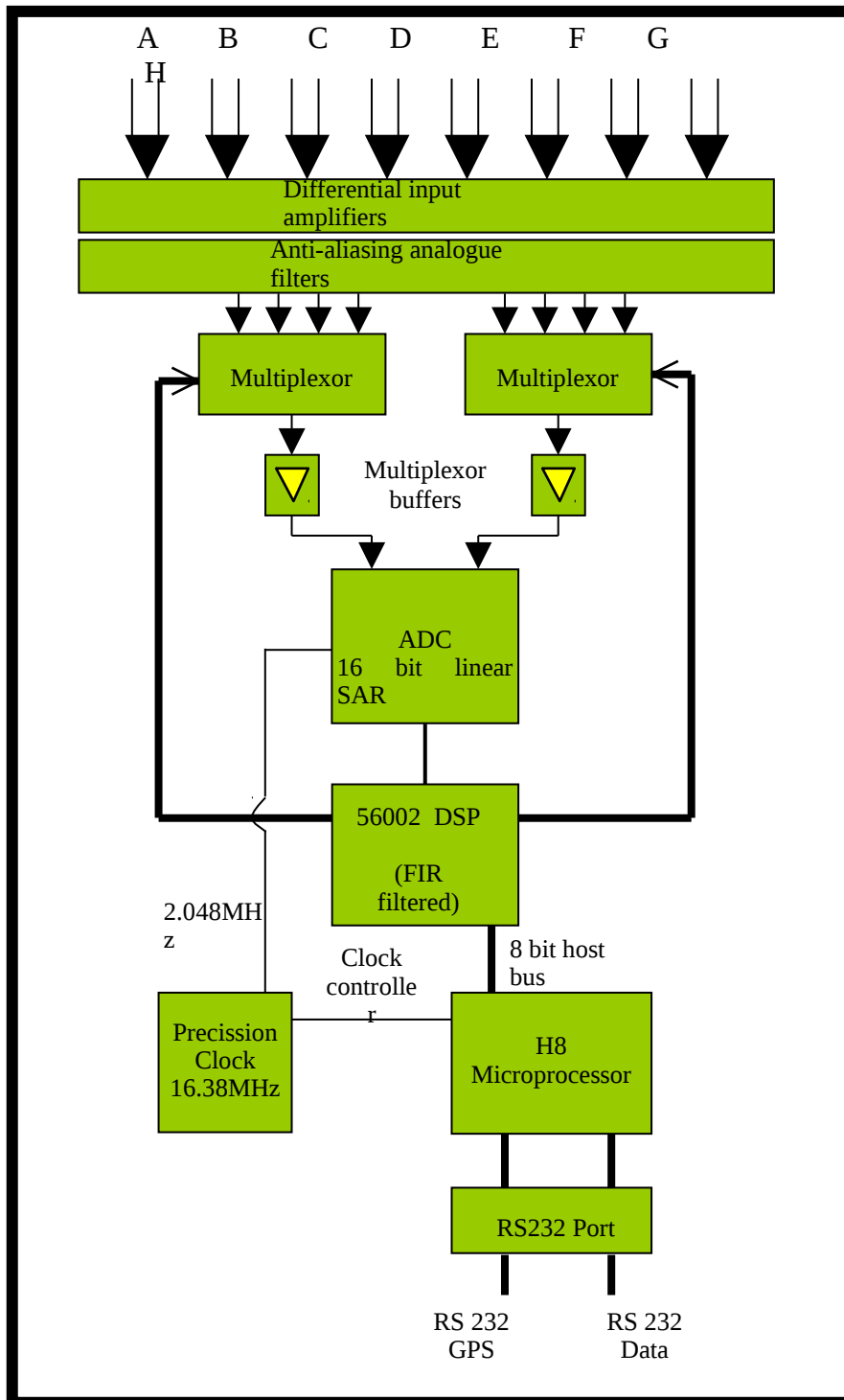
POST-TRIG

Syntax: time POST-TRIG

Sets the post-trigger recording time. time is the number of seconds of data to output after a trigger condition lapses. If an event persists for some time, *all* triggering components must fall below the threshold before the trigger condition will lapse; only then will the post-trigger period begin.

6 Inside the DM16

The DM16-R8 system design block diagram is given below. Each section of the block diagram represents a separate printed circuit board



The system is designed around a low power, high performance

16bit microprocessor (Hitachi H8/500 series) and utilises the Motorola 56002 DSP, triggered by the H8 timing system

The H8 features a large address space (1Mb - 16 *64k pages) for data storage and manipulation and many integrated functions such as multiple timers and serial i/o ports.

The modular (paged) structure of the processor architecture is used to advantage in the modular design of the system, each module being assigned to a separate 'page'. Each module is associated with an 'I/O' function and can simply be added to the system at an available page. Every 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 it's ability to synchronise the sampling of the analogue to digital converter to an external time reference so that data samples are accurately time stamped (at the source). The microprocessor timebase serves as the system time reference and can be synchronised and tuned to an external reference such as GPS to maintain sampling accurately synchronised to UTC. To avoid the cost and power consumption of multiple GPS receivers in larger arrays the systems can also be synchronised to a centrally transmitted time reference using a scheme similar to that employed by the National Radio Time Standards (WWV,MSF and DCF77). As this 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 16 bit digitizer system the microprocessor timebase is run from a precision voltage controlled oscillator which is software controlled from the external reference so that its frequency is accurately set and maintained with temperature and ageing. The control is sufficiently accurate to maintain precision sampling for long periods (several hours) in the absence of an external reference once the system has stabilised.

All the timing functions are derived via the internal timer/counter channels from the precisely set processor frequency so that sampling and time-stamping are accurately maintained with reference to UTC. The system also automatically compensates for the pure time delay introduced by the digital filtering/decimation of the DSP which provides data output at different sample rates simultaneously.

The main microprocessor board incorporates a battery-backed Real-Time Clock and RAM which is used to set the systems 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 timebase 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 DSP software consists of 3 cascaded programmable filter/decimation stages allowing multiple data output rates to be simultaneously selected. The first stage is set to decimate the data by 10 resulting in a data output rate of 200 samples/sec. The following 2 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.

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 serial port module includes 32k RAM for data buffering and formatting by the transmission/reception process.

7 Connector pinouts

7.1 Power connector

This is a Binder series 712 subminiature circular connector.

Pin	Function
1	+10 to +36 V DC power
2	0 V power

7.2 Data connector

This is a standard 9-pin “D”-type plug.

Pin	Function
2	RS232 Tx
3	RS232 Rx
5	Isolated Ground
6	RS422 Tx, +ve
7	RS422 Tx, -ve
8	RS422 Rx, +ve
9	RS422 Rx, -ve

7.3 GPS IN connector

This is a standard 9-pin “D”-type socket.

Pin	Function
6	+V Supply Out
3	GPS Rx
5	Isolated Ground
8	1Hz Reference
9	0V Supply Out

7.4 GPS OUT connector

This is a standard 9-pin “D”-type plug.

Pin	Function
3	GPS Rx
5	Isolated Ground
8	1Hz Reference

7.5 MONITOR connector

This is a standard 9-pin “D”-type socket.

Pin	Function
1	VCC
2	RS232 Tx
3	RS232 Rx
4	Bypass (Connect to VCC to enable Bypass)
5	Isolated Ground
6	RS422 Tx, +ve
7	RS422 Tx, -ve
8	RS422 Rx, +ve
9	RS422 Rx, -ve

7.6 Input connector

This is a standard 25-pin “D”-type plug.

Pin	Function
1	Signal Ground
2	Channel A, -ve
3	Channel B, +ve
4	Signal Ground
5	Channel C, -ve
6	Channel D, +ve
7	Signal Ground
8	Channel E, -ve
9	Channel F, +ve
10	Signal Ground
11	Channel G, -ve
12	Channel H, +ve
13	Signal Ground
14	Channel A, +ve
15	Signal Ground
16	Channel B, -ve
17	Channel C, +ve
18	Signal Ground
19	Channel D, -ve
20	Channel E, +ve
21	Signal Ground
22	Channel F, -ve
23	Channel G, +ve
24	Signal Ground
25	Channel H, -ve

8 Revision history

2006-11-29	C	Updated; added revision history
2001-06-01	B	Previous release