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The University of California at Santa Barbara

The George E. Brown, Jr. Network for Earthquake Engineering Simulation

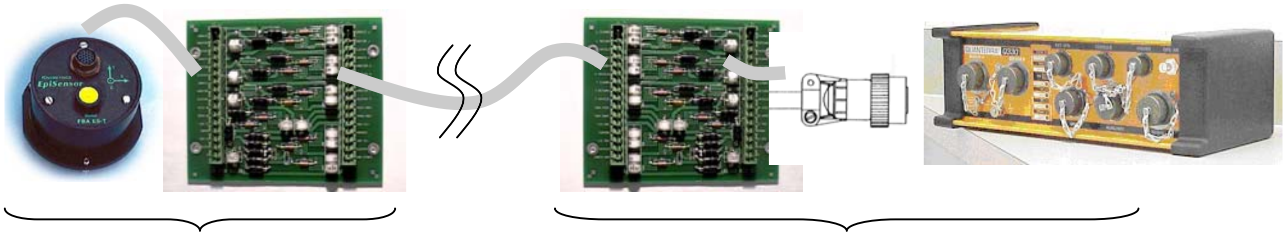
GVDA Instrumentation Guide

Prepared by The Institute for Crustal Studies, UCSB.

Revision 1.5 1/30/08

Section I: Overview

The generic hook-up of a field instrument at Garner Valley is shown in the figure below.



Sensor and LP board are in-ground/in external box

LP board, connector and Q330 are in-the-hut

In the case above, an EpiSensor surface accelerometer with three channels is connected to a local Lightning Protection board in the wellhead box before the signals are passed through an underground cable into the hut.

This cable is terminated at another lightning protection board in the hut and then typically connects to a cable with the Q330 “sensor” connector, which plugs directly into either the SensorA or SensorB input of the datalogger.

The Q330 End

Each Sensor input of the Q330 has three differential analog input channels feeding to the device’s 24-bit analog to digital converters. Each of these inputs is a true differential input with a full-scale range of +/- 20V.

This means an input potential of -20V between the +ve and –ve inputs is represented by the largest negative value out of the 24-bit ADC while +20V between +ve and –ve gives the largest positive output. One bit of the ADC represents $40/2^{24}$ Volts.

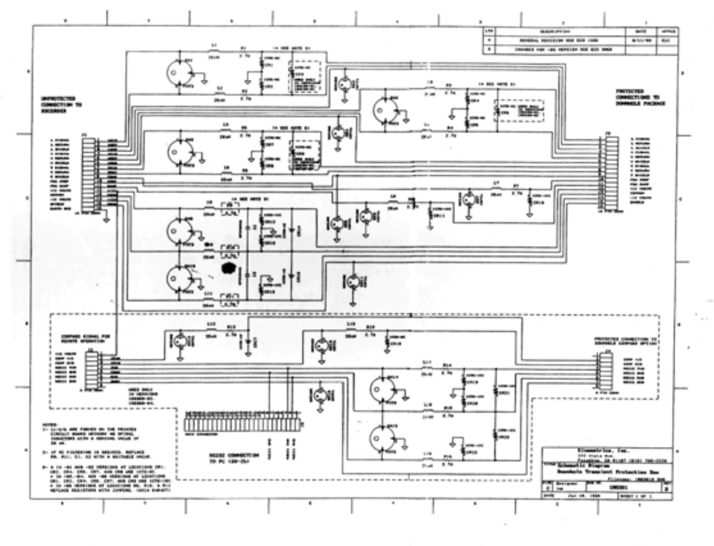
In addition to the analog input channels, the sensor connector also supplies low-current (spec?) 12V supply voltage and calibration control outputs.

There is a color code standard used for the cables from the Q330 sensor connectors to the lightning protection boards (or any other termination).

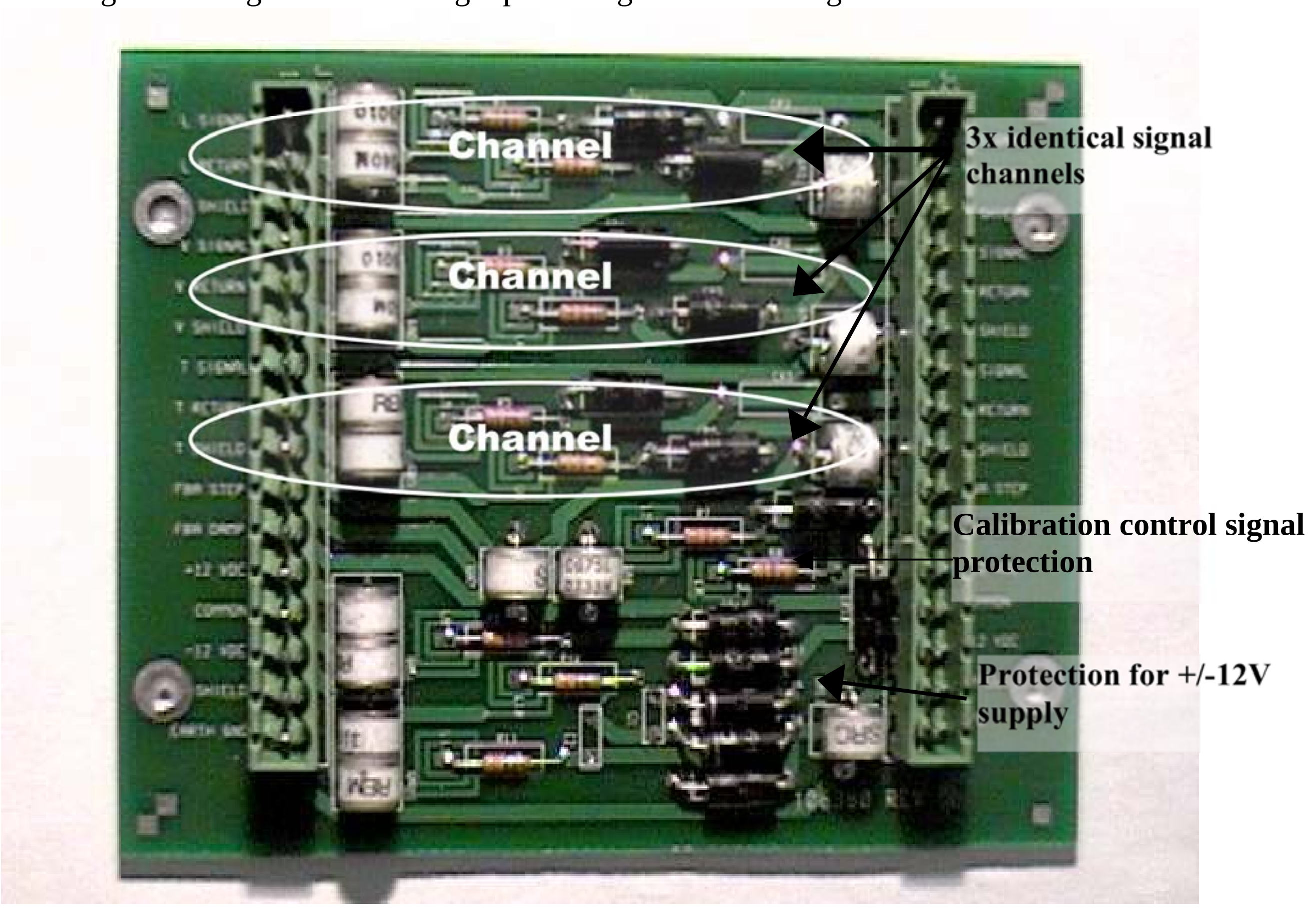
Q330 Sensor A(B)	Cable-color and pairing
+Input 1(4)	Yellow
-Input 1(4)	Black (of Yellow pair)
+Input 2(5)	Green
-Input 2(5)	Black (of Green pair)
+Input 3(6)	White
-Input 3(6)	Black (of White pair)

The Lightning Protection board

The lighting Protection boards were built by consultant based on the design by Kinemetrics.



The board layout pretty much flows as drawn in the schematic, from left to right there is the three-terminal gas-discharge tube, into a series impedance (R+L) followed by the transorbs, with the last gas-discharge tube on the right protecting the 'shield' to ground.



Channel Assignments

The ideal situation is to have tri-axial accelerometers correctly oriented to true-north, in this case the three channels would properly represent acceleration in the Up, North and East directions, in Cartesian terms these are the Z, Y and X axes.

When an instrument has not been installed with correct compass alignment the three channels are referred to as V(ertical), (L)ongitudinal and (T)ransverse corresponding to the Z, Y and X directions respectively.

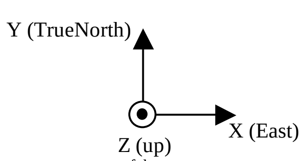
The convention for datalogger channel assignment is the Z (up) direction is channel 1, the Y (or nominally north) is channel 2 and the X (or easterly) is channel 3. (When single-channel transducers, pressure transducers etc., are used then a channel is just a channel.)

Sensor Direction (True)		*LVT Mapping*	*Q330 Channel#*
Z	**(up = positive)**	**V (z)**	**1 (4) Yellow**
N-S	**(north= positive)**	**L (y)**	**2 (5) Green**
E-W	**(east = positive)**	**T (x)**	**3 (6) White**

Thus, wiring from the sensors to the Q330s through the lightning protection etc. should map from sensor-axis to Q330 channel so as to assign up-down to channel#1, north-south to channel#2, east-west to channel#3.

Legacy wiring at Garner valley thwarts this convention with many of the old sensors swapping the channel assignment for the “L” and “T” channels, though over the coming months there will be an effort to minimize any irregularities.

Legacy silkscreen on some lightning protection boards further confuses the clarity of wiring. Every effort will be made to standardize the sequencing of wiring through LP boards so that from top-to-bottom the channel wiring will be 1,2,3 (for a tri-axial accelerometer that would ideally mean Z,N,E).

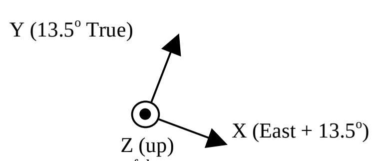


Ideal ‘Standard’ Orientation

Longitudinal (Y) is positive in the direction of true North.

Transverse (X) is positive in the direction 90° clockwise of Y i.e. East

Vertical (Z) is positive for upward components.



Non-True Orientation (example)

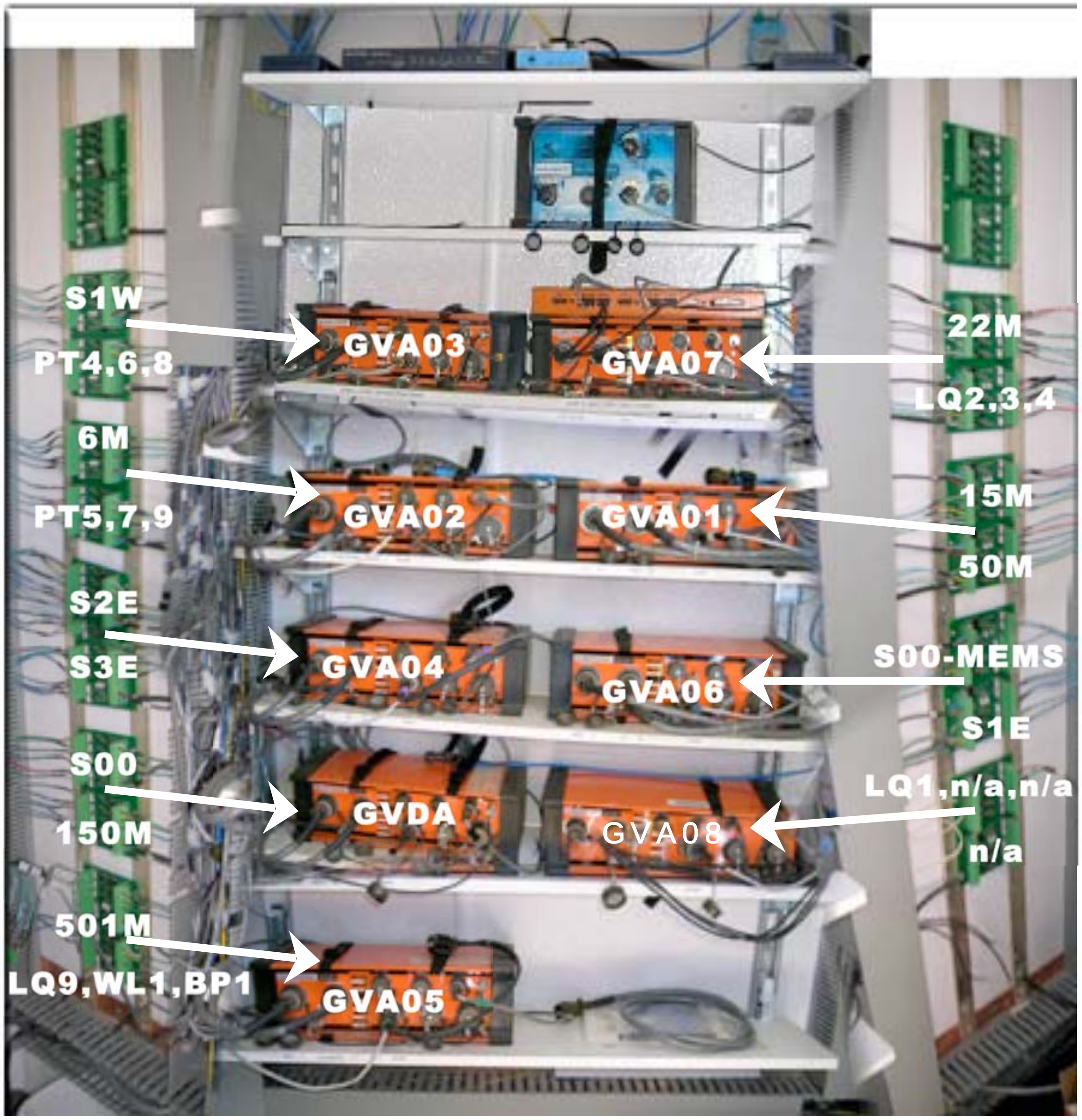
Longitudinal (Y) is positive in the direction of true North + 13.5°.

Transverse (X) is positive in the direction 90° clockwise of Y i.e. 103.5°

Vertical (Z) is positive for upward components.

Section II : The GVDA Hut

The south wall of the hut has the shelves holding the Q330 dataloggers and the networking equipment. Adjacent and in-line with the Q330s are the Lightning Protection boards where the sensor cables terminate in the hut. The photo-montage below shows the basic layout.

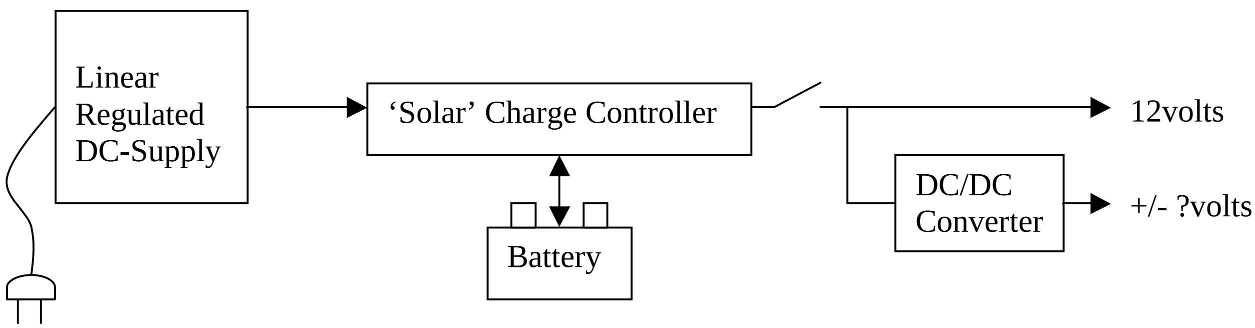


The power-supply for the sensors is routed through the +/-12V channels of the LP boards.

Power Supply Set-up

The power-supply system at GVDA has backup redundancy in two ways. The main supply is metered AC power from Anza Electric, additionally there is an auto-start generator on site which kicks-in if main power fails and finally all major data-acquisition systems also have battery back-up.

The DC voltage supply is centered on off-the-shelf “solar” charge controllers, where the DC input is from AC-in linear regulated DC supplies rather than solar panels. 12V lead-acid batteries complete the system.

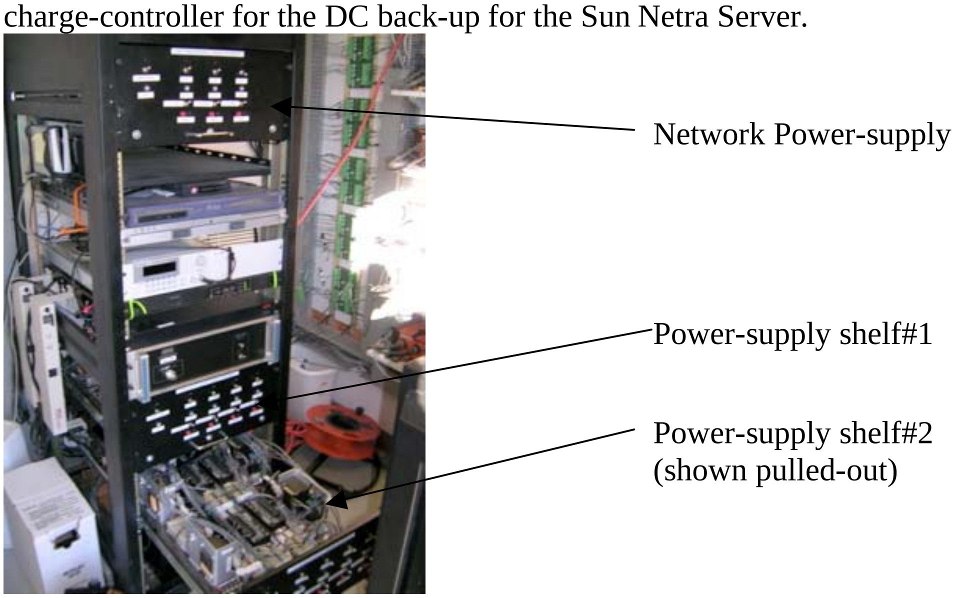


When voltages other than standard +12V are required, individual dc/dc converters are used.

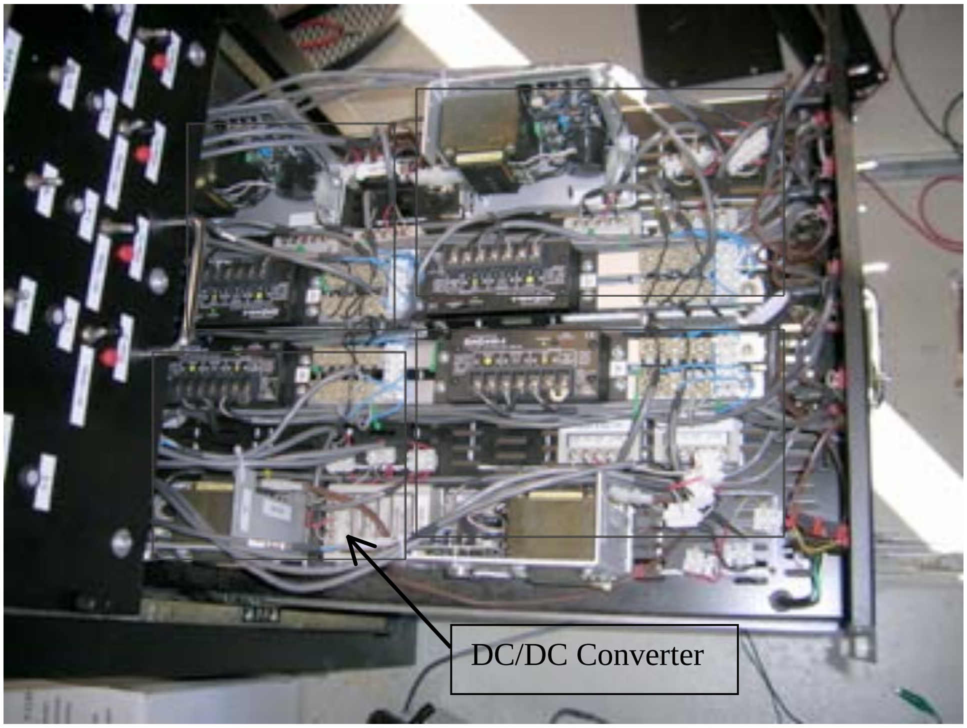
There are 10 of these solar-charger based power-supplies in the hut:

- two main power-supply rack-shelves, each with four supplies, for the data-acquisition and sensor equipment
- two more units for networking gear

Additionally there is a similar supply configuration based on a special 48V integrated AC charge-controller for the DC back-up for the Sun Netra Server.



The picture below shows Power-supply shelf #2, the four separate power-supply circuits are outlined.



The shelf has a number of front-panel switches, connectors and LEDS.

The left-most toggle-switch is a master switch on the 110V input to the shelf. Turning this off, disconnects the mains to the AC linear-regulators only. The individual supplies will simply see their ‘solar’ input voltage go away when AC is cut, so the charge controller will simply supply the load from the battery.

Each individual supply has as switch (the bottom switch) which disconnects the charge-controller’s input from the linear-regulator and connects it instead to the banana plugs on the front panel; this would allow an external power-source (a solar-panel etc.) be used to run the circuit in question.

The second per-circuit switch (the top one, the one shown in the ‘schematic’ above) disconnects the load from the output of the charge controller.

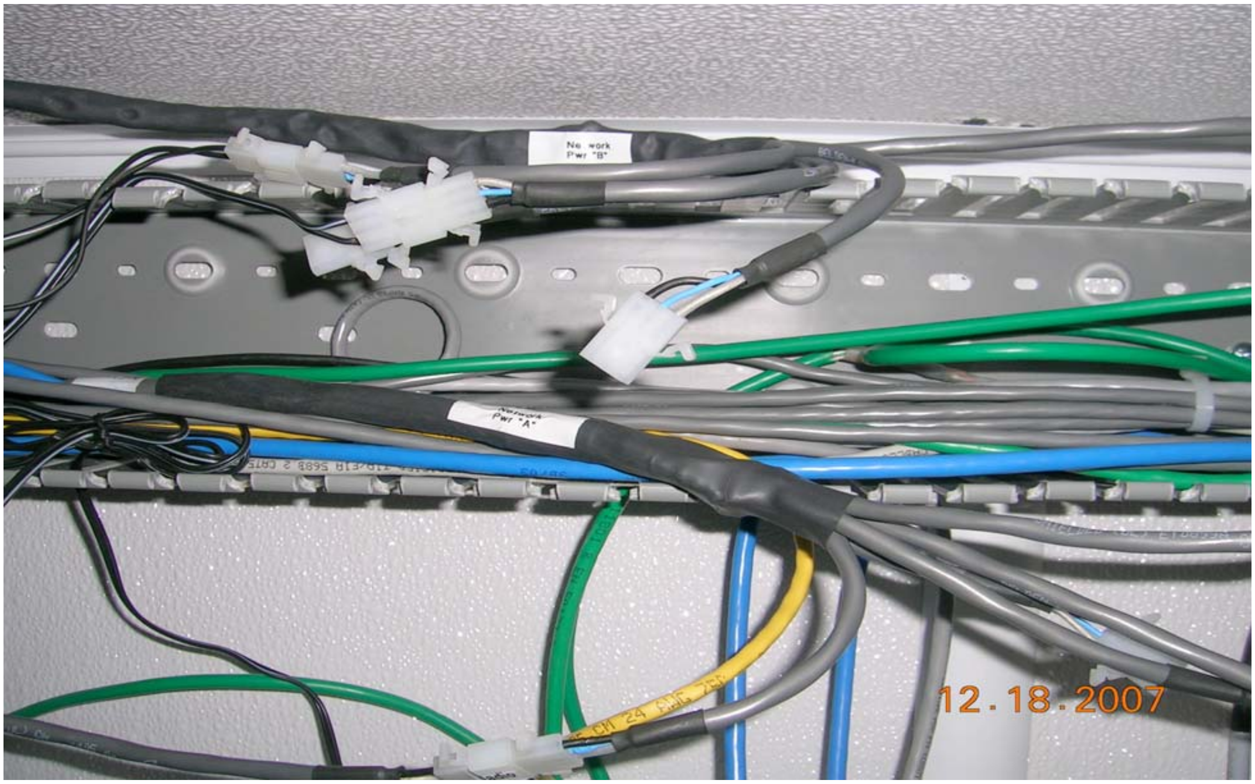
Network Power Configuration

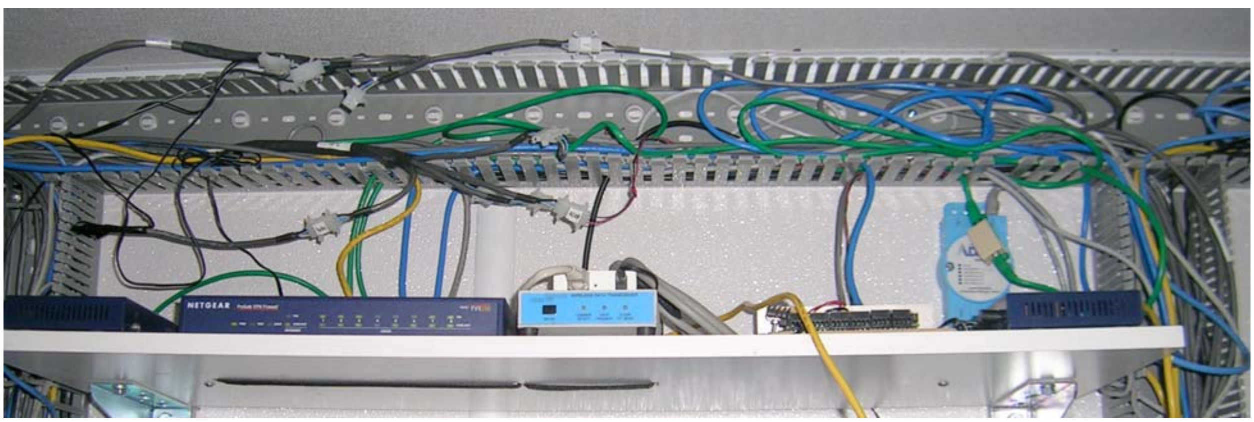
The top power-supply shelf in the GVDA rack handles all the power for the “networking” infrastructure of the hut. The set-up is as described above, an AC linear-PSU to a charge-controller, which has lead-acid batteries attached, which supplies the loads.

There are two separate ‘Network Supplies’ on the shelf labeled “Network A” and “Network B”.

Circuit	Load	Battery
Network A	WiLAN Radio	Connected to 4 batteries in parallel in battery-shack.
	Router	
	Right-hand Ethernet switch	
	Rocksite comms	
	Remote-relay control	
	HPWREN ADAM	
Network B	Marmot	Connected to 2 batteries in parallel in bottom of rack.
	Right-hand Ethernet switch	
	Modem	

The breakout for each of these supplies is in the caterpillar above the Q330 shelves, see photos below…

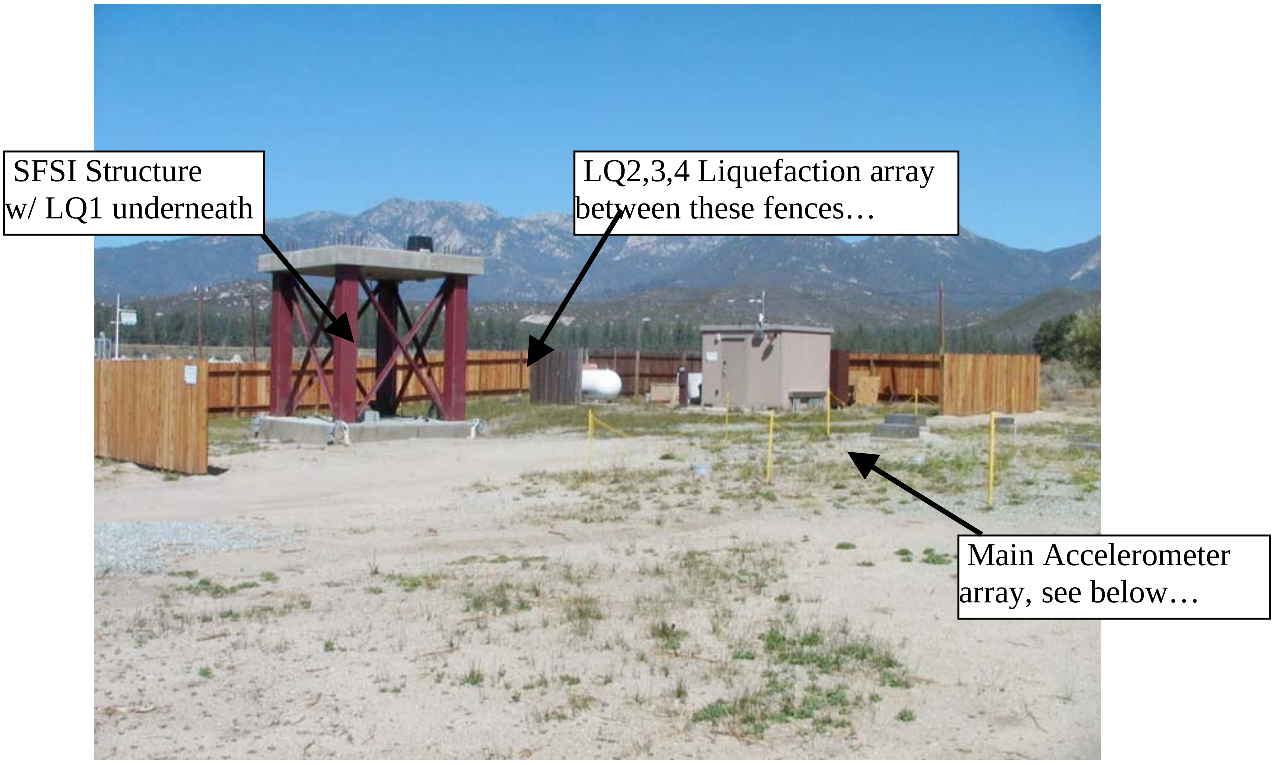




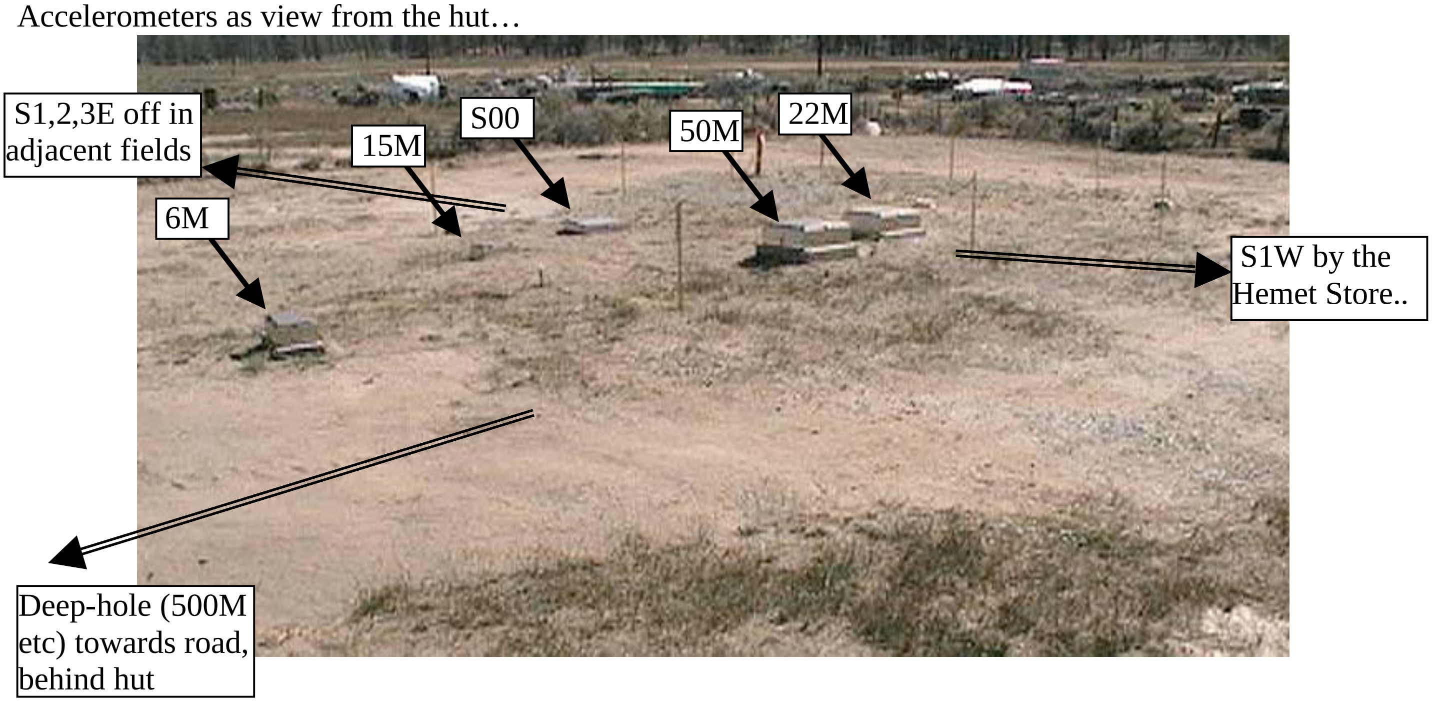
Section III: Site Layout

This section lists each sensor in turn with pictures and notes about actual cable coloring, actual LP board wiring and any other physical information of relevance.

Fig. Transducer locations at the site viewed from the gate

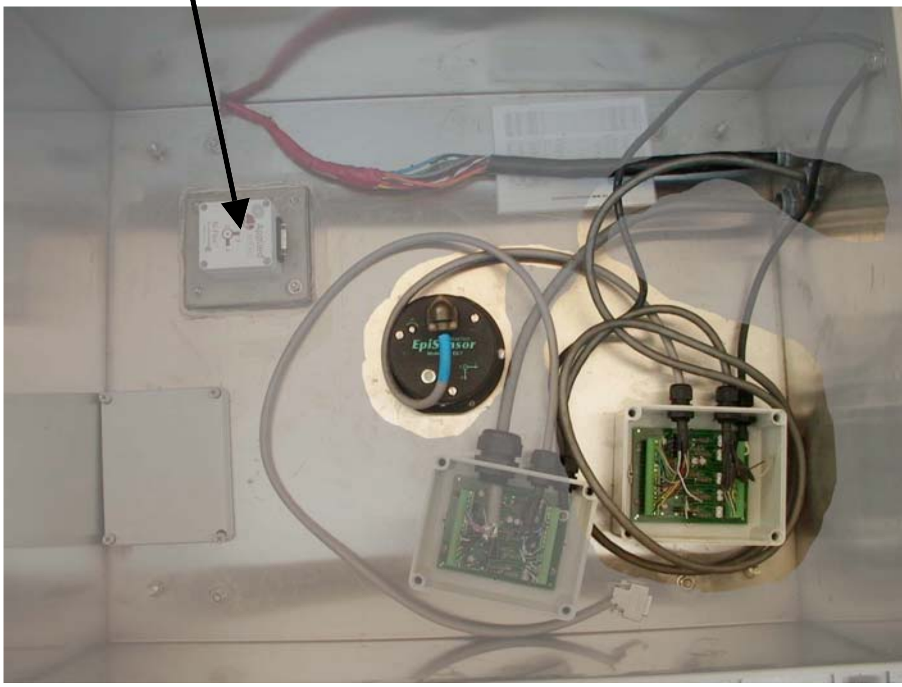


Accelerometers as view from the hut…



Sensor: S00, Location Code: 00, FBA ES-T

The Surface Accelerometer, closest to the hut, is housed in a stainless-steel Hoffman box along with a MEMS accelerometer.



NOTE: The cabling from the sensor to the LP board in the wellhead box uses color-codes from the legacy GVDA wiring where "black" was the positive!

Sensor-to-LP	**BoxLP-to-HutLP**	**LP-to-Q330**	**Notes**
Black(+)/Yellow	White/Black	White/Black	
Black(+)/Brown	Yellow/Black	Yellow/Black	
Black(+)/Red	Green/Black	Green/Black	
Black (of grn/blk pair) +12V Blue (of blu/blk pair) Com Green (of grn/blk pair) -12V	Red/Black/Blue	Clear/Black/Blue to PSU shelf	

<u>Sensor details:</u>

Type: Kinemetrics EpiCensor FBA ES-T Serial #00705
Oriented: L(y)=True North Vertical=Up
Sensitivity: 10V/g

Sensor: MEMS, Location Code: 12, SF3000L

An SF3000L shares the box with S00 above. This MEMS accelerometer shares the same orientation and sensitive as the FBA for comparison evaluation.

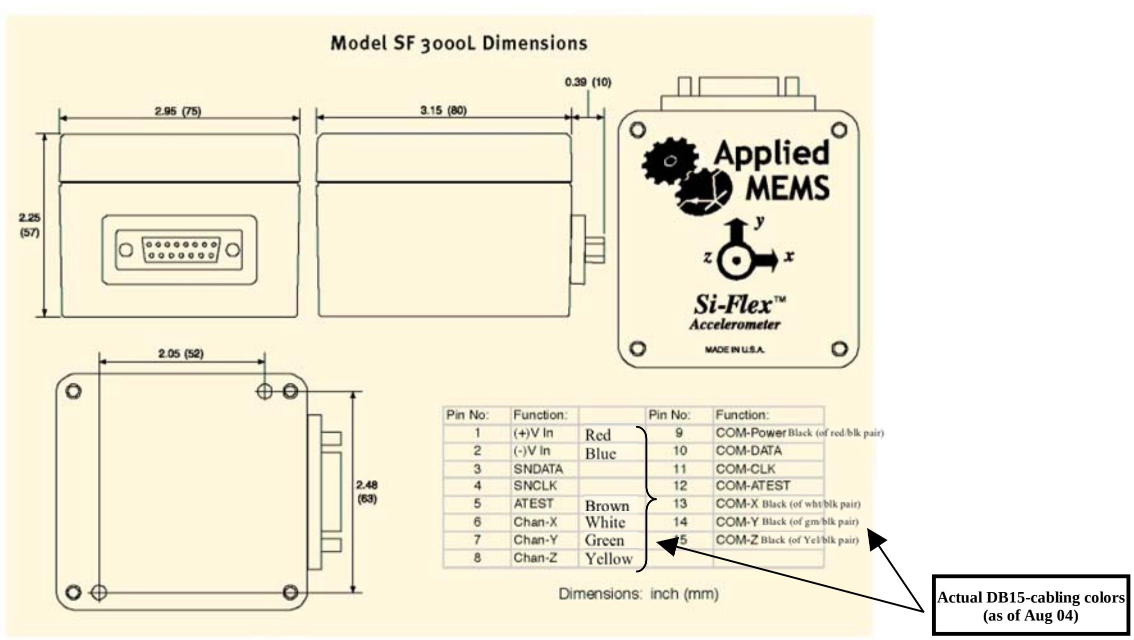
See the ‘greyed-out’ portion of the S00 wellhead box on the previous page for an impression of the MEMS mounting. The DB15 connector to the bottom right of the picture is connected to the MEMS.

NOTE: The DB15 wiring has a color-coding error that has swapped the X and Y channels relative to the standard color-coding (see wiring table below). Additionally as currently wired the LP board is in-circuit backwards with the “line” end being connected to the device to be protected and the “device” end being connected to the wire run back to the hut.

Sensor-to-LP	BoxLP-to-HutLP	LP-to-Q330	Notes
White/Black (x-dir)	*Green/Black*	Green/Black	Channel #2
Yellow/Black (z-dir)	Yellow/Black	Yellow/Black	Channel #1
Green/Black (y-dir)	*White/Black*	White/Black	Channel #3
Red +12V Black (of red/blk pair) Com Blue -12V	Red Black (of red/blk)		

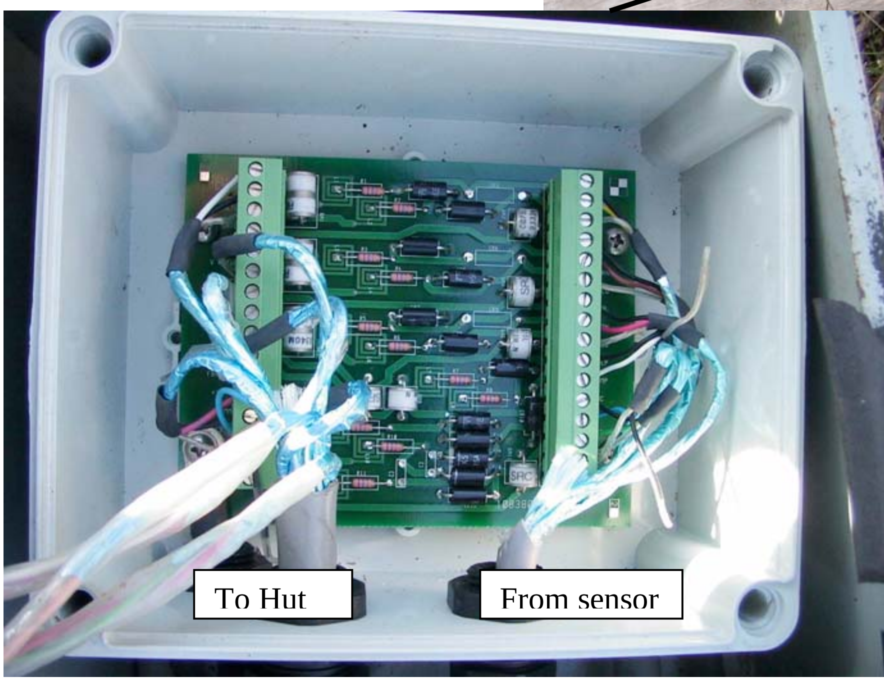
Sensor details:

Type: Applied MEMS, Inc. Si-Flex Accelerometer SF3000L Serial#440
Oriented: L(y)=True North, Vertical=Up
Sensitivity: 1.2V/g



Sensor: S1W, Location Code: 07, FBA-23

The surface accelerometer, S1W, is located by the Hemet Store in a Pelican case under the wooden board as shown in the photo below.



Sensor-to-LP	BoxLP-to-HutLP	LP-to-Q330	Notes
Black(+)/Yellow	White/Black	White/Black	
Black(+)/Brown	Yellow/Black	Yellow/Black	
Black(+)/Red	Green/Black	Green/Black	
Black (of grn/blk pair) +12V Green (of grn/blk pair) -12V Blue (of blu/blk pair) Com	Red Blue Black (of red/black)		

Sensor details:

Type:	Kinemetrics FBA-23 Serial #31964(vertical component)
+ve o/p Oriented:	L=193.5^{o} V=Down
Sensitivity:	5V/g

Sensor: S1E, Location Code: 08, EPI ES-T (SN#2491)

Sensor: S2E, Location Code: 09, EPI ES-T (SN#732)

Sensor: S3E, Location Code: 10, FBA 23 (SN#31973(vertical component))

Surface accelerometers in the field to the east of the hut that form a linear surface array with S1W and S00 sensors.

FBA 23's physically oriented to true-north but generate positive output for south and down accelerations with a sensitivity of 5V/g. The EPIs are oriented to true-north but generate positive output for North, up and east accelerations with a sensitivity of 10V/g.

Sensor: 6M, Location Code: 01, FBA 23 DH

Sensor details:

Type:	Kinemetrics FBA-23 DH Serial #45529(vertical component)
+ve o/p Oriented:	L=180^o V=Down
Sensitivity:	5V/g

Sensor: 15M, Location Code: 02, FBA 23 DH

Sensor details:

Type:	Kinemetrics FBA-23 DH Serial #38283(vertical component)
+ve o/p Oriented:	L=98^o V=Up
Sensitivity:	5V/g

Sensor: 50M, Location Code: 04, FBA 23 Special

Sensor details:

Type:	Kinemetrics FBA-23 Special Serial #35627(vertical component)
+ve o/p Oriented:	L=23.5^o V=Up
Sensitivity:	5V/g

Sensor: 501M, Location Code: 06, FBA 23 Special

Sensor details:

Type:	Kinemetrics FBA-23 Serial #33738(vertical component)
+ve o/p Oriented:	L=166.9^o V=Up
Sensitivity:	5V/g

Sensor: 22M, Location Code: 03, Planned

Sensor: 150M, Location Code: 05, Hypo-Sensor SN#181 10V/g

Sensor: 500M, Location Code: 11, Decommissioned

Sensor: PT4 to 9, Location Code: 43 to 48, KPSI Model-30-432-10100

A collection of pore-pressure transducers in the 500M borehole at various depths.

Each sensor is wired into the Lightning Protection box and then back to the hut in a multi-pair cable.

All sensors are 0 to 100PSIA input for an analog output of 0-5V.

Sensor	Depth/Serial #	Serial #	Loc-code/Cable-pair
PT4	0m	0700988	43 blk/orn
PT5	333m	0709085	44 blk/red
PT6	339m	0709084	45 blk/yel
PT7	417m	0709083	46 red/grn
PT8	428m	0709082	47 blk/wht
PT9	494m	0700989	48 blk/brn

Sensor: LQ9, Location Code: 68, Druck PDCR 940, 0 – 50PSIG

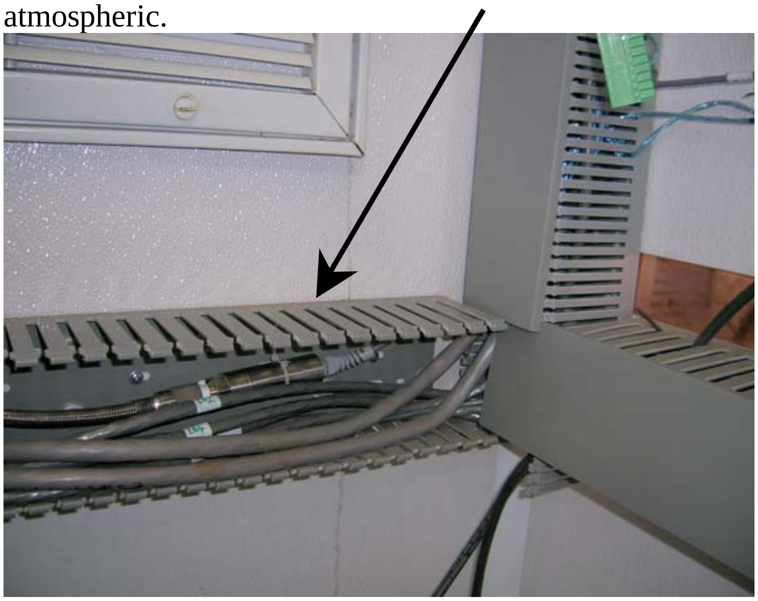
Seems to be faulty…

At a depth of 12.4m.
Output 0 to 0.1V
Serial# 881401

Sensor: BP1, Location Code: 69, KPSI 30-432-1020

Barometric pressure transducer measuring 0 to 20PSIA to and analog output of 0 to 5V.

Located in the hut, in the caterpillar under the A/C return vent, with a pressure tube to outside atmospheric.



Sensor: LQ1 to 4, Location Code: 60 to 63, Paroscientific 8WD020

These sensors are piezometers under the SFSI structure (loc code 60) and forming the liquefaction array (loc codes 61 to 63) to the west of the hut.

Sensor	Depth	Serial #	PTAC Channel	Comment
LQ1 (loc#60)	11’ 6”	93467	Ptac#2 B	Under SFSI
LQ2 (loc#61)	20’ 3”	93457	Ptac#2 A	
LQ3 (loc#62)	28’ 10”	93451	Ptac#1 B	
LQ4 (loc#63)	33’	93458	Ptac#1 A	

The transducers are controlled and monitored over a serial-interface. Each sensor has a four conductor cable (to the right in the wiring photo below) interface.

Color	**Description**
Red	Positive power-supply
Green	Common
White	Tx (from sensor to converter)
Black	Rx (to sensor from converter)

Liquefaction Layout

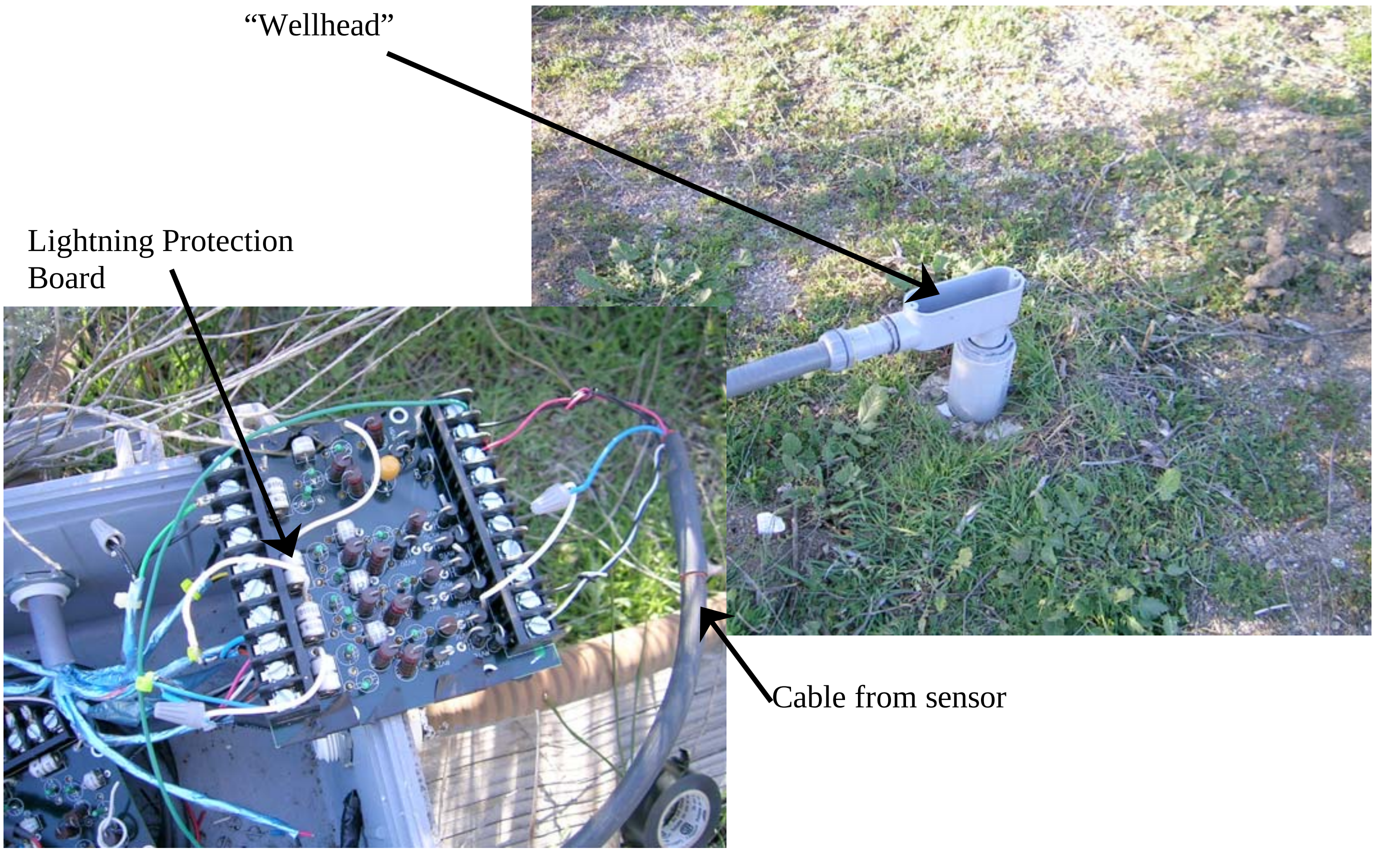
Sensor-to-LP	BoxLP-to-HutLP	LP-to-PTAC	Notes
White/(blk+shield tied)	White/Black	White	
Black/(blk+shield tied)	Green/Black	Green	
Red +12V Green Com	Red/Black	Clear/Black to PSU	

Sensor details:

Type: Paroscientific, 0-20m, 0-45PSIA (model#8WD020)
Sensitivity/Output: Programmable.

Sensor: WL1 KPSI Transducer for water level, Location Code: 70

A KPSI Model 30-430-0050 is used in a borehole (behind the hut) at a depth of 14ft as a water level monitor. This is an analog transducer with a 0 to 50 PSIA for a 0 to 5V output.



Sensor-to-LP	BoxLP-to-HutLP	Notes
White	Blue (of Blue/Blk)	Analog output relative to Gnd
Red	Blk (of blk/Grn)	+12V
Black	Grn (of Blk/Grn)	Gnd
Blue	Shield or Wht/Blk pair	Cable Shield

Sensor details:

Type: KPSI, 30-430-0050 0-50PSIA

Sensitivity/Output: 10PSI/V

Appendix I: Note on gain calculations

This Appendix shows *examples* of the calculation mechanisms for finding gain, 'calib' etc. values associated with cascaded stages in typical data-acquisition configurations….

Accelerometers

For accelerometers the device will be specified as volts-out per "g", in other words the analog output voltage generate by a physical acceleration of 1g.

To convert this to volts per m/s^2, just remember "g" = 9.80665 m/s^2 (NIST value)

So if an Episensor is rated as 10V/2g then the gain is $10V/(2x9.806)m/s^2 = 0.50989\ V/(m/s^2)$

To convert to nanometers remember $1nm = 1x10^{-9}m$ or $m=1x10^{9}nm$. Thus for the example above, the Episensor gain is $5.0989x10^{-10}\ V/(nm/s^2)$

If this signal is feed into a Q330 datalogger, the analog signal will be sampled by a 24-bit ADC which has a full-scale input range of 40V. In other words the sensitivity of the ADC is $40V/2^{24}$ counts or one count is equivalent to an input voltage of $2.384x10^{-6}V$ put another way the datalogger gain is $2.384x10^{-6}V/count$

Putting these stage gains together, the system gain can be seen to be

$$5.0989x10^{-10}\ V/(nm/s^2) * (1/2.384x10^{-6)}\ count/V = 0.00021388\ count/(nm/s^2)$$

And that's equivalent to the factor for mapping ADC value (counts) to acceleration (calib)…

$$4675.518\ (nm/s^2)/count$$

It is expected that schema rt1.0 SEGTYPE of "A" will be used for accelerometers which represents data in nm/s^2.

Pressure Transducers

When dealing with a Paroscientific pressure transducer the calculation of system gain is complicated by the configurability of the transducer and the ‘PTAC’ data converter combination.

The PTAC output voltage range is 0 to 10V, however the pressure range that maps to this full-scale output range is programmable by setting a low pressure that will map to 0V output and a high-pressure that will map to 10V with the range between mapped linearly. Additionally the pressure units used is programmable into the transducers.

Thus 0 to 10V is configured to map to Low (pressure-units) to High (pressure-units) meaning the instrument gain is given by 10V / (H-L) pressure-units.

For example, if the units are set to kPa and the Low and High values to 0 and 350 the gain would be… 10V/310kPa. (the transducers are rated for 0-45PSIA thats approx 0 – 310kPa)

This analog voltage is then applied to a Q330 channel with its 2^{24} ADC for a 40V full-scale so the counts to kPa would be

$$310kPa/10V * 40V/2^{24} = 73.909x10^{-6} kPa/count$$

It is expected that schema rt1.0 SEGTYPE of “K” will be used for pressure-transducers which represents data in kPa.

Appendix II: Applied MEMS SF3000L Data

SI-FLEX™ SF3000L LOW-NOISE TRI-AXIAL ACCELEROMETER

Applied MEMS

The Only Limit Is Your Dream™

an INPUT/OUTPUT company

Si-Flex™ SF3000L Low-Noise Tri-Axial Accelerometer

The SF3000L is a closed-loop accelerometer that offers unmatched noise performance and robustness.

Description

Originally developed for oil and gas exploration, thousands of Si-Flex™ accelerometers are routinely deployed as the core technology behind VectorSeis – a revolutionary seismic data acquisition platform offered by Input/Output, Inc. (www.i-o.com).

Features such as wide dynamic range, excellent bandwidth, low distortion, high shock tolerance and thermal stability distinguish the Si-Flex line of sensors from conventional accelerometer products. These features combined into a miniature size and cost-effective design make the Si-Flex accelerometer well suited for a variety of applications.

Tech Specs

- Three-axis output
- ± 3 g full scale
- 300 ng/√Hz noise level
- Self test feature

Applications

- Earthquake detection
- Homeland security & military systems
- Seismic imaging
- Structural monitoring
- Tilt & level measurements

Typical Specifications @ 25C

Parameter	Value	Unit
Linear Output Range	± 3	g peak
Sensitivity	1.2	V/g
Frequency Response	DC to 1000	Hz
Dynamic Range (100Hz Bandwidth)	120	dB
Noise (10 to 1000 Hz)	300 to 500	ng/√Hz
Cross-axis rejection	> 46 (34 min)	dB
Shock Limit (0.5 ms/½ sine)	1000	g peak
Vibration (20 Hz - 2000 Hz)	60	g pk-pk
Operating Temperature Range	- 40 to + 85	°C
Sensitivity Temperature Coefficient	75	ppm/°C
Offset Thermal Coefficient	± 100	µg/°C
Linearity Error	± 0.1	% Full Scale
Input Voltage	± 6 to ± 15	Volts DC
Quiescent Current	< 30	mA
Self Test	TTL Level	Voltage
Weight	1	lb
Enclosure moisture rating	67	IP Rating

Note 1 - Wider response available by special order

"These performance parameters are unmatched by any other commercially available MEMS accelerometer."

– Input/Output

APPLIED MEMS • Product Sheet

See www.appliedmems.com for more details.