# Nabelek-Gorda-YR3 (2014-2015)
# LC4x4 Generalized Response and Calibration Factor

These calculations are for the generalized case and assume the signal is in the sensor frequency range giving a flat response. Frequency response ranges are indicated.

*SENSOR RESPONSE INFO:*

For the Differential Pressure Gauge (DPG) sensitivity:
Using measurements from strain gauge full scale outputs, the average is about 57 mv/7e3 PA. (FSO is 75e-3V/7e3PA). According to Cox *et al* there is a mechanical attenuation factor due to the compressibility of the oil and the compliance of the chamber. They estimate this as 0.86. Willoughby *et al* say they measured the response and deduced this factor as 0.924. Using a value of 0.9 is suggested until a better value can be determined. Thus the STAGE 1 gain should be 5.7e-2*0.9/7e3 or:

**S(DPG) = 7.3 µV/Pa -or- (7.3e-6 V/Pa)**
*flat response: 0.002 Hz (500 sec) to ~30+ Hz*

Frequency response information:

| Parameter | Nominal Value | Units |
|---|---|---|
| Zeros (1) | 0 | Rad/s |
| Poles (1)* | -0.012568 | Rad/s |
| Normalization | 1 | |
| Normalization Frequency | 0.3 | Hz |

** Single Pole @ (1/-79.57).*

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For the L28LB seismometer sensitivity:
Transduction constant --> 1.57 * sqrt(R-coil) V/m/s with R-coil = 630 ohm nominally this gives 39.53 V/m/s. SIO uses 70% coil current damping, (R-shunt-ss = (7860+51) ohm single-sided, divide by 2 to effective R-shunt damping for differential signal), thus R-shunt-diff = 3956 ohm, which gives:

**S(L28) = 34.10 V/m/s** *flat response: ~4.5 Hz and above*

Frequency response information (for a damped oscillator):
Two zeros at 0, two poles at $\omega_0\left(\delta \pm i\sqrt{1-\delta^2}\right)$ where $\delta = 0.701$ (damping value).

| Parameter | Nominal Value | Units |
|---|---|---|
| Zeros (2) | 0 0 | Rad/s |
| Poles (2) | 19.820 +/- i*20.164 | Rad/s |
| Normalization | -1 | |
| Normalization Frequency | 4.5 | Hz |

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For the Trillium-240-OBS seismometer sensitivity:
the manufacturer quotes 1196.5 V*s/m over +/-20V for a full differential signal. SIO-4x4-LP uses only a single-sided input to the A/D, effectively halving the sensitivity, thus:

**S(T240-ss) = 598.25 V/m/s** *flat response: 0.004167 Hz (240 sec) to 35 Hz*

Trillium 240 OBS Seismometer Frequency response information:
(From Trillium 240 OBS User Guide - page 10)

**Table 3-2** Poles and zeroes

| Parameter | | Nominal values | Units |
|---|---|---|---|
| $z_n$ | Zeroes | 0<br>0<br>–108<br>–161 | rad/s |
| $p_n$ | Poles | –0.01815 ±0.01799i<br>–173<br>–196 ±231i<br>–732 ±1415i | rad/s |
| $k$ | Normalization factor | 2.316 x $10^9$ | |
| $S_{sensor}$ | Passband sensitivity at 1 Hz | 1196.5 | V·s/m |
| $f_0$ | Normalization frequency | 1 | Hz |

**NOTE: Sensor sensitivity listed in Table 3-2 is for full differential response; SIO uses single sided input (halving this number to 598.25 V*s/m).

*ELECTRONICS RESPONSE INFO:*

The sensitivity of the A/D is as follows:
With reference filter voltage of V-filt = 100 ohm the voltage range is +/- 2.47 V,
max counts over this range are –Vref = –6,100,300 to +Vref = 6,102,081.
This gives S(a/d) = 4.94 / 12,202,381 = 0.405 x 10**-6 V/count = 0.405 microV/count, or:

**S(a/d) = 0.405 µV/count -or- (4.05e-7 V/count)**

*Note: A/D reaches full 24-bit range (i.e. -8388608 to 8388607) @ overvoltage of +/- 3.3 V. However, the response in this overvoltage range is roughly nonlinear.*
*Note2: If V-filt = 10 ohm the voltage range is +/- 2.50 V → S(a/d) = 0.410 microV/count.*

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*PRE-AMP GAIN INFO:*
Pre-amp gain settings for sensor/channel on all LC4x4 OBS deployments are:

**gain(DPG) = 64**
**gain(T240-ss-high) = 0.200**
**gain(L28) = 16**

*Note: To keep the Trillium on scale at the A/D input (max +/- 2.47 V), signal form the Trillium seismometers output are attenuated using an analog voltage divider on the pre-amp board:*
*V-T240-div = R-T240-gnd-eff / (R-T240-sig + R-T240-gnd-eff) = 795 / (6980 + 795) = 0.102*
*V-T240-high= V-T40-div = R-T40-gnd-eff / (R-T40-sig + R-T40-gnd-eff) = 1746 / (6980 + 1746) = 0.200*

*TOTAL SYSTEM RESPONSE INFO:*
Total system response then becomes: S(total) = S(a/d)/[S(sensor)*gain]

**LC4x4 Generalized Total System Response:**

**LC4x4-LP units:**

| | | |
|---|---|---|
| **DPG pressure response** | **= 0.867 mPa/count** | *(500 sec to ~30+ Hz)* |
| | **= 8.67e-4 Pa/count** | |
| **Trillium-240-OBS Velocity response** | **= 3.385 (nm/s)/count** | *(240 sec to 35 Hz)* |
| | **= 3.385e-9 (m/s)/count** | |

**LC4x4-SP units:**

| | | |
|---|---|---|
| **DPG pressure response** | **= 0.867 mPa/count** | *(500 sec to ~30+ Hz)* |
| | **= 8.67e-4 Pa/count** | |
| **L28 Velocity response** | **= 7.423 (nm/s)/count** | *(~4.5 Hz and above)* |
| | **= 7.423e-10 (m/s)/count** | |