# HRD-24 Manual

# HRD24 Manual

## Revision History

Style Sheet is: X:\Company\SmartMasters\Orion

Filenames are: X:\Company\Manuals\
G:\Manuals & graphics\Manuals\ReferenceManual\Components\HRD24\RevD
X:\Company\Manuals\hrd\RevB\HRD24aTitleWP

| Rev | Date | Author | Description |
|---|---|---|---|
| A | 18 Feb 97 | Mark Hayman | Initial release. V5.10 software |
| B | 18 Mar 98 | Mark Hayman | Manual updated for remote GPS |
| C | 24 Nov 99 | Mark Hayman | Update CMG40T connection table<br>Update Appendix A<br>Add Appendix I - HRD Grounding Scheme |
| D | 24 May 00 | Mark Hayman | Update Appendix A |

Approval: ________________________________

Table of Contents

# 1. Introduction

Congratulations on your choice of HRD24 digitizer. As you use your new HRD24 digitizer we know you will appreciate the many features that provide excellent performance.

It is very important to understand how the HRD24 digitizer operates before you use it. On the following pages you will find a wealth of information regarding all aspects of HRD24 digitizer. Please read the instructions carefully.

If you have problems or need technical support, please submit requests for technical support by e-mail or fax. This permits you to fully explain your problem and include "evidence" as it allows us to submit your problem to the most knowledgeable person for reply.

**by e-mail:** **support@nanometrics.ca**

**by fax:** **To: Support at fax (613) 592-5929**

**by phone:** **Please ask for Support at (613) 592-6776**

**Nanometrics Inc.**
**250 Herzberg Road**
**Kanata, Ontario Canada**
**K2K2A1**

# 2. Organization of this Manual

This manual is organized in ten major sections:

| | |
|---|---|
| **Chapter 1** | Introduction. |
| **Chapter 2** | Organization of this Manual. |
| **Chapter 3** | Unpacking and Post Delivery Inspection identifies the components you have purchased. It also references an "as-shipped" section. |
| **Chapter 4** | This chapter discusses how to use the digitizer for the first time |
| **Chapter 5** | Hardware setup is covered here |
| **Chapter 6** | Software configuration is covered in this chapter |
| **Chapter 7** | This chapter gives an overview of the HRD24 |
| **Chapter 8** | Servicing is covered here. |
| **Appendices** | These list mostly tabular material such as error messages, and pin connections. |

# 3. Unpacking & Post Delivery Inspection

Open and inspect the shipment for possible damage. Carefully check each item for damage or defects.

The system should have the following contents:

1. HRD24 digitizer
2. GPS Antenna and Mounting Bracket
3. 2m Antenna Cable
4. HRD24 digitizer Manual
5. As-shipped Sheet
6. Release Notes (if applicable)
7. HRD Test program (on diskette)

### Checking the As-Shipped Sheets

As written, this manual covers the HRD. Please study the as-shipped data sheet to determine the exact configuration of the digitizer. The as-shipped sheet lists the serial numbers of the parts shipped, the exact hardware configuration and calibration constants associated with your hardware. It also includes a hard copy of the as-shipped sheet of the HRD24 digitizer. This will determine how your HRD24 digitizer operates when first turned on. Several features may have been added to the digitizer since this manual was released. Such new features are described in the Release Notes which have precedence over what is in the manual.

### Backup

It is strongly recommended that you backup the diskette.

# 4. Getting Started

## Introduction

This section is intended to provide the information required to verify that the HRD is performing correctly when received by the customer. Prior to proceeding with field installation, we recommend reading the entire manual before finalizing on the many options which are available to match the digitizer to the actual application.

### Getting on the air - basics

To get started you will need the equipment shown in the table below:

| Quantity | Description |
|---|---|
| 1 | Power Supply, 10V-15V, 2A or 12V battery |
| 1 | IBM compatible personal computer (PC) with DOS, OS2 or WIN95/NT. This should include a VGA graphics adapter and an unused serial port |
| 1 | Seismometer or signal generator (optional) |
| 1 | Test cable |

This startup procedure verifies that the HRD is running and then displays waveform traces on the PC screen using ViewDat test program.

Copy the files from the disk to a new directory on your hard disk and make this the working directory. Using the cable harness provided, connect the HRD to the power supply (Red and Black Banana Plugs) and connect HRD to the COM port on the PC.

Start the ViewDat from the command prompt (see Appendix A).

Once the HRD has finished its self test it will start transmitting data.

In the waveform display mode of ViewDat, the HRD test program, a trace for each active channel will appear on the screen. With no input signal connected to the HRD24 signal input connector, you should see noise for all channels. To increase the sensitivity of the display and see the noise in more detail, change the scale factor of the screen display.

To check the HRD24 using a signal generator connect the signal source to the HRD using the pinout given in section 9.3. Full scale voltage input will be $+/- \ 5.3 \times 10^5 \ S_D$ where $S_D$ is digitizer input sensitivity in nV/bit as stated in the as-shipped sheet. Input impedance for the HRD is also stated on the as-shipped sheet.

# 5. Configuring the Hardware

### Transmit - only sites

The simplest HRD24 installation is at a remote site where there is no reverse communications link and the digitizer simply requires power from a 12V source. The transmit data and return would be connected to either a radio or a modem using RS232 convention. The HRD24 input impedance may have been set at the factory to correctly damp the seismometers which are to be used. Please consult the as-shipped sheet to verify. If it is set at a high impedance level (20K) the user must either provide the correct external damping resistors or, alternatively, add the damping resistors to the empty resistor locations on the HRD24 analog board. Please see Appendix A for instructions on how to set the damping resistors. The user may have the optional calibration support. Described below is the calibration procedure.

*Signal Connector* — Connect the seismometer signal coil pins to the HRD24 input signal connector using sensor connector pins A-B, F-G, and L-M. Use twisted pair cable with shield and connect the shields to pins E, K, and R respectively. Note that the HRD24 inputs are differential with respect to ground.

*Power Connector* — Connect the 12V power source to pin A (+12V) and pin B (+12V rtn.). Note that the power ground is isolated from the HRD24 signal ground, digital ground, and the HRD24 container. Connect TX of the output data pair to pin R with the ground reference connected to pin N and then route the cable to the modem/radio/PC. The RS232 output will drive cable lengths up to 30m.

### Full Duplex Links

This refers to links which can transmit data in both directions concurrently. Such a service is normally provided with modems, but when using radio links, requires a reverse radio link as well. With full duplex links calibration support as described below is normally implemented.

### Configuration Port

A second communication path is available for reconfiguring a running digitizer on the fly. It is called the config port or USCB port.

### Calibration Support (Not Implemented)

The HRD24 can initiate calibration sequences on receipt of commands over an RS232 link if the calibration option for the digitizer has been purchased.

If the seismometers are equipped with calibration coils, then the user should consider if additional pairs of wires should be used to connect the calibration coils to the HRD24. The connection to the digitizer depends on whether an active or passive sensor is used.

See the as-shipped sheet for the sensitivity, range and output impedance.

### Analog Input Characteristics

#### Input Impedance

The input impedance of the HRD24 is normally set to suit the customers sensors (see as-shipped sheet). The user may change the input impedance to dampen the seismometer response if desired. There is one resistor required for each channel to set the impedance.

The resistor value is determined by the desired input impedance and the parallel resistance of 5.0Mohms. $R_{set} = (R_{damp} * 5 * 10^6) / (5 * 10^6 - R_{damp})$. For most practical applications set the resistor value to the desired input impedance. The resistors to set are R85, R86, and R87 (on the ADC board #642) for channels 1-3 respectively. Please see the drawing in the servicing chapter for the location of these resistors. If the unit has six channels then channels 4-6 can be set in exactly the same way.

### Input Sensitivity

The as-shipped input sensitivity of the HRD24 is shown in the as-shipped sheets. The user may change the input sensitivity if desired. There is one resistor required for each channel to set the sensitivity.

***NOTE: there are two different styles of ADC cards. The as-shipped sheet will indicate which style is in your digitizers.***

**New Style: after June 96 (Part #10981)**

gain = 1.275 uV/bit / desired sensitivity (uV/bit)
Rgain = 2 * 10e4 / (gain x 2 -1)

The maximum input voltage will be 40 Vpp/gain.

**Old Style: before June 96 (Part #10128)**

gain = 1.92 uV/bit / desired sensitivity (uV/bit)
Rgain = 2 * 10e4 / (gain -1)

The maximum input voltage will be 20 Vpp/gain.

The sensitivity can be increased by soldering one resistor per channel onto the ADC printed circuit board. For example, to achieve an overall sensitivity of 192 nV per bit (old style), each gain-setting resistor should be set to 2.22K ohms. Figure 8.1 on page 24 shows the location of the gain-setting resistor for each channel. The gain resistor for channel 1 is R18, channel 2 is R19, and channel 3 is R60.

The resistors to set are on the ADC board drawing #642 for channels 1-3 respectively. If the unit has six channels then channels 4-6 can be set in exactly the same way.

## Sensor Interface

### Sensor Power

Sensor power is not provided as a standard feature but it is available as a no-charge factory option. +/- 12V at 10mA can be provided using 3 pins on the sensor connector which are reserved as follows:

| | |
|---|---|
| +12V | Sensor pin S |
| -12V | Sensor pin U |
| Gnd | Sensor pin T |

### Active Sensor Interface

The HRD24 can optionally control active sensors such as the Guralp CMG-3T broadband seismometer. When this option is selected the pin designations of the signal connector changes to provide the appropriate signals. Refer to pinouts for connections.

The signal input impedance will be set to the high impedance state for this type of sensor.

*Calibration* — The calibration signal will appear on only one pin of the signal connector. It will be generated when ever calibration is enabled. There are three calibration enable signals intended to enable the internal relays of the seismometer. These signals are open drain signals that are active low. They can withstand voltages up to 20 Volts.

| | |
|---|---|
| *Mass Position Indication* | The mass position indicators from the seismometer are connected to three of the SOH analog inputs in the digitizer (this is available). |
| *Mass Locking/Unlocking* | The masses may be locked or unlocked by the digitizer software. The digitizer generates the logic signals required to control the seismometer lock/unlock functions. |
| *Mass Centering* | The masses may be centered by the digitizer software. The digitizer generates the logic signals required to control the seismometer centering function. |
| *6 Channel Digitizer* | Installation for 6-channel digitizers proceeds as for 3-channel units. Note that the 6-channel HRD24 uses two sensor connectors each following the same pinout. The front panel labels the connectors SIGNAL A and SIGNAL B respectively. |

## Basic troubleshooting

### HRD looks dead after power on

Check batteries.

Check connections.

Check fuses.

### Unable to communicate with HRD on startup

If the HRD fails to send any data carefully examine the terminal emulator (ZOC, ViewDat, ProcommPlus) output. If you see a message "Frame error" possibly accompanied by some garbage data, the HRD is probably sending data at a different baud rate than that for which HRD test program is configured. Carefully check the factory documentation to determine for what baud rate the HRD was configured.

### Noisy data

Is the data bad on all channels, or just one or two? If this is the case, you should carefully check the corresponding connections. Check to ensure that the channel responds to an input stimulus. (Disconnecting it, or lightly tapping the sensor should prove sufficient) Do one or more channels show a flat line? Do the state of health header fields indicate a problem with that channel? Try switching the sensors around to see if the problem stays with the same channel or moves.

### GPS not locking

Most problems with the GPS engines can be traced to a poorly placed antenna. If the GPS is not receiving well, try repositioning the antenna to a more favourable location. Lastly, ensure the antenna cable is not hanging from the antenna. Secure the antenna cable with a few tie wraps near the antenna to carry the weight of the cable.

The GPS should lock on its own if there is sufficient signal strength. If the GPS is not locking within 15 minutes of power-on, follow the procedure below:

1. Go to the GPS screen on ViewDat.
2. Examine the GPS status on the screen. Are any satellites being tracked?
3. Examine the signal strength values. The signal strength (S/N) from the satellites should be greater than 38.
4. Reposition the antenna to a better location.
5. The GPS clock should lock now.

# 6. Firmware Configuration

## Overview

Configuration Parameters tell the HRD24 how it should operate. There are two sets of configuration parameters:

1. Stored User Settings (those in Flash, saved from a previous session)
2. User Settings in RAM

### Stored User Settings

Stored User Settings are User Settings that are stored into the Flash memory and do not lose their values even after power is switched off. The HRD should be configured correctly when received.

### User Settings in RAM

User Settings in RAM are read in by the HRD on powerup from the Stored User Settings.

The User Settings in RAM are those that you are actually changing when you modify parameters. These settings may be saved for use by selecting 'P' from the main menu or discarded by selecting 'R' from the main menu or powering off the HRD.

### Accessing the HRD24 Setup

To access the menu of parameters, use a terminal or PC with a terminal emulator connect to com 2 of the HRD24. Any terminal emulator such as ZOC, Procomm or Crosstalk can be used. Start the terminal emulator. The default communication parameters are 9600, 8 bits, no parity, 1 stop bit, unless the user had previously changed these parameters. Upon startup, the following dialog should appear on the screen:

Tcp version 5.10, compiled Feb 20 1997 20:25:56

Press 'M 'key within 5 seconds or during memory test

Queue Event, empty
Queue Tx1, empty
Queue Tx2, empty
Queue Old, empty
Queue Junk, count = 191, head = 10000, tail = 3faf8
Channel 1, empty
Channel 2, empty
Channel 3, empty
Channel 4, empty
Channel 5, empty
Channel 6, empty
Channel Status, empty
Pointer Tx, empty
Memory Buffer, messages = 191

When these messages appear hit an 'm' or 'M' to access the HRD24 menus. The Setup Menu (Main Menu) will then appear as follows:

**Orion / HRD Setup Menu**

C: Configuration menu

U: Upload new firmware
P: Program user settings
R: Restart and run with saved settings

**Menu Option:**

If you wait more than 5 seconds, you will still have the ability to enter the menu again by pressing 'm' or 'M' anytime after the DSP starts digitizing data. At that point, the data flow will halt when you are in the menu and later resume again using the new parameters you have specified.

The sub-menus can be reached by pressing the corresponding key, for example: type 'C' to access the Configuration sub-menu. To exit from the Main Menu type 'R'. This allows the HRD24 to start normal data acquisition. To exit from any given sub-menu press the Escape key. This brings you back one level of menu. Typing a space or pressing the Enter key redisplays the current menu. The digitizer is not case sensitive.

If the startup message does not appear or is different then please consult the factory. The menus may also be remotely accessed via a dial-in modem, if the digitizer has been so configured.

## Configuration Menus

The configuration menus allow the user to tailor the HRD24 for a specific application. Care must be taken when configuring these parameters. Understand what a parameter does before changing it. Generally, the HRD24 and Orion are preconfigured at the factory and the user should not have to modify the parameters in these menus.

After the HRD has been reconfigured, the "Program user settings" option in the top-level Setup Menu must be selected to save the new configuration.

### Configuration Top Level Menu

All of the items in the main configuration menu are submenus.

**HRD Configuration Menu**

H: Edit hardware setup parameters
I: Edit input sensitivity & impedance parameters
G: Edit gps power cycling parameters
S: Edit soh calibration parameters
L: Edit log settings parameters
D: Edit digitizer parameters
P: Edit data port parameters
O: Edit Orion specific parameters
X: Edit temperature coefficients

### Configuration Submenus

#### Hardware Setup Menu

The parameters in this menu tell the software what hardware is in the HRD. The serial number should not be changed unless some board swapping is done. The number of channels defines the number of physical ADC channels present. This is usually 3 or 6 channels. The number of memory banks defines the number of 256K blocks of memory present in the HRD. For HRDs with no memory, this value is 0. For Orion this value is 8, and HRDs with expanded memory the value is 13. The PIC version number applies to the Orion only which is preconfigured and should not be changed. The last item sets the baud rate for the configuration port.

**Hardware Setup Edit Menu**

| | | |
|---|---|---|
| S: | Serial number: | 000153 |
| C: | Number of channels: | 3 |
| B: | Number of memory banks: | 0 |
| P: | Pic version number: | 2 |
| B: | Configuration Baud rate: | 9600 |

## Input Sensitivity & Impedance Menu

The input sensitivity & impedance menu is used to store the ADC gain and damping resistor values. When you change the ADC gain and damping resistor values, update this table at the same time. It saves having to disassemble the HRD24/Orion in the future to determine the values. The first value is the sensitivity and the second value is the impedance as shown in the menu below. These values are not used within the HRD24. On the Orion, these values are used by the Channel Sensitivity menu and should be set correctly.

**Input Sensitivity & Impedance Menu**

| | | sensitivity (nV/bit) | impedance (ohms) |
|---|---|---|---|
| 1: | Channel 1: | 1.000 | 1.000 |
| 2: | Channel 2: | 1.000 | 1.000 |
| 3: | Channel 3: | 1.000 | 1.000 |
| 4: | Channel 4: | 1.000 | 1.000 |
| 5: | Channel 5: | 1.000 | 1.000 |
| 6: | Channel 6: | 1.000 | 1.000 |
| A: | Channels 1-3 | | |
| B: | Channels 4-6 | | |
| C: | Channels 1-6 | | |

## GPS Power Cycling Menu

The GPS edit menu configures the power cycling parameters for the GPS engine. The GPS may be have power cycling enabled (1) or disabled (0). If power cycling is disabled the GPS engine is on continuously (this is recommended for most HRD applications). Power cycling is used to conserve power and trades off against timing accuracy. The power interval is the time between GPS power ups. Every 30 minutes is recommended. The maximum on duration is the time the GPS will remain on if it cannot lock (5 minutes is recommended).

**GPS Power Cycling Menu**

| | | |
|---|---|---|
| C: | Enable power cycling: | 1 |
| I: | Power interval (min): | 60 |
| D: | Maximum power duration (min): | 10 |

## SOH Calibration Menu

The SOH information is transmitted by the HRD in a floating point format of user units such as temperature. This menu allows the user to set the conversion factors for the SOH values. The conversion factors are sensitivity (units/v) and offset (units) and the conversion formula is:

SOHValue = Sensitivity (units/v) * value (V) + offset (units)

The value is a factory calibrated voltage measurement of the SOH input. The first value in the menu below is the sensitivity and the second is the offset.

**SOH Calibration Menu**

| | | Units Per Volt | Units Offset |
|---|---|---|---|
| A: | Fast soh 1: | 1.000 | 0.000 |
| B: | Fast soh 2: | 1.000 | 0.000 |
| C: | Fast soh 3: | 1.000 | 0.000 |
| 1: | Slow soh 1: | 1.000 | 0.000 |
| 2: | Slow soh 2: | 1.000 | 0.000 |
| 3: | Slow soh 3: | 1.000 | 0.000 |
| F: | Fast soh 1-3 | | |
| S: | Slow soh 1-3 | | |

## Log Settings Menu

This menu sets how often the SOH information is recorded and transmitted. The verbosity sets the HRD instrument log reporting detail. This should be set to normal(30). The verbose mode (31) is used for debugging only.

The fast and slow SOH interval set how often the fast and slow SOH information is recorded and transmitted. This value is in seconds. Fast SOH can be sampled a maximum of once a second and slow SOH can be sampled a maximum of every 8 seconds. Typically, these values are set to once a minute to once every 10 minutes. The setting will depend somewhat on the transmission link bandwidth.

**Log Settings Menu**

| | | |
|---|---|---|
| V: | Verbosity: | 31 |
| F: | Fast SOH interval (sec): | 60 |
| S: | Slow SOH interval (sec): | 60 |
| G: | GPS interval (sec): | 60 |

## Digitizer Menu

The DSP edit menu sets up the parameters associated with the seismic data channels. The number of channels is the transmitted number of channels. You can have a 3 channel digitizer and only transmit one channel of data. The sample rate may be any of the following sample rates:

10, 20, 40, 50, 80, 100, 125, 200, 250, 500, 1000 s/s

The DC removal may be enabled(1) or disabled(0). The DC removal filter is a first order IIR filter which is done after all the FIR filtering. The DC removal filter frequency may be set in the following range of 1 to 1000 milliHertz.

**Digitizer Menu**

| | | |
|---|---|---|
| C: | Number of channels: | 1 |
| S: | Sample rate: | 100 |
| D: | DC removal enabled: | 1 |
| F: | DC removal frequency (mHz): | 50 |

## Data Communications Menu

This menu sets up the data port on the HRD. The baud rate may be any of the standard baud rates. Changing the tx baud rate will change the rx baud rate also, however a different rx baud rate may be specified. Radio mode may be enabled(1) or disabled(0). If the HRD is connected to a radio transmitter this mode should be enabled. In radio mode, the HRD adds filler characters and scrambles the data to keep the transmitter working well.

The bundles per packet defines the length of the transmission packets. This allows the user to tailor the HRD to the radio link. If the link is noisy then shorter packets are called for. If the link is quiet, the packet can be longer. Typically, 59 bundles per packet is used in most installations. See the data format section for more information on this. If the data communications link supports 2 way communications and the acquisition program will request missing data, re-tx requests may be enabled (1), otherwise re-tx requests should be disabled (0). The tx twice may be enabled (1) or disabled (0). The tx twice delay (in seconds) sets the time delay for transmit twice.

**Data Port Menu**

| | | | |
|---|---|---|---|
| B: | Tx & Rx Baud rate: | 9600 | 9600 |
| N: | Bundles per packet: | 59 | |
| R: | Enable radio mode: | 1 | |
| X: | Enable re-tx requests | 0 | |
| 2: | Enable tx twice: | 2 | |
| D: | Tx twice delay (sec): | 60 | |

### TCXO Calibration Menu

This menu is sets the temperature curve for the ADC crystal. The only time these values should be changed is when ADC or TCP cards are swapped between HRDs. DO NOT USE this menu otherwise. These coefficients are calibrated at the factory and should never need to be changed. Consult the factory for further details.

**Temperature Coefficients Menu**

| | |
|---|---|
| U: | Upload new coefficients |
| I: | Initialize coefficients |
| C: | Check coefficient checksum |
| V: | View coefficients |

### Orion Specific Menu

In this menu, the Enable Orion mode must be set to 0. This puts the HRD into HRD mode. Do not change the other parameters.

**Orion Specific Menu**

| | | | | |
|---|---|---|---|---|
| O: | Enable Orion mode: | 0 | | |
| M: | Disk heat mode: | 3 | | |
| H: | Minutes of heat per degree: | 8 | | |
| R: | Safe disk temperature range (C): | 5 | 50 | |
| V: | Battery voltage levels: | 12.25 | 11.5 | 10.9 |

# 7. Technical Description

## Overview of the Hardware

### Functional capabilities

The HRD24 will digitize from one to six channels of data with sample rates from 10 s/s to 1000s/s. Data are assembled into packets with a CRC for error detection. Each packet includes a comprehensive header which holds parameters such as the sequence number, time in long seconds and the oldest packet available. See the appendix for more information on the data format.

The HRD24 may have two software filters. The first filter is a decimating FIR (Finite Impulse Response) filter which is used for low pass filtering of the data. This is always required due to the nature of Delta-Sigma converters. The second filter is an optional IIR (Infinite Impulse Response) high pass filter to remove the DC offset from the data. Appendix D shows the corner frequencies of these software filters.

An internal or external GPS clock is used for time synchronization.

The SETUP menu is used to configure the digitizer parameters to suit the application and to store these parameters in the non-volatile Flash memory chip. A full list of configurable parameters is given in the Configuring the Firmware chapter.

### HRD Time and output data timing

The HRD24 keeps internal time which is referenced to a GPS clock. If the GPS clock is not locked the HRD24 can free run on its own internal oscillator. When the GPS relocks, the HRD24 will phase lock back onto the GPS time. All data from the HRD24 is time stamped with the absolute UTC time.

### Hardware Description

This section gives a brief overview of the digitizer hardware. Later sections of the manual will define the software. The input impedance and digitizer sensitivities are user setable parameters which are set through one resistor respectively for each channel. The user should refer to the as-shipped data sheet to get the actual values for these parameters.

A hardware block diagram is shown in Figure 7.1.

#### Differential Amplifier

There is an input differential amplifier for each channel input signal. The gain of this stage is used to set the overall system sensitivity. Gains of between 1 and 256 are typical. A potentiometer is associated with each input and is adjusted to give maximum common mode rejection. The input impedance is usually left as a high impedance input (>50K). The gain and input impedance are user setable parameters which are set through one resistor respectively for each channel. The user should refer to the as-shipped data sheet to get actual values for the resistors.

#### Analog Anti-alias Filter

The anti-alias filter requirements are quite low due to the high input sample rate used with delta-sigma converters. The anti-alias filter is a 5th order Bessel filter to give linear phase response. A single operational amplifier generates the low pass poles. The filter has a gain of 1 and is configured for low noise.

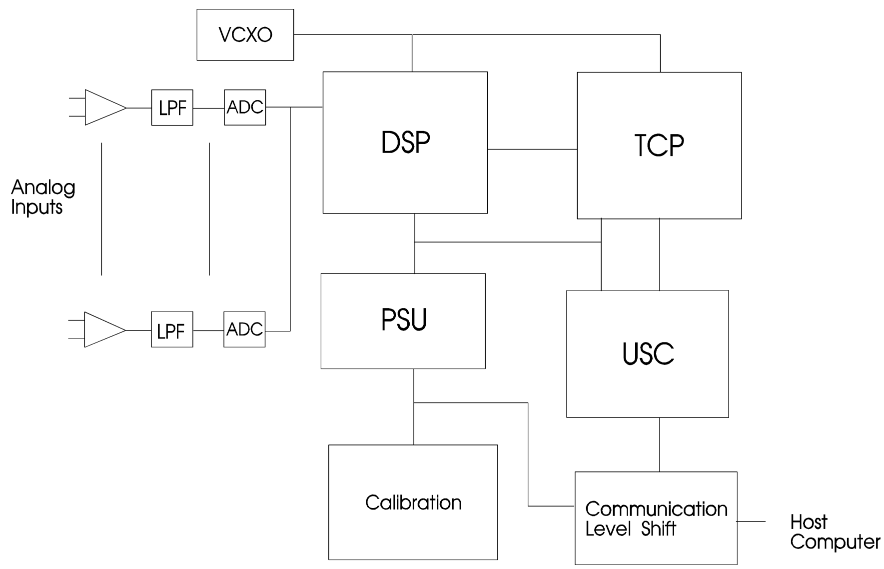
#### Analog-digital Converter (ADC) & Digital Anti-alias Filter

A 120 dB Delta-sigma modulation ADC is used for conversion. This IC samples at a high rate, digitally filters and decimates the data, and then outputs the data. This output data is then filtered and decimated by the DSP before the final resolution is achieved. Different sample rates are achieved by decimating more or less. Delta Sigma ADC output one bit of data at a high rate which is to be filtered to produce higher resolution at lower sample rates. Sample rate is traded off for resolution. This works because the delta sigma modulator has all its quantization noise at frequencies which are later filtered out.

**Figure 7.1**

### DAC and Calibration (Optional)

Calibration signals are obtained from a laser-trimmed precision 12 bit D/A converter chip. Under




software control, the calibration signal can be set to any value with a resolution of 1 in +/- 2048. Full scale is usually +/- 5V. Calibration relays switch the calibration signal to one side of the calibration coil. Another pole on the relay grounds the other end of the calibration coil when active. The as-shipped sheet specifies actual calibrator parameters. When determining sensor sensitivity, allowance must be made for the wire loop resistance and the calibration coil resistance.

### Output Ports

The internal hardware is controlled by ports on the TCP, several eight bit ports and some programmable logic. The TCP interfaces with the RS232 status bits and the universal serial controller (USC) for RS232 data.

When the calibration and/or active sensor control option is selected the TCP controls the calibration DAC and two eight bit control ports. This selects the calibration port, the calibration output signal level and frequency in addition to the active sensor control lines.

### State-of-Health

The HRD24 monitors a number of analog state-of-health (SOH) channels, six 'slow' and three 'fast'. Three of the slow channels are used internally to monitor the input voltage, the internal temperature of the VCXO and the radio signal to noise ratio. The remaining are externally available to the user.

The three external user SOH channels have input amplifiers configured as virtual ground inverters. There is a low pass filter incorporated with a 1.6Hz roll off. An open input will appear as a +2.5V input. These inputs have a range of +/- 25V and a nominal sensitivity of 48.8mV/bit.

The battery level monitor has a nominal sensitivity of 24.4 mV/bit, with an offset of +0.1V as a result of internal voltage drops.

The temperature monitors each have nominal input sensitivities of 0.217°C/bit with an offset of -61°C.

These SOH are typically sampled at 0.125Hz. The software controls how often they are logged.

In addition to these SOH there are three FAST SOH channels typically sampled at one Hz. These FAST SOH have an input range of ±10V and a sensitivity of 19.7mV/bit. An open input will appear as a 2.5V input. These inputs are used to monitor mass position in an active sensor.

The scale calibration factor is built from two constants. One is the actual sensitivity of the HRD SOH digitizer which is expressed in millivolts per least significant bit and is a factory setting. The other constant is the sensitivity of the sensor. This might be expressed as "units" per volt. For example, with a temperature sensor, this might be set to 44 degrees Celsius per volt. Both of these parameters are set in the appropriate SOH Config menu.

The offset is used to allow for the sensor not producing zero output volts when registering zero "units". The offset is expressed in "units". For example, for a temperature sensor, the offset is expressed in degrees Celsius.

The appropriate scale and offset values for the internal SOH parameters are determined during the final test and are entered into the as-shipped configuration file. A hard copy of this file is shipped with the digitizer.

### Watchdog Timer

The main processor in the HRD24 has a built in watchdog timer that protects the HRD from getting hung in an endless software loop. If for any reason the watchdog is not serviced by the software at the correct frequency, an automatic hardware reset signal is generated which restarts the entire digitizer.

### RS232D I/O

The HRD supports communication using RS232 convention. One external port will always be configured for RS232 communication. There are also status lines (CTS, DTR, and RING) which may be used for communication with a modem.

*Note: RS232 convention states that:*

} 'MARK' or off = '1' = -ve voltage on signal line

} 'SPACE' or on = '0' = +ve voltage on signal line

*where all voltages are measured with respect to logic ground.*

### RS422 I/O

One communication port of the HRD24 can be configured for communication using RS422 conventions. The receivers have a differential threshold of +/- 200mV and can accept a common mode voltage of +/- 7V.

*Note: RS422 convention states that:*

} 'MARK' or off = '1' = -ve voltage on signal line

} 'SPACE' or on = '0' = +ve voltage on signal line

*where voltage measurements are made between the '+' terminal and the '-' terminal.*

### Flash Memory

A Flash memory chip is used to store both firmware and user parameters. The contents of this chip are read on system initialization to establish such parameters as sample rate. A menu driven interface is provided to change those parameters.

#### CPU

The HRD24 uses two separate processors, a Motorola DSP56002 and an Intel 80C196NT. The DSP interfaces to the ADCs and performs the digital filtering on the raw data. After filtering is completed the data is transferred to the 80C196NT. This processor collects a packet of data and generates the correct output format before transmitting the packet of data to the host. It also performs many other timing and housekeeping functions.

#### Internal Construction

The HRD24 digitizer is designed to accept Eurocard size boards. They plug into a custom backplane. The chassis supports up to 6 cards. However, not all positions are populated at all times.

A minimum system (3 channel) consists of 5 cards: analog, TCP, communications, Mem-Cal and power supply. The analog board contains the front-end analog components and the interface between the DSP and the ADC. The TCP contains both processors, the USC, and SOH ADC circuits. The power supply contains a switching power supply. The comms card contains RS232/RS422 level shifting, SOH amplifiers and transient protection. The Mem-Cal board contains 2.0 megabytes of RAM and calibration circuits.

A six channel digitizer has an additional analog board installed beside channels 1-3. The board for channels 4-6 is different than the board for channels 1-3. However, they may be placed in either ADC slot. The board for channels 1-3 must be present at all times when the unit is running. Note that a 1-3 channel ADC is different from a 4-6 channel ADC and they are not interchangeable.

#### Internal batteries

This rechargeable lithium battery is used by the GPS engine to maintain its satellite almanac and other parameters and to run a low power real time clock. The lithium battery will maintain the GPS for 3 to 6 months.

## Overview of the Firmware

### Acquisition Software

#### Introduction

HRD24 software operates in the following areas:

- FIR low pass and decimation to support the sigma delta AD converters
- Precision time keeping and synchronization with UT using GPS
- Continuous non-approximating broadband seismic data compression
- Power on self-test
- Support and digital filtering and recording of internal and external state-of-health signals
- Support of a comprehensive information and error logging facility

#### Code storage and software updates

The software code supports three processors. Low level code is stored in electrically programmable ROM. Service procedures allow the low level code to be updated without disassembling the HRD24.

# 8. Servicing

## Maintenance

### Repair philosophy

Object is to troubleshoot to the board level and replace the board.

### Disassembly Instructions

The following tools are required:

1. Phillips screwdriver for #4 and #8 screws.

Instructions:

1. Remove all power from the HRD24.
2. Remove the screws around the edge of the front plate.
3. Remove the card cage chassis from the can.
4. Disconnect the connectors from the card cage
5. Remove the four screws holding the card cage front cover to the card cage

The cards may be removed from the card cage by extracting the cards.

### Assembly Instructions

The assembly instructions are the reverse of the disassembly instructions.

## Configuration Port

The configuration port is an RS-232 port used for configuration and firmware downloading. It is a three pin port: RX, TX, and GND. The port is on the power/communications connector:

| | |
|---|---|
| TX | Pin H |
| GND | Pin M |
| RX | Pin K |

A cable for connecting to the factory test port can be purchased from Nanometrics. To build one, use the following components:

| | | |
|---|---|---|
| 26 pin connector | Souriau | 851-06EC16-26S |
| D-sub 9 Pin Female | AMP | DE09-S |
| Shroud for D-sub | Amphenol | 17D-09DV |
| 24 AWG 3 conductor Cable | | |

The cable should be wired as follows:

| Signal Name | From Souriau Conn. | To D-Sub | Wire Gauge (AWG) |
|---|---|---|---|
| TX | Pin H | Pin 2 | 24 |
| GND | Pin M | Pin 5 | 24 |
| RX | Pin K | Pin 3 | 24 |

See Appendix F for other cables.

## Software & Firmware Updates

### Firmware Update Procedure

New firmware is downloaded through the factory test port. See the section above for a description of the factory test port.

1. Copy the firmware received on the update diskette to the PC's hard drive
2. Connect cable to factory test port via the communications connector.
3. Connect the cable to a PC communications port.
4. Start a PC terminal emulator program.
5. Set baud rate to 9600, 8 data bits, no parity, 1 stop bit.
6. Disable all modem handshaking options like RTS/CTS, DSR, Xon/Xoff DCD detection
7. Power up the HRD24.
8. There should be a few beeps on the emulator then the text
   "TCP Version X.XX, compiled (date, time)
   Press 'M' key within 5 seconds or during memory test".
   If this does not appear, then check connections and emulator settings. Note the firmware version and date at this point.
9. Press the "M" key. A menu will appear when the memory test is complete. The memory test takes 15 seconds to complete.
10. Press the "U" key to select the upload new firmware option.
11. From the terminal emulator, initiate an ASCII upload of the new hex file on the update diskette.
12. The firmware is uploaded into the HRD24. This will take about 1 minute. When the upload is complete, a message "upload completed, programming flash" will appear. A few seconds later the flash will be programmed and the HRD24 reboots. The text for the TCP version will appear again and it should display the new firmware version and date. At this point the firmware upload procedure is complete. The HRD24 is now ready for use.
    If the download fails, a download error message will be displayed, try downloading again.

***NEVER powerdown the HRD24 while it is doing a upload. This will have catastrophic results.***

## Internal Configuration Options

### Related to the seismometer input

#### Input Impedance

The ADC board provides space for an optional input shunt resistor which can be used to damp a seismometer. Calculate the required damping resistor value using instructions provide by the seismometer manufacturer. 'Active' seismometers such as the Guralp CMG40 should be used with no damping resistor.

The input impedance of the HRD24 is normally shipped in a high impedance state (see as-shipped sheet). The user may change the input impedance to dampen the seismometer response if desired. There is one resistor required for each channel to set the impedance.

The resistor value is determined by the desired input impedance and the parallel resistance of 5.0Mohms. Rset = (Rdamp * 5 * 10e6) / (5 * 10e6 - Rdamp). For most practical applications set the resistor value to the desired input impedance. Figure 9.2 shows the location of the damping resistor for each channel. The damping resistor for channel 1 is R85, channel 2 is R86, and channel 3 is R87. The resistors are located on the ADC board for channels 1-3 respectively. If the unit has six channels then channels 4-6 can be set in exactly the same way.

### Input Sensitivity

The as-shipped input sensitivity of the HRD24 is shown in the as-shipped sheets. The user may change the input sensitivity if desired. There is one resistor required for each channel to set the sensitivity.

The resistor value is determined by the following formulae:

***NOTE: there are two different styles of ADC cards. The as-shipped sheet will indicate which style is in your digitizers.***

**New Style:**

gain = 1.275 uV/bit / desired sensitivity (uV/bit)
Rgain = 2 * 10e4 / (gain x 2 -1)

The maximum input voltage will be 40 Vpp/gain.

**Old Style:**

gain = 1.92 uV/bit / desired sensitivity (uV/bit)
Rgain = 2 * 10e4 / (gain -1)

The maximum input voltage will be 20 Vpp/gain.

***For the rest of this chapter, all the calculations assume that a new style HRD24 ADC is used!***

The sensitivity can be increased by soldering one resistor per channel onto the ADC printed circuit board. For example, to achieve an overall sensitivity of 192 nV per bit, each gain-setting resistor should be set to 1.62K ohms. Figure 9.2 shows the location of the gain-setting resistor for each channel. The gain resistor for channel 1 is R18, channel 2 is R19, and channel 3 is R60. The resistors to set are on the ADC board for channels 1-3 respectively. If the unit has six channels then channels 4-6 can be set in exactly the same way.

Note with no gain resistor installed, the gain = 0.5 and the sensitivity = 2.55 uV/bit

The input impedance should be left in the high impedance state.

| Seismometer | Input Sensitivity | Input Gain | Input Gain Resistors | System Sensitivity |
|---|---|---|---|---|
| CMG40T | 800 nV | 1.6 | 9.09K ohms | 1nm/s |
| CMG40T | 2550 nV | 1 | none | 3.186 nm/s |

### Configuring for an active seismometer with mass position monitoring

The first step required when connecting to an active seismometer is setting the input sensitivity and input impedance of the ADC. The input sensitivity would either be chosen to give a system sensitivity of 1nm/s or to set the full scale levels of the seismometer and the HRD24 to be the same. Connection to an active sensor (such as CMG40T) will consist of connecting the main sensor coil to the signal inputs with the positive (+) coil connected to the positive (+) input and negative (-) to negative (-). Connect the '+' calibration output to the motor coil '+' and the '-' calibration output to the motor coil return. The output impedance of the calibration signal is 500 ohm with a maximum current of 10mA at a voltage of 5V. A series resistor is used on the calibration '+' outputs to ensure the current is limited to this value. This is not a factor with active sensors since they buffer the calibration signal internally.

The connection for three components of the CMG40T sensor is as follows:

| **Sensor Connector** | **Signal Name** | **CMG40T** |
|---|---|---|
| A | Channel 1 + | A - pair 1 |
| B | Channel 1 - | B - pair 1 |
| C | Calibration 1 + | P - pair 4 |
| D | Calibration 1 - | |
| E | Channel 1 Gnd | N-inner shield 1 |
| F | Channel 2 + | C - pair 2 |
| G | Channel 2 - | D - pair 2 |
| H | Calibration 2 + | |
| J | Calibration 2 - | |
| K | Channel 2 Gnd | inner shield 2 |
| L | Channel 3 + | E - pair 3 |
| M | Channel 3 - | F - pair 3 |
| N | Calibration 3 + | |
| P | Calibration 3 - | |
| R | Channel 3 Gnd | inner shield 3 |
| S | +12 V Sensor | c - pair 7 |
| T | Gnd Sensor | b - pair 7 |
| U | -12 V Sensor | |
| V | Chassis Gnd | outer shield to converter cage |
| W | Cal 1 Enable | R - pair 4 |
| X | Cal 2 Enable | |
| Y | Cal 3 Enable | |
| Z | Logic Gnd | shield 4, 7, 5, 6 |
| a | Mass Pos. 1 | G - pair 5 |
| b | Mass Pos. 2 | J - pair 5 |
| c | Mass Pos. 3 | L - pair 6 |

The best performance will be found using cables built in the following manner:

The connection to each sensor should be made with a 6 pair, double shielded with individual internal shielding, 24 AWG (or smaller) cable. An example cable of this type would be Belden 8166. The inner shields of the cable should be connected only at the connector and the sensor end should be left open. The inner shield should be kept isolated from the outer shield. The outer shield should be connected to the chassis ground and to the sensor chassis ground. If the sensor has a ground pin the connection can be done using that pin, however if there is no ground connection (i.e. SS1 sensor) then the chassis connection should be made by connecting to the shell of the connector with as short a connection length as possible. A second cable should be connected directly from the battery to the CMG40T for the power connection.

See the next section to configure for passive seismometer calibration with current calibration drive.

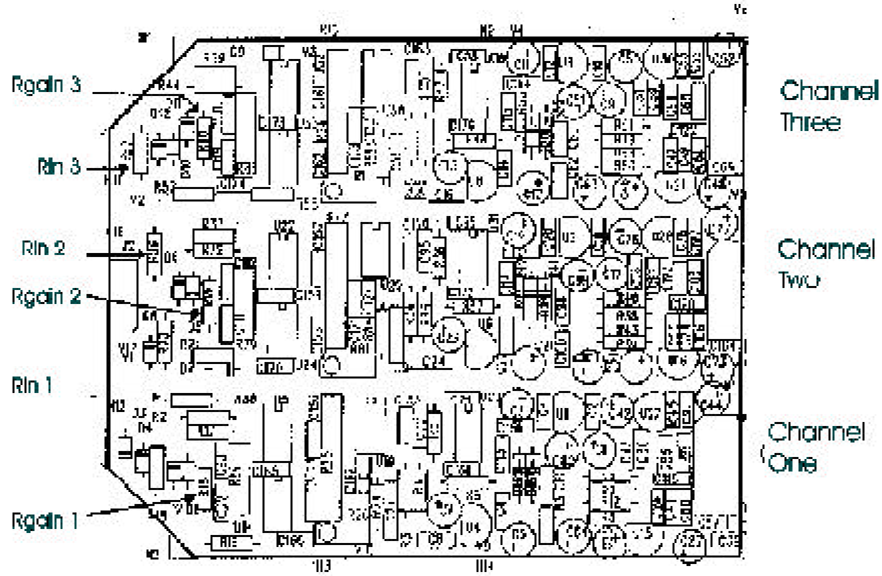



**Figure 8.1**

*Configuring for a passive seismometer*

The first step required when connecting to a passive seismometer is setting the input sensitivity and input impedance of the ADC. The input sensitivity would normally be chosen to give a system sensitivity of 1nm/s. The input impedance should be set to a value to give the critical damping resistance of the seismometer.

| Seismometer | Input Sensitivity | Input Gain | Gain Resistors | Input Impedance |
|---|---|---|---|---|
| Geotech S13 | 378 nV | 3.37 | 3.48K ohms | 5360 ohms |
| Kinemetrics SS1 | 159 nV | 8.02 | 1.33K ohms | 4220 ohms |
| Mark Prod. L4C | 170.1 nV | 7.49 | 1.43K ohms | 8870 ohms |

Connection to a passive sensor will consist of connecting the main sensor coil to the signal inputs with the positive (+) coil connected to the positive (+) input and negative (-) to negative (-). Connect the '+' calibration output to the motor coil '+' and the '-' calibration output to the motor coil return. The output impedance of the calibration signal is 500 ohm, with a maximum current of 10mA at a voltage of 5V. A series resistor is used on the calibration '+' outputs to ensure the current is limited to this value.

The best performance will be found using cables built in the following manner:

> The connection to each sensor should be made with a 2 pair, double shielded with individual internal shielding, 24 AWG (or smaller) cable. An example cable of this type would be Belden 8162. The inner shields of the cable should be connected only at the connector and the sensor end should be left open The inner shield should be kept isolated from the outer shield. The outer shield should be connected to the chassis ground and to the sensor chassis ground. If the sensor has a ground pin the connection can be done using that pin, however if there is no ground connection (i.e. SS1 sensor) then the chassis connection should be made by connecting to the shell of the connector with as short a connection length as possible.

The connection for three manufacturers of the several passive sensors is as follows:

| Sensor Connector | Signal Name | Geotech S13 | Kinemetrics SS1 | Mark Products L4C |
|---|---|---|---|---|
| 1 | Channel 1 + | A - pair 1 | A - pair 1 | A - pair 1 |
| 2 | Channel 1 - | B - pair 1 | B - pair 1 | B - pair 1 |
| 3 | Calibration 1 + | C - pair 2 | D - pair 2 | C - pair 2 |
| 4 | Calibration 1 - | D - pair 2 | E - pair 2 | D - pair 2 |
| 5 | Channel 2 Gnd | inner shields 1,2 | inner shields 1,2 | inner shields 1,2 |
| 6 | Channel 2 + | A - pair 3 | A - pair 3 | A - pair 3 |
| 7 | Channel 2 - | B - pair 3 | B - pair 3 | B - pair 3 |
| 8 | Calibration 2 + | C - pair 4 | D - pair 4 | C - pair 4 |
| 9 | Calibration 2 - | D - pair 4 | E - pair 4 | D - pair 4 |
| 10 | Channel 2 Gnd | inner shields 3,4 | inner shields 3,4 | inner shields 3,4 |
| 11 | Channel 3 + | A - pair 5 | A - pair 5 | A - pair 5 |
| 12 | Channel 3 - | B - pair 5 | B - pair 5 | B - pair 5 |
| 13 | Calibration 3 + | C - pair 6 | D - pair 6 | C - pair 6 |
| 14 | Calibration 3 - | D - pair 6 | E - pair 6 | D - pair 6 |
| 15 | Channel 3 Gnd | inner shields 5,6 | inner shields 5,6 | inner shields 5,6 |
| 16 | +12 V Sensor | | | |
| 17 | Gnd Sensor | | | |
| 18 | -12 V Sensor | | | |
| 19 | Chassis Gnd | E - all outer shields | Connector shell - all outer shields | E - all outer shields |

See the previous section to configure for mass position monitoring with voltage calibration drive.

### User Configurable Jumper Settings

Mem-Cal:

| | | |
|---|---|---|
| J3 | 1-2 | Calibration Enable = +5V |
| J3 | 2-3 | Calibration Enable = +12V |

### Factory configured jumpers

The  is configured using jumpers on various boards. The function of all the jumpers are explained in the following tables. Please see the as-shipped sheets for the actual jumper settings. Note that where applicable, jumper pin 1 has a square pad. The following jumper settings are set at the factory. These jumpers should never be changed. They are listed here for reference only. User configurable jumpers are considered under the function in which the jumper is referenced.

**ADC 1-3:**

| *Jumper* | *Setting* | *Function* |
|---|---|---|
| J3 | 1-2 | PS_SYNC |
| J6 | 5-6 | Channel 1 Address |
| J7 | 1-2 | Channel 2 Address |
| J8 | 1-2 | Channel 3 Address |
| J10-J18 | 2-3 | Time Slot |

**Mem-Cal:**

| *Jumper* | *Setting* | *Function* |
|---|---|---|
| J5 | 1-2 | Voltage Calibration |
| J4 | -- | Not Used |
| J7 | -- | Not Used |
| J6 | 2-3 | SOH1 = Mass POS 1 |

**ADC 4-6:**

| *Jumper* | *Setting* | *Function* |
|---|---|---|
| J6 | 3-4 | Channel 4 Address |
| J7 | 2-3 | Channel 6 Address |
| J8 | 2-3 | Channel 6 Address |

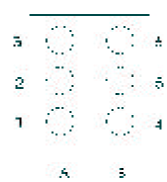
**TCP:**

| *Jumper* | *Setting* | *Function* |
|---|---|---|
| J5 | 1-2 | USCA CLK |
| J6 | 1-2 | USCB CLB |
| J11 | 1-2 | Flash Program |

**COMMS:**

| *Jumper* | *Setting* | *Function* | *Jumper* | *Setting* | *Function* |
|---|---|---|---|---|---|
| J3A | 1-2 | Event_In CMOS Level | J3B | 5-6 | Event_In CMOS Level |
| J4A | 2-3 | Event_Out CMOS Level | J4B | 5-6 | Event_Out CMOS Level |
| J5A | 2-3 | RX232 | J5B | 5-6 | CTS232 |
| J6A | 2-3 | TX232 | J6B | -- | N/A |
| J7A | -- | | J7B | 3-4 | RTS232 |
| J7C | -- | | J12A | 1-2 | AUX_CLK |
| J12B | 5-6 | USCA_RI | | | |

Pinout for J12, J3, J4, J5, J6:



## Standard seismometer configurations

*Kinematics Ranger*

Generator constant 345  volt-seconds/ meter
Gain set to 8.02 with 1.33K ohm gain set resistor
Damping set to 4200 ohms with damping resistor
Configure for current drive with no mass position monitoring
System sensitivity 1 nanometer per second per bit

*Mark Products L4C*

Generator constant 276.4 volt-seconds/ meter
Gain set to 7.49 with 1.43K ohm gain set resistor
Damping set to 8870 ohms with damping resistor
Configure for current drive with no mass position monitoring
System sensitivity 1 nanometer per second per bit

*Geotech S13*

Generator constant 629 volt-seconds/ meter
Gain set to 3.37 with 3.48K ohm gain set resistor
Damping set to 5340 ohms with damping resistor

Configure for current drive with no mass position monitoring
System sensitivity 1 nanometer per second per bit

*Guralp CMG40T*

Generator constant 800 volt-seconds/ meter
Gain set to 1.6 with 9.09K ohm gain set resistor
Damping set to open circuit with no damping resistor
Configure for voltage drive with mass position monitoring
System sensitivity 1 nanometer per second per bit

OR

Generator constant 800 volt-seconds/ meter
Gain set to nominal with no gain set resistor
Damping set to open circuit with no damping resistor
Configure for voltage drive with mass position monitoring enabled
System sensitivity 3.186 nanometers per second per bit

# Appendix A - Connector Pinouts

This section describes the HRD connector pin assignments.

**Power / Comms Connector**

| Pin Number | Signal Name | Isolated | I/F Level | RS-232 | RS-422 | External GPS RS-422 | External GPS RS-232 |
|---|---|---|---|---|---|---|---|
| | | | | Data Port (USCA) Isolated | Data Port (USCA) Isolated | | |
| A | + Vin (+12v) | Yes | | | | | Power |
| B | -Vin Ret (Ground) | Yes | | | | | Return |
| C | N/C | - | | | | | |
| D | USCA-TClkIn | Yes | RS-232 | | | | TX-CLK |
| E | CTS/Rx- | | | CTS | RX- | | CTS/RX |
| F | USCA-DTR/GPS-GND | Yes | RS-232/GND | | GPS-RX | GPS-GND | GND-ISO |
| G | RTS/Tx+ | | | RTS | TX+ | | RTS/TX |
| H | USCB-TX | No | RS-232 | | | | TX-CFG |
| J | USCA-RI/GPS-Rx + | Yes | RS-232/422 | | GPS -TX | GPS-Rx + | RI |
| K | USCB-RX | No | RS-232 | | | | RX-CFG |
| L | USCA-DCD/GPS-Rx - | Yes | RS-232/422 | | GPS - 1 Hz | GPS-Rx - | DCD/RX |
| M | USCB-GND | No | RS-232 | | | | GND-CFG |
| N | USCA-GND | Yes | | | | | GND-ISO |
| P | USCA-Rx | | | RX | RX+ | | |
| R | USCA-Tx | | | TX | TX- | | |
| S | PIC-RX | Yes | CMOS | | | | |
| T | PIC-TX/HRD-PwrOn | Yes | CMOS | | | | |
| U | N/C | - | | | | | |
| V | Event In +/1Hz + | Yes | RS422 | | | 1Hz + | |
| W | Event In -/1Hz - | Yes | RS422 | | GPS-GND | 1Hz - | |
| X | Event Out +/GPS-Tx+ | Yes | RS422 | | | GPS-Tx + | |
| Y | Event Out -/GPS-Tx - | Yes | RS422 | | | GPS-Tx - | |
| Z | External SOH #1 | No | | | | | |
| a | External SOH #2 | No | | | | | |
| b | External SOH #3 | No | | | | | |
| c | SNR | No | | | | | |

***Note: To support external GPS, the HRD must be factory configured (ECO156) and the Ring, DCD and DTR functions on USCA will not be available for use.***

**Signal Connector**

| Pin Number | Signal Name |
|---|---|
| A | Ch #1 + |
| B | Ch #1 - |
| C | Cal #1 + |
| D | Cal #1 - |
| E | Ch #1 Ground |
| F | Ch #2 + |
| G | Ch #2 - |
| H | Cal #2 + |
| J | Cal #2 - |
| K | Ch #2 Ground |
| L | Ch #3 + |
| M | Ch #3 - |
| N | Cal #3 + |
| P | Cal #3 - |
| R | Ch #3 Ground |
| S | +12V Sensor |
| T | Ground Sensor |
| U | -12V Sensor |
| V | Chassis Ground |
| W | Cal #1 En. |
| X | Cal #2 En. |
| Y | Cal #3 En. |
| Z | Logic Ground |
| a | Mass Pos #1 |
| b | Mass Pos #2 |
| c | Mass Pos #3 |

# Appendix B - Data Format

### Introduction

This data transmission format facilitate the transfer compressed seismic data along with a wide variety of status information from an instrument to a central site. It supports error free transmission of data using retransmission requests of bad packets. It also supports polled networks. The data format requires that the instrument have an accurate time source (i.e. GPS) for time tagging the data prior to compression and transmission. The compression algorithm is based on taking the first difference of the data and packing the data into bytes, words, or long words . This algorithm achieves about 1.3 bytes per sample at maximum compression.

Most of the status messages can be transmitted at a user defined frequency. This allows the user to tailor ratio of data to status information. This is important on limited bandwidth or noisy transmission mediums. The status information in data format is expandable. As new status information messages are created, they can be added to the data format without affecting the existing information.

Lastly, the data format is simple to implement on small microprocessors. The compression algorithm is simple and requires little memory and processing power.

The following objectives were used in designing the data format:

1. support compressed data
2. support retransmit of packets for error correction
3. support polled networks
4. compatible with Orion
5. simple compression/decompression algorithm
6. simple to implement
7. expandable
8. programmable frequency for status information
9. not wasteful of bandwidth

## Description of Packets

All the data (seismic and status data) is gathered into sequenced and time stamped packets. These packets start with a synchronization word plus a Old packet available word and finish with a CRC. The packets consist of 17 byte 'bundles' of data. Each bundle is an independent collection of data. Each packet contains a timestamp bundle followed by n data bundles where n is odd. In order to word align packets, an odd number of bundles is used. This principally benefits the TCP.

The number of bundles in a packet is a programmable parameter. The number of bundles is odd and has a range of 1-255. This allows the packet size to be tailored to the data link. The packet size should be optimized for the data link. Short packets should be used on noisy error prone data links. Packets may be the same size for the entire network, or different on each branch (a branch is connected to one FEP) of the network. All instruments on a given branch must use the same packet size. Short messages must be paddled out to the packet size. Outgoing packets may have a different packet size.

In summary:

- } a channel is a unique stream of information
- } an instrument may transmit 1 or more channels of information
- } a packet contains information from only one channel
- } a packet is a uniquely identifiable collection of information that is transmitted
- } packets are a configurable fixed size
- } a branch connects 1 or more instruments to one FEP
- } all instruments on a branch use the same incoming packet size
- } all instruments on a branch use the same outgoing packet size
- } outgoing packets do not have the Oldest packet word
- } incoming packets contain data, status, or configuration information
- } outgoing packets contain retransmit requests, or configurations
- } Outgoing is from the central site to remote site, incoming is the opposite
- } all data is represented in the little endian format (intel format)

## CRC for the Packets

For simplicity CRCs should be an addressable data size, i.e. 8, 16 or 32 bits. Sending 32 bits (4 bytes) is too much overhead, 8 bits is not sufficient Therefore select 16 bits as the CRC size.

There are 2 good common standard 16 bits polynomials, the CRC-16 and the 16 bit CRC-CCITT. The reversal of these polynomials are also known to be good and are also used. The Orion uses the 16 bit CRC-CCITT. Therefore select the 16 bit CRC-CCITT as the CRC polynomial.

On the bit level CRCs can be calculated from either end. Normally CRCs are calculated most significant bit first, i.e. the byte 0xD5 is done 11010101. Reflected CRCs are calculated least significant bit first, i.e. thye byte 0xD5 is done 10101011. Bits of a byte are transmitted over a serial link least significant bit first. Most CRCs calculated for transmission over a serial link are done least significant bit first. The Orion uses a reflected CRC algorithm. Therefore, select a reflected CRC algorithm is to be used.

If the accumulated CRC value is 0, it is unaffected by the 0 byte and errors may not be detected. The CRC should not be initialized to 0 if messages contain leading 0s may occur. Since the receiver syncs on a non-zero sync word, this is not a problem if these bytes are included. The Orion uses 0xFFFF as its initial value for the CRC. Therefore, select 0 as the initial value for the CRC.

If the CRC is sent as is, the accumulated CRC value afterwards is then 0. This can pose problems if messages have the CRC and trailing 0s, see above. Modifying the CRC before transmitting it has little to gain and complicates matters. The Orion XORs the CRC with 0xFFFF before transmitting it and checks for 0xF0B8 on receive. Therefore, select transmitting the CRC as is.

```
#define CrcUpdate(usCrc,ubByte) \   ((usCrc) >> 8) ^ ausCrcTable [((usCrc) &
0xff) ^ (ubByte)]
SendByte (ubByte)
{
        usCrc = CrcUpdate (usCrc,ubByte);
        UscTx = ubByte ^ ubScramble;
}
```

```
RecvByte ()
{
       ubByte = UscRx ^ ubScramble;
       usCrc = CrcUpdate (usCrc, ubByte);
       return ubByte;
}
SendMsg (pubData)
{
       usCrc = 0;
       SendByte (ubSync1);
       SendByte (ubSync2);
       SendLong (ulOldestSequenceNumber);
       for (us = 0; us < usNumberMsgByte, us ++)
       SendByte (pubData [us]);
       usCrc2 = usCrc;
       SendWord (usCrc2);
}

RecvMsg (pubData)
{
       while (1)
       {
              while (1)
              {
                     while (1)
                     {
                            usCrc = 0;
                            if (RecvByte() == ubSync1)
                                   break;
                     }
                     if (RecvByte () == ubSync2)
                            break;
              }
              ulOldestSequenceNumber = RecvLong ();
              for (us = 0; us < usNumberMsgByte, us ++)
                     pubData [us] = RecvByte ();
              usCrc2 = usCrc;
              if (usCrc2 == RecvWord () && usCrc == 0)
                     break;
       }
}


unsigned short ausCrcTable[256] ={
  0x0000, 0x1189, 0x2312, 0x329B, 0x4624, 0x57AD, 0x6536, 0x74BF, 0x8C48,
0x9DC1,
  0xAF5A, 0xBED3, 0xCA6C, 0xDBE5, 0xE97E, 0xF8F7, 0x1081, 0x0108, 0x3393,
0x221A,
  0x56A5, 0x472C, 0x75B7, 0x643E, 0x9CC9, 0x8D40, 0xBFDB, 0xAE52, 0xDAED,
0xCB64,
  0xF9FF, 0xE876, 0x2102, 0x308B, 0x0210, 0x1399, 0x6726, 0x76AF, 0x4434,
0x55BD,
  0xAD4A, 0xBCC3, 0x8E58, 0x9FD1, 0xEB6E, 0xFAE7, 0xC87C, 0xD9F5, 0x3183,
0x200A,
  0x1291, 0x0318, 0x77A7, 0x662E, 0x54B5, 0x453C, 0xBDCB, 0xAC42, 0x9ED9,
0x8F50,
  0xFBEF, 0xEA66, 0xD8FD, 0xC974, 0x4204, 0x538D, 0x6116, 0x709F, 0x0420,
0x15A9,
  0x2732, 0x36BB, 0xCE4C, 0xDFC5, 0xED5E, 0xFCD7, 0x8868, 0x99E1, 0xAB7A,
0xBAF3,
```

```
  0x5285, 0x430C, 0x7197, 0x601E, 0x14A1, 0x0528, 0x37B3, 0x263A, 0xDECD,
0xCF44,
  0xFDDF, 0xEC56, 0x98E9, 0x8960, 0xBBFB, 0xAA72, 0x6306, 0x728F, 0x4014,
0x519D,
  0x2522, 0x34AB, 0x0630, 0x17B9, 0xEF4E, 0xFEC7, 0xCC5C, 0xDDD5, 0xA96A,
0xB8E3,
  0x8A78, 0x9BF1, 0x7387, 0x620E, 0x5095, 0x411C, 0x35A3, 0x242A, 0x16B1,
0x0738,
  0xFFCF, 0xEE46, 0xDCDD, 0xCD54, 0xB9EB, 0xA862, 0x9AF9, 0x8B70, 0x8408,
0x9581,
  0xA71A, 0xB693, 0xC22C, 0xD3A5, 0xE13E, 0xF0B7, 0x0840, 0x19C9, 0x2B52,
0x3ADB,
  0x4E64, 0x5FED, 0x6D76, 0x7CFF, 0x9489, 0x8500, 0xB79B, 0xA612, 0xD2AD,
0xC324,
  0xF1BF, 0xE036, 0x18C1, 0x0948, 0x3BD3, 0x2A5A, 0x5EE5, 0x4F6C, 0x7DF7,
0x6C7E,
  0xA50A, 0xB483, 0x8618, 0x9791, 0xE32E, 0xF2A7, 0xC03C, 0xD1B5, 0x2942,
0x38CB,
  0x0A50, 0x1BD9, 0x6F66, 0x7EEF, 0x4C74, 0x5DFD, 0xB58B, 0xA402, 0x9699,
0x8710,
  0xF3AF, 0xE226, 0xD0BD, 0xC134, 0x39C3, 0x284A, 0x1AD1, 0x0B58, 0x7FE7,
0x6E6E,
  0x5CF5, 0x4D7C, 0xC60C, 0xD785, 0xE51E, 0xF497, 0x8028, 0x91A1, 0xA33A,
0xB2B3,
  0x4A44, 0x5BCD, 0x6956, 0x78DF, 0x0C60, 0x1DE9, 0x2F72, 0x3EFB, 0xD68D,
0xC704,
  0xF59F, 0xE416, 0x90A9, 0x8120, 0xB3BB, 0xA232, 0x5AC5, 0x4B4C, 0x79D7,
0x685E,
  0x1CE1, 0x0D68, 0x3FF3, 0x2E7A, 0xE70E, 0xF687, 0xC41C, 0xD595, 0xA12A,
0xB0A3,
  0x8238, 0x93B1, 0x6B46, 0x7ACF, 0x4854, 0x59DD, 0x2D62, 0x3CEB, 0x0E70,
0x1FF9,
  0xF78F, 0xE606, 0xD49D, 0xC514, 0xB1AB, 0xA022, 0x92B9, 0x8330, 0x7BC7,
0x6A4E,
  0x58D5, 0x495C, 0x3DE3, 0x2C6A, 0x1EF1, 0x0F78
};
```

## Outgoing Packets

All outgoing packets are a fixed size of 30 bytes. There are no retransmit requests from the destination for outgoing packets.

The basic format is as follows:

| | |
|---|---|
| 2 bytes | Synchronization Word = AA BB |
| 2 bytes | Instrument ID (5 bits model type, 11 bits serial number) |
| 4 bytes | Long Seconds |
| 1 byte | Packet Type |
| 3 bytes | Packet Information Header |
| 4 x 4 bytes | Data Section |
| 2 bytes | Packet CRC |

### Retransmission Request by Sequence Number Packet

| | |
|---|---|
| 1 byte | Packet type = 1 |
| 1 byte | Channel |
| 2 bytes | Spare |
| 4 bytes | Sequence number 1 requested |

| | |
|---|---|
| 4 bytes | Sequence number 2 requested |
| 4 bytes | Sequence number 3 requested |
| 4 bytes | Sequence number 4 requested |

### Retransmission Request by Sequence Number Range Packet

| | |
|---|---|
| 1 byte | Packet type = 2 |
| 1 byte | Channel |
| 2 bytes | Spare |
| 4 bytes | First sequence number requested |
| 4 bytes | Last sequence number requested |
| 8 byte | Spare |

### HRD Calibration Packet

| | | |
|---|---|---|
| 1 byte | | Packet Type = 6 |
| 1 byte | | Channel Mask (ch 1, 2, 3, 4 = 1, 2, 4, 8) |
| 2 bytes | | Spare |
| 4 bytes | us-int32 | Start Time (long seconds) |
| 4 bytes | float | Frequency in Hz (0.01 <= freq < sample rate / 2) |
| 4 bytes | float | Amplitude in Volts (0 < amp <= 5.0) |
| 2 bytes | us-int32 | Duration in seconds (0 < duration <= 3600) |

## Incoming Packets

All incoming packets consist of a synchronization pattern, oldest packet available for a data stream, timestamp bundle, n other bundles, and a CRC:

| | |
|---|---|
| 2 bytes | Synchronization Word |
| 4 bytes | Oldest Packet Available for a Data Stream |
| 17 bytes | Packet Header Bundle |
| 17 * n bytes | n bundles where n is odd |
| 2 bytes | Packet CRC |

### Compressed Data Packet

A data packet always consists of a timestamp bundle followed by n data bundles (where n is user defined). A timestamp bundle contains a sequence number, the time of the first sample, instrument ID (model and serial number), sample rate of packet and channel number, and the first sample.

#### Compressed Data Packet Header Bundle

| | |
|---|---|
| 1 byte | Packet type = 1 ( bit 5 = 1 is for retransmit) |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second |
| 2 bytes | Instrument ID [5 bit model type, 11 bit serial number] |
| 4 bytes | Sequence Number |
| 1 byte | Sample Rate, Channel # [5 bits for sample rate, 3 bits for channel #] |
| 3 bytes | X0 (first sample) |

The instrument ID defines the instrument type transmitting the channel of data. Currently the following instrument ID's are defined:

| | |
|---|---|
| 0 | HRD |
| 1 | ORION |

| | |
|---|---|
| 2 | RM3 |
| 3 | RM4 |
| 4-31 | Reserved for future use |

The sample rate is an enumerated value. The table below defines the different sample rates:

| | | | | | |
|---|---|---|---|---|---|
| 0 | reserved | 6 | 40 s/s | 12 | 250 s/s |
| 1 | 1 s/s | 7 | 50 s/s | 13 | 500 s/s |
| 2 | 2 s/s | 8 | 80 s/s | 14 | 1000 s/s |
| 3 | 5 s/s | 9 | 100 s/s | 15 | 25 s/s |
| 4 | 10 s/s | 10 | 125 s/s | 16 | 120 s/s |
| 5 | 20 s/s | 11 | 200 s/s | 17-31 | reserved for future use |

### Data Bundle

A data bundle contains between 4 and 16 compressed samples of data. The samples are compressed using a first difference algorithm. The data is compressed as byte, word, or long differences. Each set of four bytes contains either 4 byte differences, 2 word differences, or 1 long difference. The compression bits indicate how each set of 4 bytes is packed. For each 4 byte set there are 2 compression bits. The compression bits are packed into a byte as follows:

| | | | |
|---|---|---|---|
| byte : | ww xx yy zz | where the compression bits indicate: | |
| | ww- data set 1 | 00 | not used |
| | xx- data set 2 | 01 | byte difference |
| | yy- data set 3 | 10 | word difference |
| | zz- data set 4 | 11 | long difference |

The format of the data bundle is as follows:

| | |
|---|---|
| 1 byte | Compression Bits |
| 4 bytes | Compressed data set 1 |
| 4 bytes | Compressed data set 2 |
| 4 bytes | Compressed data set 3 |
| 4 bytes | Compressed data set 4 |

## Null Bundle

This bundle is provided to pad out packets. The first occurrence of a Null bundle indicates that there is no further data in the packet. The null bundle contains no useful information. The receiver should disregard this bundle and all remaining bundles, and skip to the next packet.

| | |
|---|---|
| 1 byte | Bundle Type = 9 |
| 16 bytes | Filler |

## Filler Packet

A filler packet is required for radio links. Non-zero data must always be transmitted by radios. To accomplish this the instruments transmit filler packets whenever there is no data to transmit. Repeaters discard received filler packets and generate their own filler packets for transmission. This method is required because a repeater can also multiplex.

The only valid data in a filler packet is the bundle type. The rest of the packet is filled a value that is good for radio transmission (to be defined)

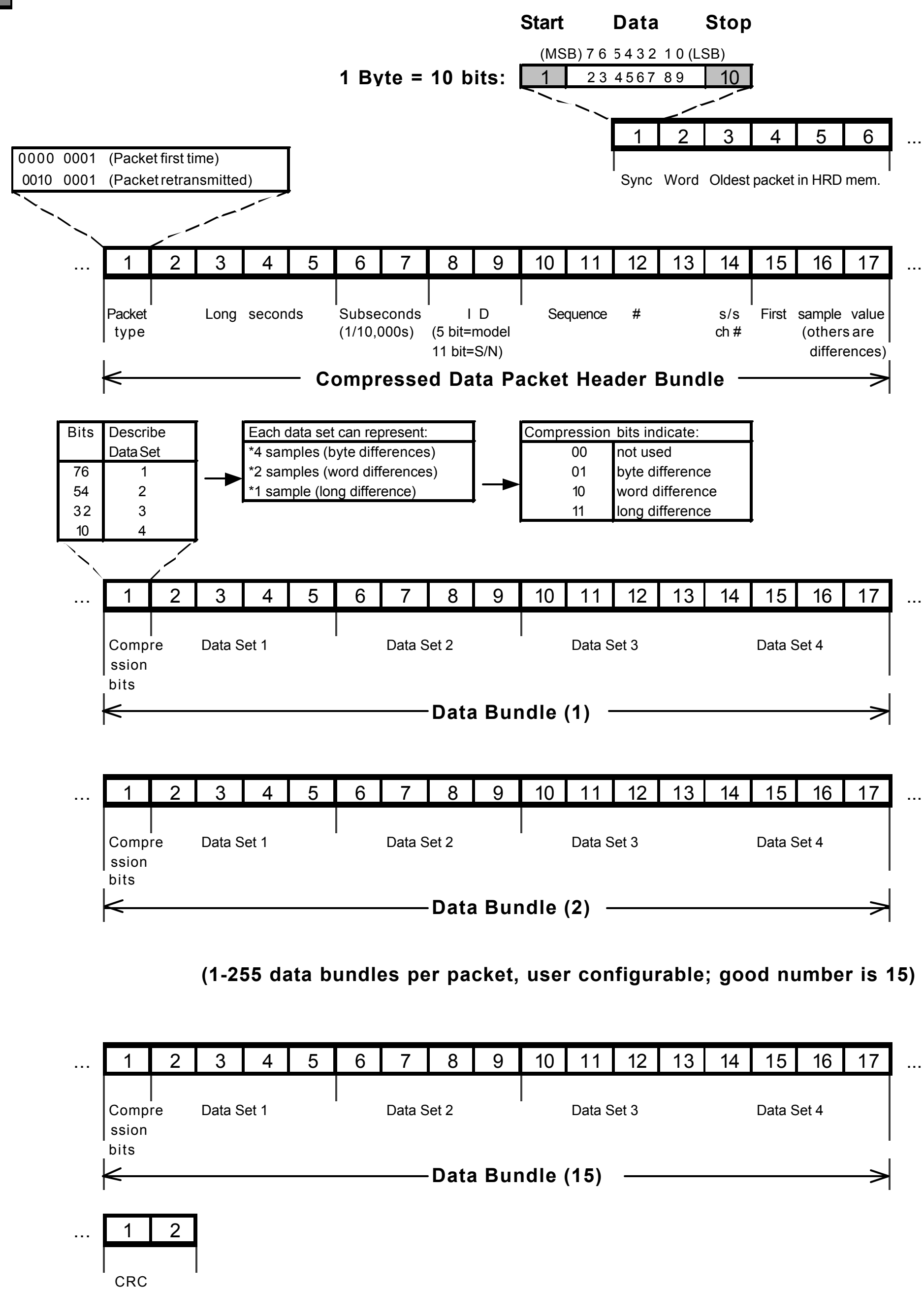
### Filler Packet Header Bundle

| | |
|---|---|
| 1 byte | Packet type = 9 ( bit 5 = 1 is for retransmit) |
| 16 bytes | defined as filler characters |

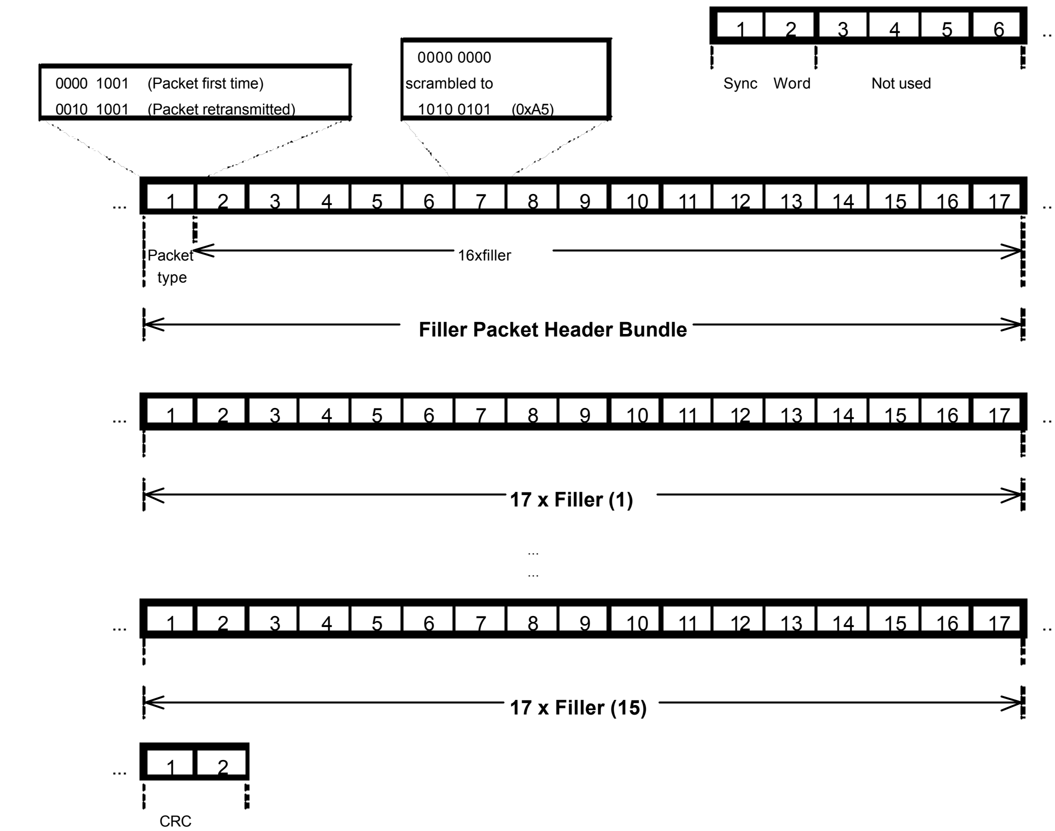
***Note : scrambler default is 0xA5***

The following is a graphical illustration of an incoming data stream, containing only data packets and filler packets. An actual data stream will also have state-of-health packets.

## D a) Compressed Data Packet



## F b) Filler Packet




## Bandwith Estimate Example

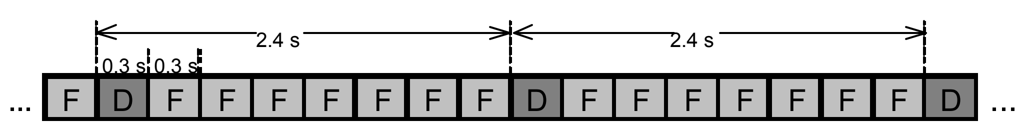
1 ch
100 s/s
9600 baud
15 bundles/packet
signal always quiet (byte difference)

→

16 samples/bundle x 15 bundles = 240 samples/packet
(takes 240/100=2.4 s to digitize a packet)

(6+17+15x17+2)x10=2800 bits/packet
1/9600 s/bit => 2800/9600 = 0.2916666 s/packet

bandwith is used only 0.291666/2.4=0.1215=12.15%
minimum needed baud rate is 9600*0.1215=1166.66 baud
with Sync abd Status packets => cca 1200 baud



## Status Packet

A status packet consists of a status timestamp bundle followed by n status bundles. A status timestamp consists of a sequence number, the time (nominal time when the packet was created), instrument ID (model and serial number).

Status bundles have a general format that is outlined below:

| | |
|---|---|
| 1 byte | bundle type = xx |
| 4 bytes | Long seconds |
| 12 bytes | Defined by the specific bundle type |

or

| | |
|---|---|
| 1 byte | bundle type = xx |
| 16 bytes | Defined by the specific bundle type |

### State-of-Health Packet Header Bundle

| | |
|---|---|
| 1 byte | Packet type = 2 (bit 5 = 1 is for retransmit) |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second, this value always 0 |
| 2 bytes | Instrument ID [5 bit model type, 11 bit serial number] |
| 4 bytes | Sequence Number |
| 4 bytes | Reserved for future use |

The instrument ID defines the instrument type transmitting the channel of data. Currently the following instrument ID's are defined:

| | |
|---|---|
| 0 | HRD |
| 1 | ORION |
| 2 | RM-3 |
| 3-31 | Reserved for future use |

#### Fast External State-Of-Health Bundle

| | |
|---|---|
| 1 byte | bundle type = 32 |
| 4 bytes | long seconds |
| 4 bytes | float of calibrated fast SOH1 in volts or units |
| 4 bytes | float of calibrated fast SOH2 in volts or units |
| 4 bytes | float of calibrated fast SOH3 in volts or units |

#### Slow External State-Of-Health Bundle

| | |
|---|---|
| 1 byte | bundle type = 33 |
| 4 bytes | long seconds |
| 4 bytes | float of calibrated slow SOH1 in volts or units |
| 4 bytes | float of calibrated slow SOH2 in volts or units |
| 4 bytes | float of calibrated slow SOH3 in volts or units |

#### HRD Slow Internal SOH Bundle

| | |
|---|---|
| 1 byte | bundle type = 34 |
| 4 bytes | long seconds |
| 4 bytes | float of battery voltage measured at PSU in volts |
| 4 bytes | float of VCXO temperature in degrees Celsius |
| 4 bytes | float of radio SNR in xxxx |

### GPS Time Quality Bundle

| | |
|---|---|
| 1 byte | bundle type = 39 |
| 4 bytes | long seconds |
| 2 bytes | GPS on time |
| 2 bytes | GPS off time during the last cycle |
| 2 bytes | GPS time to lock in seconds |
| 2 bytes | Time difference at lock in counts (divide by 3.84 to get microseconds) |
| 2 bytes | VCXO offset (div. by 16 to get the DAC offset) |
| 1 byte | Reason GPS turned off:<br>0 -PLL finished correcting time error<br>1 -GPS on time expired |
| 1 byte | Final GPS mode:<br>0 -3D navigation<br>1 -2D navigation<br>2 -tracking 1 sat or more<br>3 -searching for satellites |

### VCXO Calibration Bundle

| | |
|---|---|
| 1 byte | Bundle type = 7 |
| 4 bytes | Long seconds |
| 2 bytes | VCXO value |
| 2 bytes | Time difference at lock in counts (divide by 3.84 to get microseconds) |
| 2 bytes | Time Error (in counts) |
| 2 bytes | Frequency Error (in counts/sec or counts/ 16 secs) |
| 2 bytes | Crystal temperature |
| 1 byte | PLL Status?( 1=fine locked, 2=coarse locking, 3 =temp. ref, gps off, 4=temp ref, gps on) |
| 1 byte | GPS Status(0=3D, 1=2D, 2=1 sat, 3=search, 4= gps off, 5-6=gps error) |

### Null Bundle

This bundle is provided to pad out packets. The first occurrence of a Null bundle indicates that there is no further data in the packet. The null bundle contains no useful information. The receiver should disregard this bundle and may skip to the next packet.

| | |
|---|---|
| 1 byte | Bundle Type = 9 |
| 16 bytes | Filler |

### Min-Max1 Bundle

The activity indicator provides a 1 Hz or slower filtered summary of a seismic data channel. This would be used to provide the end user with a summary of the collected data. This allows the user to quickly browse large quantities of data for events. The data may be filtered using a 5th order filter. The filter may be low pass, high pass, or band pass. In order not to lose the higher frequency information, the minimum and maximum over the interval of the filtered signal is stored. The interval is a programmable value of 1s or greater.

| | |
|---|---|
| 1 byte | Bundle type = 10 |
| 4 bytes | Long seconds |
| 3 bytes | Filtered min. over 1st interval |
| 3 bytes | Filtered max. over 1st interval |
| 3 bytes | Filtered min. over 2nd interval |
| 3 bytes | Filtered max. over 2nd interval |

### Min-Max2 Bundle

The activity indicator provides a 1 Hz or slower filtered summary of a seismic data channel. This would be used to provide the end user with a summary of the collected data. This allows the user to quickly browse large quantities of data for events. The data may be filtered using a 5th order filter. The filter may be low pass, high pass, or band pass. In order not to lose the higher frequency information, the minimum and maximum over the interval of the filtered signal is stored. The interval is a programmable value of 1s or greater.

| | |
|---|---|
| 1 byte | Bundle type = 11 |
| 4 bytes | Long seconds |
| 3 bytes | Filtered min. over 1st interval |
| 3 bytes | Filtered max. over 1st interval |
| 3 bytes | Filtered min. over 2nd interval |
| 3 bytes | Filtered max. over 2nd interval |

### Instrument Log Bundle

Any errors or warnings generated by the instrument are stored in this bundle. Some typical errors or warnings are GPS locked/unlocked, low battery, clock adjustments, external events, self test errors, status of disk space, duty cycle, etc.

| | |
|---|---|
| 1 byte | Bundle type = 12 |
| 4 bytes | Long seconds |
| 2 bytes | Error code , where bits 0-11= error code, bits 12-15 = data format, |
| 2 bytes | Error Level |
| 8 bytes | Error Parameters |

ErrorLevel is a bit mapped value which is broken down as follows:

| | |
|---|---|
| bits 0-7 | Area (each bit identifies a separate area)- currently unused |
| bits 8-10 | Processor (TCP, Aux, DSP) |
| bits 11-15 | Error Level (Fatal, error, warning, info, debug |

### GPS Location Bundle

This bundle contains the latitude and longitude of the instrument's GPS antenna. This bundle has a programmable measurement frequency. The latitude and longitude is stored in an extended floating point format.

| | |
|---|---|
| 1 byte | Bundle type = 13 |
| 4 bytes | Long seconds |
| 4 bytes | Latitude |
| 4 bytes | Longitude |
| 4 bytes | Elevation |

### GPS Satellite Status/Reference Time Error Bundle

This bundle contains the status of the GPS engine's satellite tracking channels. It records the signal to noise ratio, activity, and satellite number for the five satellite tracking channels. The activity indicates whether the GPS channel is idle, searching or locked to a satellite signal. This information is very useful in diagnosing a GPS engine that is not locking.

| | |
|---|---|
| 1 byte | Bundle type = 15 |
| 4 bytes | Long seconds |
| 2 bytes | Status bits (see Rockwell manual, contains operating mode, figure of merit) |
| 10 bytes | GPS Satellite Channel - 2bytes per channel |

where the 2 bytes are defined:

| | |
|---|---|
| bits 0-4 | Satellite PRN code (0-31) |
| bits 5-7 | Unused |
| bits 8-13 | Signal to Noise Ratio (0-63) |
| bits 14-15 | Activity 0=idle, 1 searching, 3=tracking |

### D1 (Early) Threshold Trigger Bundle

The D1 threshold trigger bundle reports the start of a threshold trigger event. It is sent at a programmable time after the start of a trigger. It reports the start time of the trigger, along with some statistics about the trigger. The D1 trigger bundle is followed by a D2 trigger which reports the end of a trigger. The D1 bundle contains the peak amplitude, the half period of the amplitude, and the samples after trigger of the peak amplitude.

| | |
|---|---|
| 1 byte | Bundle type = 20 |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second |
| 2 bytes | LTA value (low word of LTA which is a long, hi word in D2) |
| 2 bytes | Half period of peak amplitude |
| 2 bytes | Samples after trigger of peak amplitude |
| 1 byte | Channel# (3 bits) \| trigger # (5 bits) |
| 3 bytes | Peak amplitude |

### D2 (Late) Threshold Trigger Bundle

The D2 threshold trigger bundle reports the end of a threshold trigger event. It is sent at a programmable time after a trigger is finished. It reports the end time of the trigger, along with some statistics about the trigger. The D2 bundle contains the peak amplitude, the half period of the amplitude, and the samples after trigger of the peak amplitude for the entire trigger event.

| | |
|---|---|
| 1 byte | Bundle type = 21 |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second |
| 2 bytes | LTA value (hi word of LTA which is a long, low word in D1) |
| 2 bytes | Half period of peak amplitude |
| 2 bytes | Samples after trigger of peak amplitude |
| 1 byte | Channel# (3 bits) \| trigger # (5 bits) |
| 3 bytes | Peak amplitude |

### D1 (Early) STA/LTA Trigger Bundle

The D1 STA/LTA trigger bundle reports the start of a STA/LTA trigger event. It is sent at a programmable time after the start of a trigger. It reports the start time of the trigger, along with some statistics about the trigger. The D1 trigger bundle is followed by a D2 trigger which reports the end of a trigger. The D1 bundle contains the peak amplitude, the half period of the amplitude, and the samples after trigger of the peak amplitude.

| | |
|---|---|
| 1 byte | Bundle type = 22 |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second |
| 2 bytes | LTA value (low word of LTA which is a long, hi word in D2) |
| 2 bytes | Half period of peak amplitude |
| 2 bytes | Samples after trigger of peak amplitude |
| 1 byte | Channel# (3 bits) \| trigger # (5 bits) |
| 3 bytes | Peak amplitude |

### D2 (Late) STA/LTA Trigger Bundle

The D2 STA/LTA trigger bundle reports the end of a STA/LTA trigger event. It is sent at a programmable time after a trigger is finished. It reports the end time of the trigger, along with some statistics about the trigger. The D2 bundle contains the peak amplitude, the half period of the amplitude, and the samples after trigger of the peak amplitude for the entire trigger event.

| | |
|---|---|
| 1 byte | Bundle type = 23 |
| 4 bytes | Long seconds |
| 2 bytes | Sub-seconds in 10,000th of a second |

| | |
|---|---|
| 2 bytes | LTA value (hi word of LTA which is a long, low word in D1) |
| 2 bytes | Half period of peak amplitude |
| 2 bytes | Samples after trigger of peak amplitude |
| 1 byte | Channel# (3 bits) \| trigger # (5 bits) |
| 3 bytes | Peak amplitude |

Event Bundle

| | |
|---|---|
| 1 byte | Bundle type = 24 |
| 4 bytes | Long Seconds |
| 4 bytes | End Time in Long seconds |
| 1 byte | Cause (1=external, 2=internal, 4=manual (calibration)) |
| 1 byte | Trigger Flags (1 bit per trigger, LSB = trigger 0) |
| 6 byte | spare |

# Appendix C - Instrument Log Messages

The HRD24 instrument log provides a record of the normal ongoing operation of the instrument, as well as specific incidents which may affect data quality or timing. The HRD24 generates 5 different categories of message:

| | |
|---|---|
| Information | Document the normal operation of the HRD24. |
| Warnings | Minor incidents which may slightly affect data quality or timing. |
| Errors | Incidents which may result in significant loss of data. |
| Fatal Errors | Serious malfunctions of the HRD24. |
| Debug Info | Verbose trace messages. |

This is a complete list of the messages generated by the HRD24 digitizer. Some of the messages in this list are relevant only to an HRD24 digitizer running in Orion mode. All the messages that reference the "AUX" should never occur while running in HRD24 mode.

### Informational Messages

Message 1039: DSP diag RC=r cnt=n.

The DSP diagnostics returned the value r on the nth time run. This is an informational message if r is 0 and a warning message otherwise.

Message 1041: TCP turn LEDs on.

The TCP turned on the LEDs after detecting a user button press.

Message 1042: TCP turn LEDs off.

The TCP turned off the LEDs after powering off the AUX or after 5 minutes of no user activity.

Message 1054: Recording Started.

Data recording has started as requested by the AUX.

Message 1055: Recording stopped.

Data recording has stopped as requested by the AUX.

Message 1056: Window started ssss-eeee.

The recording window from time ssss to time eeee has started.

Message 1057: Window ended ssss-eeee.

The recording window from time ssss to time eeee has ended.

Message 1060: Pll fine locked.

The TCP is phase locked. It is using the average of several seconds of GPS messages. The absolute time error is less than 10 microseconds.

Message 1061: Pll coarse locking.

The TCP is phase locking, skewing the time to the correct.

Message 1068: GPS lost navigation.

The GPS engine is not able to generate a navigation solution using the satellites in view.

Message 1069: GPS gain navigation.

The GPS engine is now able to generate a navigation solution using the satellites it is tracking.

Message 1070: User button pressed.

The TCP detected a user button press. The next message indicates the action taken which is turning on the LEDs or powering on the AUX.

| | |
|---|---|
| Message 1072: | GPS power on.<br>The TCP powered the GPS on so that it can correct its internal time. |
| Message 1073: | GPS power off.<br>The TCP powered the GPS off after it had corrected its time to within 1 microsecond or after the maximum on time had elapsed. |
| Message 1075: | Disk heater on, dd seconds, tt C.<br>The TCP powered the disk heater on to warm it up in preparation of starting the AUX processor. There are dd seconds of memory left and the current disk temperature is tt degrees Celsius. |
| Message 1076: | Disk heater off, dd seconds, tt C.<br>The TCP powered the disk heater off after warming it up in preparation of starting the AUX processor. There are dd seconds of memory left and the current disk temperature is tt degrees Celsius. |
| Message 1079: | Disk temperature tt C.<br>The temperature of the disk cartridge has passed one of the safety limits to tt degrees Celsius. If the disk is too hot or too cold the AUX processor may not work correctly. The disk may be heated to within temperature specifications or these limits may be disregarded. |
| Message 1080: | GPS engine state sssss.<br>The GPS engine state has changed to sssss, which is one of the following:<br>Search — The GPS engine is searching for satellites.<br>Track — The GPS engine is tracking at least one satellite.<br>2D Nav — The GPS engine is navigating in 2D, constant altitude.<br>3D Nav — The GPS engine is navigating in 3D. |

#### Warning Messages

| | |
|---|---|
| Message 1024: | TCP version m.nn.<br>The TCP startup message with version number m.nn. |
| Message 1025: | Clock zap sss, mmm<br>The internal time of TCP has changed by sss seconds and mmm milliseconds. A discontinuity in data timing will result. |
| Message 1026: | TCP rx msg=mmm, st=xx.<br>The TCP received the unexpected message mmm from the AUX while in state xx. |
| Message 1039: | DSP diag RC=r cnt=n.<br>The DSP diagnostics returned the value r on the nth time run. This is an informational message if r is 0 and a warning message otherwise. |
| Message 1043: | GPS error, ssss.<br>The TCP detected an error in the reception of messages from the GPS. The error ssss is one of the following:<br>Missing — No GPS was detected at startup.<br>Overrun — A byte was not received in time.<br>Frame — A byte was received with an invalid stop bit.<br>Parity — A byte was received with an invalid parity bit.<br>InvSync — A message header had an incorrect sync word.<br>HdrCs — A message header had an incorrect checksum.<br>DataSize — A data message had an invalid length. |

| | | |
|---|---|---|
| | DataCs | A data message had an incorrect checksum. |
| | BufFull | The GPS message buffer was full. |

Message 1044: GPS lost lock.

The GPS has lost lock; its time is unreliable. The TCP is no longer using the GPS for phase locking its time.

Message 1045: GPS gain lock.

The GPS has gained lock; its time is now valid. The TCP is once again using the GPS for phase locking its time.

Message 1046: GPS online.

Messages are now being received from the GPS.

Message 1047: GPS offline, rebooting.

The TCP has not received a valid message from the GPS in over 10 s. Power to the GPS is turned off immediately and back on in 10 s.

Message 1049: TCP rx err len=nnn, xxxx

The TCP received an invalid message from the aux of length nnn. The status word from the serial port was xxxx.

Message 1050: Inv msg len exp nnn got mmm.

The TCP received an invalid message length from the aux. The message said it was nnn bytes; instead it received mmm bytes.

Message 1052: Config saved ok.

The configuration was saved successfully. The TCP is now rebooting to use the new configuration.

Message 1062: Battery voltage, nn.nn.

The input voltage has changed over a battery voltage threshold value. The current voltage reading is nn.nn volts.

Message 1066: Rx invalid config

The TCP received an invalid configuration from the AUX. The TCP is ignoring it and continuing to run with its current configuration.

Message 1071: PLL did not fine lock.

The GPS was on for its maximum allowed duration before it could correct its time error to within 1 microsecond. The GPS is being turned off anyway.

Message 1074 Using xxxx power source.

The Orion switched the source of its input voltage. The Orion will use the mains/charger power supply if present, otherwise it will use the external battery if it has not been discharged, otherwise it will use the internal batteries.

Message 1077 Disk removed.

The Orion has detected that the disk cartridge has been removed. The AUX processor will not be booted until after it has been inserted. If not inserted before running out of memory, data will be lost.

Message 1078 Disk inserted.

The Orion has detected that the disk cartridge has been inserted.

Message 1081: GPS time error sss, mmm.

The GPS is reporting the digitizer time is incorrect by sss seconds and mmm milliseconds. This error must remain stable for some time before the digitizer will accept it as correct. If the time error is 0, this indicates that the GPS is no longer indicating that the digitizer time is incorrect.

Message 1082: Digitizer time valid.

The digitizer time is now accepted as correct and any the GPS must indicate the same error for a prolonged period for it to be accepted. Any large errors in with respect to GPS time are corrected by resetting the GPS engine.

Message 1083: Digitizer time invalid.

The GPS engine has repeatedly indicated that the digitizer time is wrong so the digitizer will believe it and proceed as on startup.

Message 1085: Charger mode mmmm.

The internal disk charger is now on either a slow charge or off, indicated by mmmm.

### Error Messages

Message 1034: DSP send cmd not ready.

The TCP tried to send a command to the DSP but it was not ready to receive one. The TCP will restart the DSP to ensure proper acquisition.

Message 1035: DSP send cmd failed.

The TCP sent a command to the DSP which it did not acknowledge as completed. The TCP will restart the DSP to ensure proper acquisition.

Message 1036: DSP send word not ready.

The TCP tried to send a word to the DSP but it was not ready to receive one. The TCP will restart the DSP to ensure proper acquisition.

Message 1037: DSP send word failed.

The TCP sent a word to the DSP which it did not acknowledge as received. The TCP will restart the DSP to ensure proper acquisition.

Message 1038: DSP read word not ready.

The TCP tried to read a word from the DSP but it was not ready to send one. The TCP will restart the DSP to ensure proper acquisition.

Message 1040: DSP startup failure.

The TCP failed to download the runtime code to the DSP.

Message 1053: Config failed to save.

The configuration failed to save. The TCP is continuing to run with its current configuration.

Message 1065: Mem bank invalid m of n

A memory check detected an error in memory bank m. The memory was configured to use n memory banks.

Message 1067: DSP invalid bundle xxxx.

The TCP received an invalid bundle from the DSP. The TCP is ignoring this bundle and is allowing the DSP to continue to digitize.

### Fatal Error Messages

Message 1029: TCP: AUX time out.

The AUX is not communicating with the TCP. This results in the TCP cycling power to the AUX. If the communications problem repeats, the TCP will also reboot itself.

Message 1048: DSP time out, restarting

The DSP has not sent a valid message to the TCP in over 2 s. The DSP will be restarted.

Message 1051: Mem corrupt in ffff.

A memory buffer corruption was detected in function ffff. The TCP is rebooting.

Message 1059: Mem pointer invalid, xxxxxx.

The TCP detected the invalid pointer xxxxxx in the memory buffer.

Message 1084: Main loop stopped, rebooting.

The TCP detected that the main processing loop is no longer running. It is rebooting to recover.

The TCP may also report any message as a Fatal Message if on startup it finds an invalid memory buffer but a valid message. This message is sent as a Fatal Message to possibly help explain why it rebooted.

### Verbose Trace (Debug) Messages

Message 1058: TCP got AUX msg xxx.

The TCP received the message xxx from the AUX.

Message 1063: Event started n trigs, m.

The event detector has declared the start of an event with n triggers; m is a bitmask indicating which triggers were on at the time.

Message 1064: Event ended n trigs, m.

The event detector has declared the end of an event with n triggers; m is a bitmask indicating which triggers were on at the time.

# Appendix D - Filter Response Plots, Poles & Zeroes

## Response

Analog signals connected to the HRD24 are low pass filtered using a three stage antialias filter before being sampled at 240 kHz. This data is later low pass filtered and decimated using a 3 to 5 stage FIR filter to give the output sample rate. Depending on the requested sample rate different filters are used and different number of filter stages are required. The output bandwidth will always be 0.4 x F sample out.

The low frequency response is also configurable using the DC removal IIR filter. With no filter the response is to DC. With the DC removal filter enabled it can be set to a number of predetermined frequencies depending on the customers' application.

## System Filter Values

### Transfer Functions

The transfer functions of all the components in the HRD24 are as follows:

#### Analog Low Pass Antialias Filter

5th order Bessel Lowpass

$$F(s) = \frac{\omega_1{}^2\omega_2{}^2\omega_3}{(s^2 + \frac{s\omega_1}{Q_1} + \omega_1{}^2)(s^2 + \frac{s\omega_2}{Q_2} + \omega_2{}^2)(s + \omega_3)}$$

*Note:* 1. *Damping and Q are related by the expression D = 1/2Q*

2. *The complex frequency response is obtained by substituting* $s=-j\omega$

#### Digital FIR Lowpass

$$y(n) = \sum_{i=0}^{N-1} c(i) * x(n-i)$$

#### Optional Digital IIR Highpass.

$$y(n) = K \times [x(n) - x(n-1)] + F_1 \times y(n-1)$$

#### Digital Response (Time Domain Difference Equations)

- x(n) is current sample
- x(n-1) is previous sample, etc.
- y(n) is the output sample
- y(n-1) is the previous output sample
- c(i) is a FIR coefficient
- N is the number of coefficients
- K is the filter gain (see coefficients for calculation of value)
- $F_1$ is the filter coefficient (see coefficients for calculation of value)

### Coefficients

The values for all the coefficients for these transfer functions and for the different sample rates are:

5th Order Bessel Analog Lowpass Filter

$f_{3db}$ = 1500Hz

$\omega_1$ = 14713
$\omega_2$ = 16594
$\omega_3$ = 14202
$Q_1$ = 0.916478
$Q_2$ = 0.563536

```
Zeros          None

Poles         -2077.65          1080.15
              -2077.65         -1080.15
              -1440.9           2213.4
              -1440.9          -2213.4
              -2260.35            0.0
```

## Digital FIR Filters

The individual digital filter stages and associated decimation for each output sample rate is indicated below:

| Sample Rate | | Stage 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 10 | Coefficient set | 1 | 2 | 9 | 8 | 10 |
| | # of Coefficients | 34 | 30 | 256 | 110 | 256 |
| | Decimation | 5 | 3 | 4 | 10 | 5 |
| 20 | Coefficient set | 1 | 2 | 9 | 5 | 10 |
| | # of Coefficients | 34 | 30 | 256 | 56 | 256 |
| | Decimation | 5 | 3 | 4 | 5 | 5 |
| 40 | Coefficient set | 1 | 2 | 3 | 7 | 10 |
| | # of Coefficients | 34 | 30 | 118 | 36 | 256 |
| | Decimation | 5 | 3 | 2 | 5 | 5 |
| 50 | Coefficient set | 1 | 2 | 3 | 8 | 3 |
| | # of Coefficients | 34 | 30 | 118 | 110 | 118 |
| | Decimation | 5 | 3 | 2 | 10 | 2 |
| 80 | Coefficient set | 1 | 2 | 7 | 10 | |
| | # of Coefficients | 34 | 30 | 36 | 256 | |
| | Decimation | 5 | 3 | 5 | 5 | |
| 100 | Coefficient set | 1 | 2 | 3 | 5 | 3 |
| | # of Coefficients | 34 | 30 | 118 | 56 | 118 |
| | Decimation | 5 | 3 | 2 | 5 | 2 |
| 120 | Coefficient set | 1 | 1 | 5 | 3 | |
| | # of Coefficients | 34 | 34 | 56 | 118 | |
| | Decimation | 5 | 5 | 5 | 2 | |
| 125 | Coefficient set | 1 | 2 | 9 | 3 | 3 |
| | # of Coefficients | 34 | 30 | 256 | 118 | 118 |
| | Decimation | 5 | 3 | 4 | 2 | 2 |
| 200 | Coefficient set | 1 | 2 | 3 | 10 | |
| | # of Coefficients | 34 | 30 | 118 | 256 | |
| | Decimation | 5 | 3 | 2 | 5 | |
| 250 | Coefficient set | 1 | 2 | 3 | 9 | |
| | # of Coefficients | 34 | 30 | 118 | 256 | |
| | Decimation | 5 | 3 | 2 | 4 | |
| 500 | Coefficient set | 1 | 2 | 3 | 3 | |
| | # of Coefficients | 34 | 30 | 118 | 118 | |
| | Decimation | 5 | 3 | 2 | 2 | |
| 1000 | Coefficient set | 1 | 2 | 3 | | |
| | # of Coefficients | 34 | 30 | 118 | | |
| | Decimation | 5 | 3 | 2 | | |

***Note:** The following sets of filter coefficients are symmetric, so only the first half of each coefficient set is unique.*

## FIR 1 Filter

Coefficients:

| | | | |
|---|---|---|---|
| .37887750E-04 | .19972690E-03 | .59127680E-03 | .11983370E-02 |
| .16771960E-02 | .12344440E-02 | -.11587740E-02 | -.60717290E-02 |
| -.12610230E-01 | -.17666850E-01 | -.16153700E-01 | -.26318100E-02 |
| .26016630E-01 | .68053870E-01 | .11598610E+00 | .15823440E+00 |
| .18304990E+00 | | | |

## FIR 2 Filter

Coefficients:

| | | | |
|---|---|---|---|
| .65879140E-04 | .18999690E-03 | -.48271860E-04 | -.12167770E-02 |
| -.24576070E-02 | -.56870410E-03 | .64952830E-02 | .12949710E-01 |
| .54490100E-02 | -.21592960E-01 | -.46964620E-01 | -.27110750E-01 |
| .65665070E-01 | .20294310E+00 | .30618330E+00 | |

## FIR 3 Filter

Coefficients:

| | | | |
|---|---|---|---|
| -.10469050E-04 | -.23775850E-04 | -.57189790E-05 | .34235910E-04 |
| .30510890E-04 | -.43931380E-04 | -.74450120E-04 | .33569670E-04 |
| .13626920E-03 | .12775610E-04 | -.20250920E-03 | -.11221470E-03 |
| .24881280E-03 | .27300920E-03 | -.23787890E-03 | -.48829860E-03 |
| .12572530E-03 | .72734340E-03 | .12936810E-03 | -.93176250E-03 |
| -.55240180E-03 | .10165270E-02 | .11356850E-02 | -.87963280E-03 |
| -.18237780E-02 | .42009940E-03 | .25042740E-02 | .43635570E-03 |
| -.30083210E-02 | -.17077060E-02 | .31243130E-02 | .33271760E-02 |
| -.26257430E-02 | -.51224640E-02 | .13114520E-02 | .68085340E-02 |
| .94634530E-03 | -.79983710E-02 | -.41534900E-02 | .82323910E-02 |
| .81525810E-02 | -.70231140E-02 | -.12595930E-01 | .39059990E-02 |
| .16935290E-01 | .15189370E-02 | -.20422150E-01 | -.95799080E-02 |
| .22094260E-01 | .20608240E-01 | -.20677420E-01 | -.35219510E-01 |
| .14170540E-01 | .55255850E-01 | .19045860E-02 | -.87902020E-01 |
| -.45041460E-01 | .18229700E+00 | .41058640E+00 | |

## FIR 5 Filter

Coefficients:

| | | | |
|---|---|---|---|
| .12782890E-04 | .48643590E-04 | .11441210E-03 | .19101250E-03 |
| .21918730E-03 | .10430840E-03 | -.24262950E-03 | -.82881090E-03 |
| -.14973390E-02 | -.18942790E-02 | -.15440160E-02 | -.57334200E-04 |
| .25742180E-02 | .57240760E-02 | .80869100E-02 | .79813300E-02 |
| .40091240E-02 | -.41013180E-02 | -.14800320E-01 | -.24551390E-01 |
| -.28451320E-01 | -.21612060E-01 | -.93961880E-03 | .33307630E-01 |
| .76832370E-01 | .12189460E+00 | .15915570E+00 | .18025140E+00 |

## FIR 7 Filter

Coefficients:

| | | | |
|---|---|---|---|
| .17959570E+00 | .15658660E+00 | .11696820E+00 | .71106050E-01 |
| .29584940E-01 | -.19804620E-03 | -.15757160E-01 | -.19135740E-01 |
| -.14987090E-01 | -.82432300E-02 | -.24120900E-02 | .10071550E-02 |
| .21350310E-02 | .18729370E-02 | .11472870E-02 | .52109530E-03 |
| .16726350E-03 | .30742490E-04 | | |

## FIR 8 Filter

Coefficients:

| | | | |
|---|---|---|---|
| .53052610E-05 | .10953120E-04 | .20675100E-04 | .34052430E-04 |
| .50472810E-04 | .68211750E-04 | .84200660E-04 | .93979800E-04 |
| .91897430E-04 | .71636490E-04 | .27084270E-04 | -.46485310E-04 |

| | | | |
|---|---|---|---|
| -.15100320E-03 | -.28415160E-03 | -.43808070E-03 | -.59857000E-03 |
| -.74491660E-03 | -.85078410E-03 | -.88618130E-03 | -.82060140E-03 |
| -.62718340E-03 | -.28758020E-03 | .20297010E-03 | .83102670E-03 |
| .15615300E-02 | .23363420E-02 | .30754000E-02 | .36809580E-02 |
| .40450460E-02 | .40599480E-02 | .36310380E-02 | .26909270E-02 |
| .12135200E-02 | -.77365120E-03 | -.31805090E-02 | -.58504900E-02 |
| -.85628220E-02 | -.11041720E-01 | -.12972550E-01 | -.14024250E-01 |
| -.13876500E-01 | -.12249520E-01 | -.89338860E-02 | -.38172700E-02 |
| .30945470E-02 | .11665130E-01 | .21625100E-01 | .32581180E-01 |
| .44036450E-01 | .55420730E-01 | .66128860E-01 | .75563820E-01 |
| .83180910E-01 | .88529390E-01 | .91287400E-01 | |

## FIR 9 Filter

Coefficients:

| | | | |
|---|---|---|---|
| -.63165740E-06 | -.62659390E-06 | .12341120E-07 | .19443620E-05 |
| .52688010E-05 | .92897450E-05 | .12445590E-04 | .12748020E-04 |
| .87046720E-05 | .38979440E-06 | -.99129780E-05 | -.18047240E-04 |
| -.19491400E-04 | -.11616430E-04 | .43002920E-05 | .22504380E-04 |
| .34411790E-04 | .32263790E-04 | .13405330E-04 | -.16936110E-04 |
| -.46279200E-04 | -.59500730E-04 | -.46016810E-04 | -.63744060E-05 |
| .45373710E-04 | .85775730E-04 | .91924170E-04 | .53358520E-04 |
| -.19861020E-04 | -.97951750E-04 | -.14255550E-03 | -.12460020E-03 |
| -.40992450E-04 | .78728180E-04 | .18117280E-03 | .21176560E-03 |
| .14223950E-03 | -.10259850E-04 | -.18378220E-03 | -.29509180E-03 |
| -.27808870E-03 | -.12008070E-03 | .12294540E-03 | .34332070E-03 |
| .42759340E-03 | .31267720E-03 | .25394960E-04 | -.31720130E-03 |
| -.55291660E-03 | -.54898170E-03 | -.27285180E-03 | .17702630E-03 |
| .60176520E-03 | .78727530E-03 | .60901970E-03 | .10637440E-03 |
| -.51488380E-03 | -.96290410E-03 | -.99370050E-03 | -.53871000E-03 |
| .23864060E-03 | .99472770E-03 | .13537440E-02 | .10901390E-02 |
| .25880070E-03 | -.79823550E-03 | -.15868160E-02 | -.16872140E-02 |
| -.97042530E-03 | .30438790E-03 | .15734170E-02 | .22119950E-02 |
| .18360320E-02 | .51828330E-03 | -.11970330E-02 | -.25107530E-02 |
| -.27346700E-02 | -.16423060E-02 | .37022530E-03 | .24128750E-02 |
| .34870880E-02 | .29651350E-02 | .93716220E-03 | -.17585740E-02 |
| -.38698640E-02 | -.43023520E-02 | -.26724400E-02 | .43201660E-03 |
| .36408040E-02 | .53930380E-02 | .46822380E-02 | .16054280E-02 |
| -.25721630E-02 | -.59171980E-02 | -.67056870E-02 | -.42873790E-02 |
| .48599150E-03 | .55216500E-02 | .83789800E-02 | .74249080E-02 |
| .27166160E-02 | -.38455880E-02 | -.92457940E-02 | -.10700780E-01 |
| -.70426100E-02 | .52905760E-03 | .87573810E-02 | .13670180E-01 |
| .12425050E-01 | .48309240E-02 | -.62198690E-02 | -.15746090E-01 |
| -.18802240E-01 | -.12872000E-01 | .55895630E-03 | .16093270E-01 |
| .26359450E-01 | .25168140E-01 | .10638890E-01 | -.13085150E-01 |
| -.36463380E-01 | -.47557470E-01 | -.36446600E-01 | .57424880E-03 |
| .58698170E-01 | .12526940E+00 | .18337210E+00 | .21718010E+00 |

## FIR 10 Filter

Coefficients:

| | | | |
|---|---|---|---|
| -.58341210E-05 | -.97909810E-05 | -.14950560E-04 | -.18411240E-04 |
| -.17651870E-04 | -.10377960E-04 | .45130490E-05 | .26043100E-04 |
| .50695700E-04 | .72713060E-04 | .85281480E-04 | .82442490E-04 |
| .61274060E-04 | .23651500E-04 | -.23135700E-04 | -.67405480E-04 |
| -.95796680E-04 | -.97157430E-04 | -.66560650E-04 | -.81320900E-05 |
| .64496310E-04 | .13074540E-03 | .16840730E-03 | .16048740E-03 |
| .10159850E-03 | .17182670E-05 | -.11440040E-03 | -.21272770E-03 |
| -.25939080E-03 | -.23160750E-03 | -.12678270E-03 | .33505350E-04 |

| | | | |
|---|---|---|---|
| .20673650E-03 | .33995610E-03 | .38523620E-03 | .31579180E-03 |
| .13760430E-03 | -.10787590E-03 | -.35208950E-03 | -.51762300E-03 |
| -.54179750E-03 | -.39867720E-03 | -.11216670E-03 | .24520840E-03 |
| .56929360E-03 | .75359680E-03 | .72298160E-03 | .46145650E-03 |
| .24388810E-04 | -.47066000E-03 | -.87408170E-03 | -.10481340E-02 |
| -.91212410E-03 | -.47452460E-03 | .15975800E-03 | .81206220E-03 |
| .12786600E-02 | .13927240E-02 | .10812130E-02 | .39795400E-03 |
| -.48014670E-03 | -.12964150E-02 | -.17875410E-02 | -.17662870E-02 |
| -.11884130E-02 | -.18094000E-03 | .98108760E-03 | .19470490E-02 |
| .23942110E-02 | .21323790E-02 | .11766510E-02 | -.23782690E-03 |
| -.17093030E-02 | -.27805280E-02 | -.30777790E-02 | -.24364060E-02 |
| -.97198160E-03 | .93041830E-03 | .27128880E-02 | .38046110E-02 |
| .38003170E-02 | .26026980E-02 | .48070990E-03 | -.19821030E-02 |
| -.40427900E-02 | -.50181070E-02 | -.45043970E-02 | -.25293030E-02 |
| .41830170E-03 | .35003010E-02 | .57607290E-02 | .64147440E-02 |
| .51099710E-02 | .20761460E-02 | -.18935850E-02 | -.56389330E-02 |
| -.79612020E-02 | -.79942670E-02 | -.55064680E-02 | -.10335250E-02 |
| .42143110E-02 | .86632170E-02 | .10829570E-01 | .97904870E-02 |
| .55284280E-02 | -.96807720E-03 | -.79023240E-02 | -.13135920E-01 |
| -.14809990E-01 | -.11950010E-01 | -.48711300E-02 | .47579920E-02 |
| .14249090E-01 | .20571980E-01 | .21218270E-01 | .15025070E-01 |
| .27228040E-02 | -.12974050E-01 | -.27805090E-01 | -.36865790E-01 |
| -.35778870E-01 | -.21855210E-01 | .50520950E-02 | .42237240E-01 |
| .84486840E-01 | .12503380E+00 | .15691950E+00 | .17445760E+00 |

### DC Removal - IIR Filter

The IIR filter is implemented as a first order IIR filter using the following coefficients calculated at runtime where $SR$ is the output sample rate and $f$ is the filter's 3db corner frequency.

$$F_1 = \frac{1 - \tan(\pi \times f / SR)}{1 + \tan(\pi \times f / SR)}$$

$$K = \frac{1}{1 + \tan(\pi \times f / SR)}$$

The time constant (TC) of the filter can be calculated as follows:

$$TC = \frac{1}{2\pi \times f}$$

# Appendix E - ViewDat

### Description

VIEWDAT is a simple bench test program for the HRD digitizer. It receives HRD output data over an RS-232 serial port, provides a real-time text display of seismic data, GPS status and instrument state-of-health, and a real-time graphical display of seismic data.

### Version

1.04

### Synopsis

**Viewdat [Port] [Baud] [-bN] [-x]**

### Usage and Options

VIEWDAT may be run under DOS or in a DOS window under OS/2 using the command-line syntax given above. If you wish to use the graphical display mode of VIEWDAT you must run the program as a DOS full-screen session. The data port of the HRD should be connected to one of the serial ports (com1 or com2). To avoid missing any data, the program should be started before the HRD is powered up. However, the program may be started at any time; it will start displaying and recording data after receiving the next data sync (at the start of the next data packet).

VIEWDAT recognizes the following command-line options:

| | |
|---|---|
| *Com Port* | Specify com1 or com2 to specify to which serial port the HRD is connected. Default is com2. |
| *Baud Rate* | Specify the baud rate for communication with the HRD. Accepted values are 12(00), 24, 48, 96, 192 and 384. The default is 38400. This MUST be set to the same value as that being used for transmission by the HRD. |
| *Data Bundles per Packet (-bN)* | Specify the number of data bundles per compressed data packet. This must be an odd number in the range of 1 to 59. This MUST be set to the same value as that being used for transmission by the HRD. The default is 59. |
| *Transmission Mode (-x)* | Data transmission may be optimized for wire (default) or radio mode (-x). In radio mode the data is scrambled and the data is augmented by filler in order to maintain the full transmission baud rate. In wire mode the data is unscrambled. This parameter MUST be set to the same value as that being used for transmission by the HRD. |
| *Help (-h)* | Type VIEWDAT -h to display a usage summary. |

### Commands

VIEWDAT recognizes the following keyboard commands:

| | |
|---|---|
| V | Toggles between the two display modes (text and graphics). |
| P | Pauses the display (stops displaying incoming data). |
| R | Resumes updating the display. |
| ESC | Exit the program. |

In graphics mode VIEWDAT also provides the following commands:

| | |
|---|---|
| D | Toggle the DC removal option.<br>DC removal Off - the raw data is displayed<br>DC removal On - the packet mean is subtracted from the data before plotting. |
| +/- | Changes the vertical scale factor for the trace plots. |

## Text Mode Display

The VIEWDAT text display is divided into 4 parts:

1. The top section of the screen shows current signal statistics from each data channel,
2. the next section shows the current GPS status,
3. the third section shows the most recent state-of-health readings and
4. the bottom section logs incoming messages and communication diagnostics.

## Data Display

The VIEWDAT display is packet-based. The HRD outputs data in packets which contain a timestamp, followed by 4N to 16N data samples in a compressed format, where N is the number of data bundles per packet (see above). For example, if N = 59, each packet contains 236 to 944 samples, which corresponds to 1.2 to 4.7 seconds of data at 200 sps. VIEWDAT computes signal statistics based on the data contained within a single packet and displays the following information:

| | |
|---|---|
| *Channel Number* | The digitizer channel number (0 to 5). |
| *Sequence Number* | The sequence number of this packet. Packets are numbered sequentially for each channel. Sequence number is reset to zero when the HRD is restarted. Only the last 4 digits of the sequence number are shown. |
| *Time* | The time of the first sample in the packet in the format MM:SS.FRAC. |
| *Number of Samples* | The number of samples in the packet. This is also the number of samples over which the displayed values are calculated. |
| *Maximum* | The maximum sample value in the packet. |
| *Minimum* | The minimum sample value in the packet. |
| *Mean* | The arithmetic mean of all sample values in the packet. |
| *RMS* | The root mean square (standard deviation) of the sample values in the packet. |
| *Trend* | The rate of change of the mean value per second. This is determined through a linear regression of the sample value vs. time. |
| *ZC - zero crossings* | The number of zero crossings in the packet. |
| *Frequency* | Estimated signal frequency is based on the number of zero crossings. This is meaningful only for sinusoidal input signals. |

## GPS Display

The GPS status display shows the GPS status and activity as determined from the most recent message received.

### Status

| | |
|---|---|
| Unlocked | The GPS is off or unlocked (not providing accurate time information). |
| Coarse Lock | The GPS is locked and the instrument time is in fast-lock mode. |
| Fine Lock | The GPS is locked and the instrument time is in fine-lock mode. |

### Mode

| | |
|---|---|
| NAV3D | The GPS has a full 3D time and position solution. |
| NAV2D | The GPS has a 2D time and position solution. |
| ACQ | The GPS is searching for satellites and does not have accurate time and position. |
| ACQ COLD: | The GPS is searching for satellites in cold start mode. |

### Num Satellites

This shows the number of satellites used for the current GPS time and position solution.

### Figure of Merit

An indicator of the horizontal position accuracy: 1 = best; 9 = unlocked.

### Date, Time and Position

The middle column of the GPS display shows the time and position returned by the GPS clock. Note that the time may not be completely up to date since the GPS information messages may be buffered for some time before being transmitted to VIEWDAT.

### Channel Status

The right hand column of the GPS display shows the current activity of the 5 GPS channels. Each channel may be searching for a satellite, tracking a satellite, or idle. The display also shows the PRN number of the satellite being searched for or tracked and the signal to noise ratio of the incoming GPS signal. The signal to noise ratio must usually be over 30 in order to track a satellite; over 40 is better. Poor signal to noise ratios often indicate that the GPS antenna is obstructed.

## State of Health Display

| | |
|---|---|
| *SSOH and FSOH* | These fields show the most recent readings from the slow and fast state-of-health channels respectively. Readings are shown as counts from a 10-bit A/D and are always between 0 and 1023. |
| *Comm Rx* | This shows the number of bytes received from the HRD by VIEWDAT. |
| *Comm Ovr* | This shows the number of bytes lost due to com port overruns (should be zero). |
| *Bytes Lost* | This shows the number of bytes lost due to sync or CRC errors. This should be zero for a good communication link. Any change in this value indicates that one or more messages has been lost, usually due to noise or fading on the serial data link. |

## Graphical Display

In graphical display mode VIEWDAT plots the contents of each data packet as it is received. The vertical scale may be adjusted by pressing + or -; the current scale factor is shown in the status line at the top of the screen. The horizontal scale is adjusted automatically to the number of samples in the data packet. To the left of each trace VIEWDAT displays the maximum, minimum, mean and RMS for the current packet. The sequence number and number of samples for the displayed packet is shown in the upper left corner of the trace box; the time of the first sample is shown in the lower left corner. Definitions of all displayed fields are given above.

*Note that VIEWDAT plots packets; since packets on different channels may be generated at different times the traces shown are not, in general, aligned with each other along the time axis.*

## Environment

Viewdat will run under DOS (DOS 6.2 or higher), in DOS full-screen mode under OS/2, Windows95 or WindowsNT.

# Appendix F - Upgrading HRD firmware using ZOC

*The following is also applicable for upgrading the HRD firmware in an HRD.*

*Remove the disk cartridge from the HRD prior to upgrading its firmware.*

### Install ZOC on PC

1. Insert the appropriate ZOC installation diskette (**ZOC for OS/2** or **ZOC for Windows**) into the floppy drive of the PC.
2. Open a command prompt window.
3. Change the working directory to the floppy drive by typing **a:** at the command prompt and pressing **Enter**. (assuming A: is the floppy drive)
4. At the command prompt type **install** (if OS/2) or **setup** (if Windows) and press **Enter**.
5. If the "Destination path" box is empty, type **c:\zoc** (or a suitable alternative) in the box.
6. Press the ZOC **Install** button to start the installation.
7. When notified "All files processed - installation complete", press the **OK** button.
8. When asked "Do you want to read ZOC's DOC files now?", press the **No** button.
9. To close the command prompt window, type **exit** and press **Enter**.
10. Remove the ZOC installation diskette from the floppy drive of the PC and save it in a safe place.

### Configure ZOC

1. Start **ZOC** by double clicking on the icon created on the OS/2 desktop or from the entry in the Windows Start button menu.
2. If notified "No CTS signal from COM1", press the **Abort** button.
3. If a "License Agreement" window is displayed, press the **Agree** button.
4. If notified "New month -- do you want a phone cost report?", press the **No** button.
5. If a "Getting Started" help window is displayed, double click on the button at the top left of the help window to close it.
6. Select the **Options** item from the menu bar.
7. Select the **Settings...** item from the Options drop down menu.
8. Check that the I/O Device is set to **Serial/Modem**.
9. Check that the **Com-Port** is set to the PC com port to which the HRD configuration port is connected.
10. Check that the Com-Port baud is set to **9600**. (The Orions are shipped with the configuration port set to 9600 baud. However, it may have been changed since then.)
11. Check that the Com-Port is set to **8N1**. (8 bits data, no parity, 1 stop bit is the only option for the configuration port.)
12. Deselect the Com-Port **Valid CD signal** handshaking option. The other handshaking options should already be deselected. (The HRD configuration port does not have any of the modem control signals used for handshaking.)
13. Press the **Transfer** tab at the right (if OS/2) or at the top (if Windows) of the "Options Settings".
14. Select the **Compuserve-B+** Protocol.
15. Select both the **Disable ENQ** and the **Disable ENQ message** Compuserve-B+ options. This will prevent ZOC from hanging on binary data.

16. Select the **Zmodem** Protocol.
17. If OS/2, press the right arrow button at the bottom right to go to **[Page 2 of 2]** of the transfer options, otherwise if Windows, press the **Transfer-2** tab.
18. Change the ASCII-/Clipboard Sending option **Char delay** to **0**. This will make ASCII uploads MUCH faster.
19. Press the **Safety** tab.
20. Deselect the **... ending program** Confirm ... option.
21. Deselect the **Warning for high speed without RTS/CTS** Miscellaneous option.
22. If a "Getting Started" help window was displayed on startup press the Window tab and deselect the **Initial help window** Screen Elements option.
23. Press the **Save** button at the top of the "Options Settings" window.
24. Close **ZOC** by double clicking on the button at the top left of the ZOC window.

### Copy HRD firmware to PC's hard drive

*Note: the new HRD firmware must be copied to the PC's hard drive since uploading firmware from a floppy drive is not reliable. (A network drive is possible but a local drive is preferable.)*

1. Insert the HRD Release diskette into the floppy drive of the PC.
2. The HRD Release diskette contains 7 files.
3. The file DSPDIAGS.HEX contains a diagnostics program which the DSP runs on startup to do basic hardware checks.
4. The file DSPLOAD.HEX contains a utility program used to transfer the main DSP program into the DSP memory.
5. The file FIRS.HEX contains the FIR filter coefficients used by the DSP.
6. The file DSPxx.HEX contains the main DSP firmware (xx indicates the version number) for the digitizer.
7. The file TCPyyy.HEX contains the main TCP firmware (yyy indicates the version number) for the digitizer.
8. The file HRDzz.HEX contains the previous 5 files released in one file (zz indicates the release number) for uploading into HRDs.
9. The file HRDzz.BIN contains the binary image of the file HRDzz.HEX used for burning into flashes.
10. Open a command prompt window.
11. Change the working directory to **c:\zoc\upload** (assuming ZOC was installed in c:\zoc), at the command prompt type **cd \zoc\upload** and press **Enter**. This directory is chosen to make the ASCII uploads easier, however any directory may be chosen.
12. Copy the new HRD firmware release from the floppy, at the command prompt type **copy a:\hrd*.hex** and press **Enter**.
13. Close the command prompt window.
14. Remove the HRD Release diskette from the floppy drive of the PC and save it in a safe place.

### Accessing the HRD setup menu

1. Start **ZOC**.
2. Power on the HRD.

3. The HRD will start up with lines similar to the following:
   **TCP Version 5.12, released Mar 17 1997 16:36:40**
   **Press 'M' key within 5 seconds or during memory test**
4. Immediately press the **M** key to access the HRD menu. (There will be at least a 5 second window to press the M key, longer if there is a lot of memory to test.)
5. After a power on the memory test will end with the following lines. (the number of memory banks depends on the HRD)
   **Writing 5555 to 8 banks........**
   **Checking for 5555, writing aaaa to 8 banks........**
   **Checking for aaaa, writing 0000 to 8 banks........**
6. If the HRD has proceeded past the memory test, the menu will still be displayed and the configuration may be changed however it is **UNSAFE** to do a firmware upload. The HRD firmware may be severely corrupted (possibly unrecoverable).
7. If intending to upload new firmware, and the HRD has proceeded past the memory test or unsure if it has, power it off and start again.

### Upload new firmware

1. Access the HRD setup menu as outlined above.
2. Double check that the HRD did not proceed past the memory test.
3. Press the **U** key to select the "Upload new firmware" option. (On older firmware, press the **D** key to select the "Download New Firmware" option.)
4. The HRD will respond with "Ready to Upload..."
5. Select the **Transfer** item from the menu bar.
6. Select the **ASCII-Send...** item from the Transfer drop down menu.
7. Use the **Select ASCII Upload File** dialog box to select the file containing the new HRD firmware release. Change the Drive and Directory as necessary if the firmware was not copied to the c:\zoc\upload directory.
8. Press the **OK** button to start the upload.
9. Do not touch the HRD or the PC while the upload is in progress, this will take almost 8 minutes.
10. When it has finished the HRD will automatically program the new firmware and reboot.
11. The HRD will start up with a line indicating the new version number and release date.

### Uploading at faster than 9600 baud

*Note: 9600 baud is the fastest baud rate that is reliable on all machines. However PCs with buffered com ports (have a 16550 compatible UART) or fast 486's and pentiums should upload reliably at 38400.*

Uploading at 19200 reduces the upload time from 8 to 4 minutes, while uploading at 38400 reduces it to 2 minutes.

1. Access the HRD setup menu as outlined above.
2. Press the **C** key to select the "Configuration menu" option.
3. Press the **H** key to select the "Edit hardware setup parameters" option. (On older firmware press the **G** key to select the "Edit data communications parameters" option.)
4. Press the B key to change the "Configuration baud rate" setting.
5. Type the desired new baud rate and press **Enter**.

6. Check that the baud rate has been changed.
7. Press the **Esc** key twice to return to the main HRD setup menu.
8. Press the **P** key to select the "Program user settings" option.
9. Power off the HRD.
10. Press the button labeled 9600-8N1 at the bottom left corner of ZOC.
11. Change the Com-Port baud to the new baud rate set in the HRD.
12. Press the **Save** button.

### Creating a button for uploading firmware

*Note: this feature is only available on ZOC for OS/2.*

This feature is of most use when the file to upload is not in the c:\zoc\upload directory and requires a lot of drive and directory changing to find it using the **Select ASCII Upload File** dialog box.

1. Start **ZOC**.
2. Open the **Options Settings** window.
3. Press the **Buttons** tab.
4. Find the first line with nothing under the "Value" heading.
5. Under the "Value" heading type **^XFER=type c:\zoc\upload\hrdzz.hex 1>&%ZOCHFC% -r**. The file indicated should contain the new HRD firmware release.
6. Under the "Button Text" heading type **HRDzz** (replace zz with the appropriate release number).
7. Press the **Save** button.
8. A button should have been created with the label HRDzz at the top of the ZOC window.
9. Pressing this button is equivalent to selecting the same file using the **Select ASCII Upload File** dialog box (except no **Bytes sent** status).
10. With the HRD **off**, test the button created by pressing it.
11. A window labeled "ZOC Shell Window" should pop up with the name of the file being uploaded.
12. Double click on the button at the top left of this window to close it. Otherwise it will automatically close several minutes later when the entire file has been uploaded.
13. Close **ZOC**.

# Appendix G - Remote GPS Option for HRD

### Name

Remote GPS clock with RS-422 option

### Description

The remote GPS clock with RS-422 option can be used with HRD24 digitizers in locations where there are no provisions for installation of a GPS antenna within the reach of the antenna cable (typically 10m) from the HRD. Instead of being built into the digitizer, the GPS clock can be installed several kilometers away from the digitizer and communicate with it over a RS-422 communication link. Otherwise, it provides the same functionality to the digitizer, which is to enable time stamping of data packets at the source. It has the same data structure and operating modes as the internal GPS clock since it makes use of the same GPS engine.

#### Block schematic

Please refer to Figure 1, which explains operation of the GPS clock.

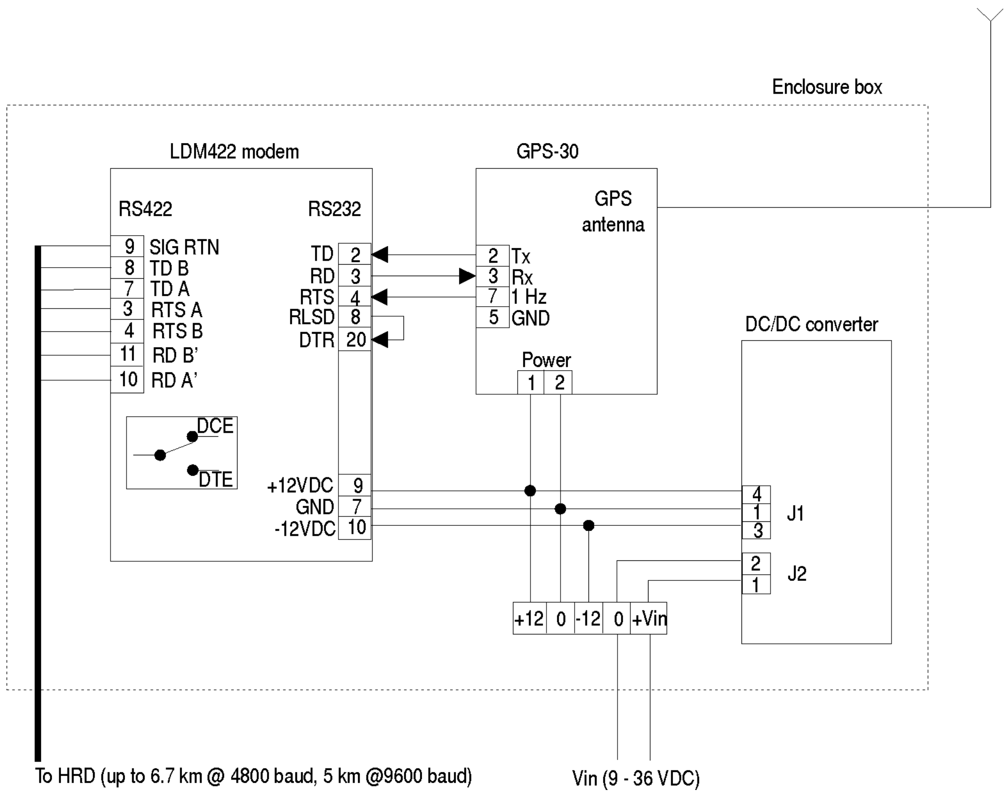



**Figure 1: The remote GPS clock with RS422 option, block schematic**

The GPS clock engine receives a signal from the GPS antenna and provides two outputs to the rest of the system: 1 Hz timing pulse which is not UTC aligned and the RS-232 message string reporting the time of each second mark. Both signals are passed to a fully isolated limited distance modem, RS-232/422 converter, which converts those RS-232 level signals into EIA RS-422 conforming signals. The signals can then be sent over a cable which may be up to 6.7 km long to the HRD 24 digitizer. The GPS clock can be controlled and interrogated by the HRD via a reverse link.

The unit is powered from an external 9 - 36 VDC / 10 W power source.

### Package

The GPS clock is packaged in a 10x8x4" NEMA 4 steel enclosure, as presented in Figure 2. The enclosure provides a degree of protection from rain, snow, windblown dust, splashing water and hose-directed water. It is intended for both indoor and outdoor installation and can be mounted on a tower, a building roof, a wall or any other convenient structure.

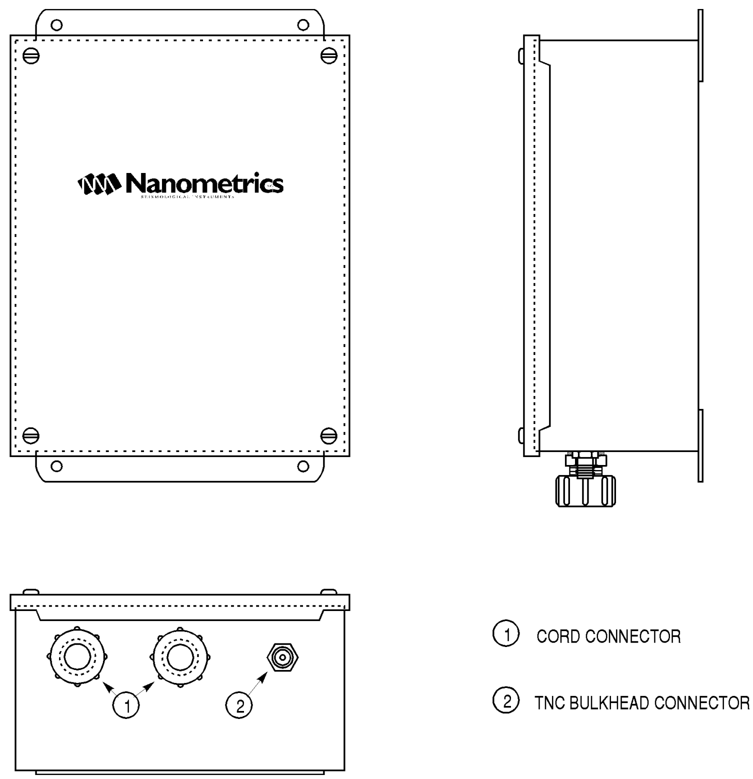



**Figure 2: The remote GPS with RS422 option, box**

### Installation

To install the GPS the user must first install the antenna. The position of the antenna is critical to the operation of the GPS. Ideally, the antenna should be placed in an electrically quiet location with a clear view to the horizon in all directions. The GPS engine tracks the satellites from the horizon to overhead and down to the horizon again. Therefore, it is important that the antenna have a clear view to the horizon. The antenna should be elevated above obstructions such as buildings, power lines, metal structures, trees, etc. The GPS engine can 'see' through foliage but the signal is scattered and attenuated. The antenna should be oriented level.

Most problems with the GPS engines can be traced to a poorly placed antenna. If the GPS is not receiving well, try repositioning the antenna to a more favourable location. Lastly, ensure the antenna cable is not hanging from the antenna. Secure the antenna cable with a few tie wraps near the antenna to carry the weight of the cable.

Attach the enclosure box to a convenient structure (wall, roof, antenna tower) in the vicinity of a DC power source. Install and connect the long RS-422 communication cable and make sure that both cord connectors on the box are tight. Connect the antenna cable.

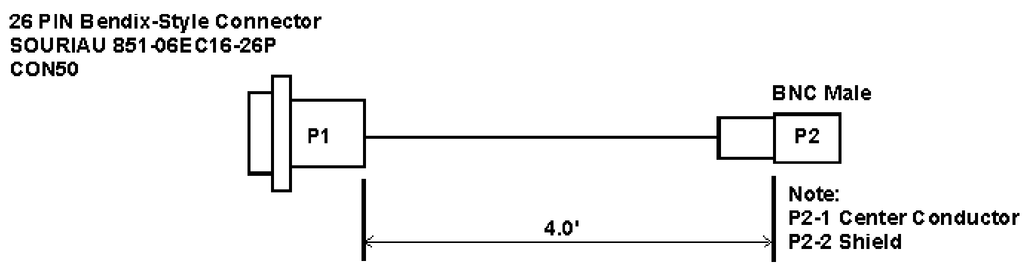
To check the operation of the remote GPS clock the same procedure should be followed as the one used when the GPS clock is built into the digitizer.

# Appendix H - External Cable Drawings

Some external cable drawings.

| ASSOCIATED DRAWINGS: |
|---|
| |
| |

| Rev. | Date | Author | Description |
|---|---|---|---|
| A | June 8/96 | MH | Initial Release |
| | | | |




**WIRING LIST**

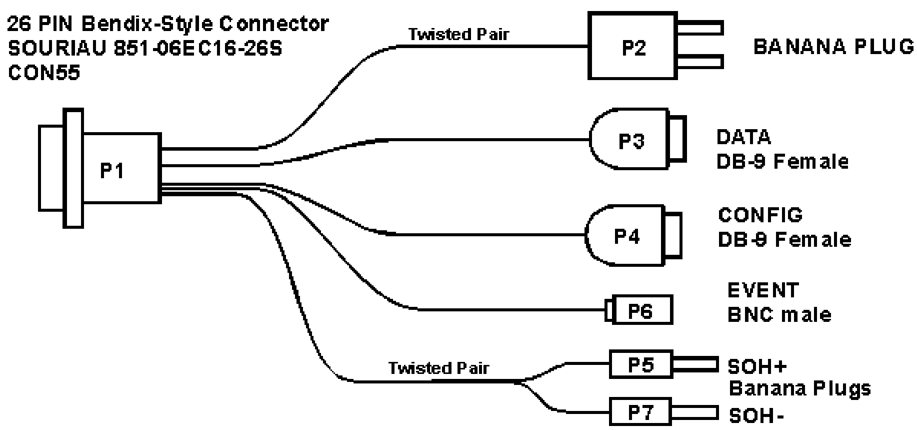
| FROM | TO | COL. | GAUGE | TYPE | LEN. | SIGNAL NAME | RUN |
|---|---|---|---|---|---|---|---|
| P1-A | P2-1 | Center | - | RG-58 | 4.0' | Signal#1+ | 1 |
| P1-F | P2-1 | | | | | Signal#2+ | 1 |
| P1-L | P2-1 | | | | | Signal#3+ | 1 |
| P1-B | P2-2 | Shield | - | RG-58 | 4.0' | Signal#1-1 | |
| P1-G | P2-2 | | | | | Signal#2-1 | |
| P1-M | P2-2 | | | | | Signal#3-1 | |
| P1-E | P2-2 | | | | | Sig#1 GND | 1 |
| P1-K | P2-2 | | | | | Sig#2 GND | 1 |
| P1-R | P2-2 | | | | | Sig#3 GND | 1 |

TITLE: **HRD Signal Test Cable**

| Drawing # | Revision | Filename | Drawn By: | Date | Sheet | Approval / Date |
|---|---|---|---|---|---|---|
| 11021 | A | 11021A.CDR | M. Hayman | June 13/96 | 1 of 1 | |

| ASSOCIATED DRAWINGS: |
|---|
| |
| |

| Rev. | Date | Author | Description |
|---|---|---|---|
| A | June 8/96 | MH | Initial Release |
| B | May 26/97 | GSI | Jumpered RTS/CTS (DATA) |

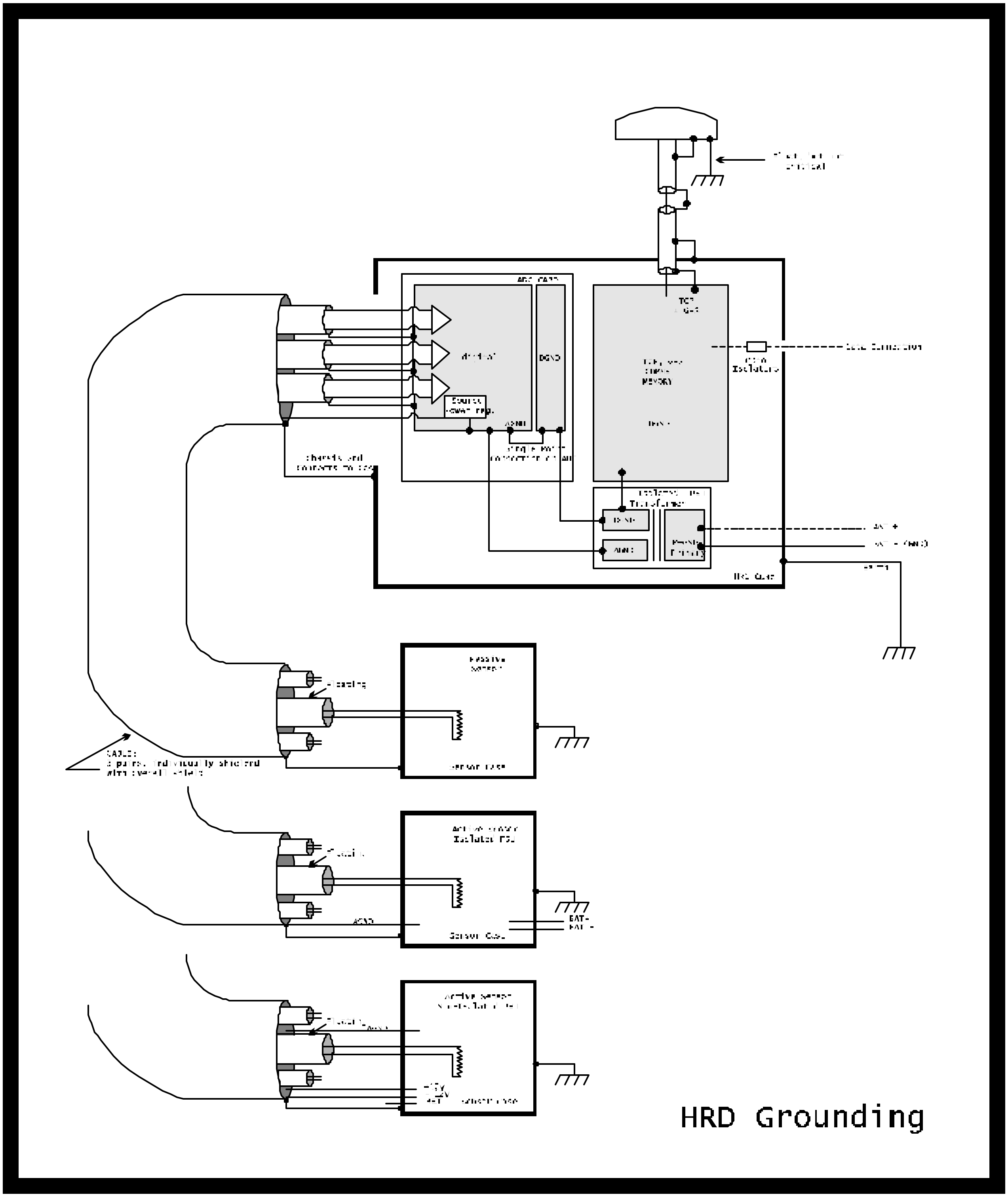



**WIRING LIST**

| FROM | TO | COL. | GAUGE | TYPE | LEN. | SIGNAL NAME | RUN |
|---|---|---|---|---|---|---|---|
| P1-A | P2-1 | Red | 18 | 83009-2 | 4.0' | Power In + | 1 |
| P1-B | P2-2 | Black | 18 | 83009-10 | 4.0' | Power In - | 1 |
| P1-P | P3-3 | Red | 22 | 8723 | 6.0' | Data-RX | 2 |
| P1-R | P3-2 | Green | 22 | 8723 | 6.0' | Data-TX | 2 |
| P1-N | P3-5 | Black | 22 | 8723 | 6.0' | Data-GND | 2 |
| P1-K | P4-3 | Red | 22 | 8723 | 6.0' | Config-RX | 3 |
| P1-H | P4-2 | Green | 22 | 8723 | 6.0' | Config-TX | 3 |
| P1-M | P4-5 | Black | 22 | 8723 | 6.0' | Config-GND | 3 |
| P1-M | P5-1 | Black | 24 | 83004 | 4.0' | SOH-GND | 4 |
| P1-Z | P5-2 | Yellow | 24 | 83004 | 4.0' | SOH1 | 4 |
| P1-a | P1-Z | | | Jumper | | SOH2 | 5 |
| P1-b | P1-Z | | | Jumper | | SOH3 | 6 |
| P1-V | P6-1 | Center | - | RG-58 | 4.0' | EVENT-IN+ | 7 |
| P1-W | P6-2 | Shield | - | RG-58 | 4.0" | EVENT-IN- | 7 |
| P3-7 | P3-8 | Black | 24 | 83004 | 0.5" | JMPR CTS/RTS | 8 |

| TITLE: | | | | | | Approval |
|---|---|---|---|---|---|---|
| **HRD PS/Comms Test Cable** | | | | | | |
| Drawing # | Revision | Filename | Drawn By: | Date | Sheet | Date |
| 11022 | B | 11022B.CDR | M. Hayman | June 13/96 | 1 of 1 | |

# Appendix I - HRD Grounding


HRD Grounding