An external calibrator system for the Hyperion Sensors

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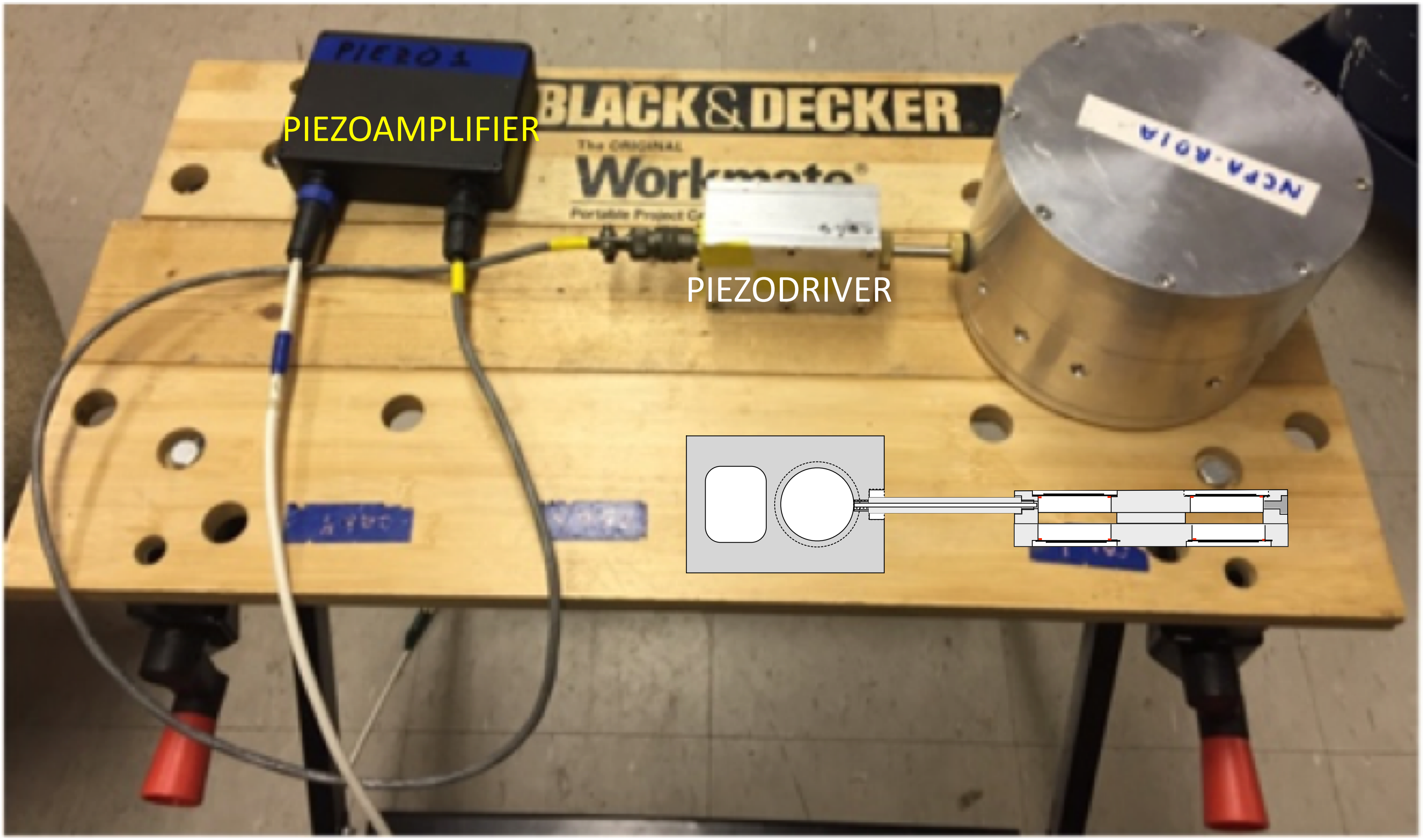
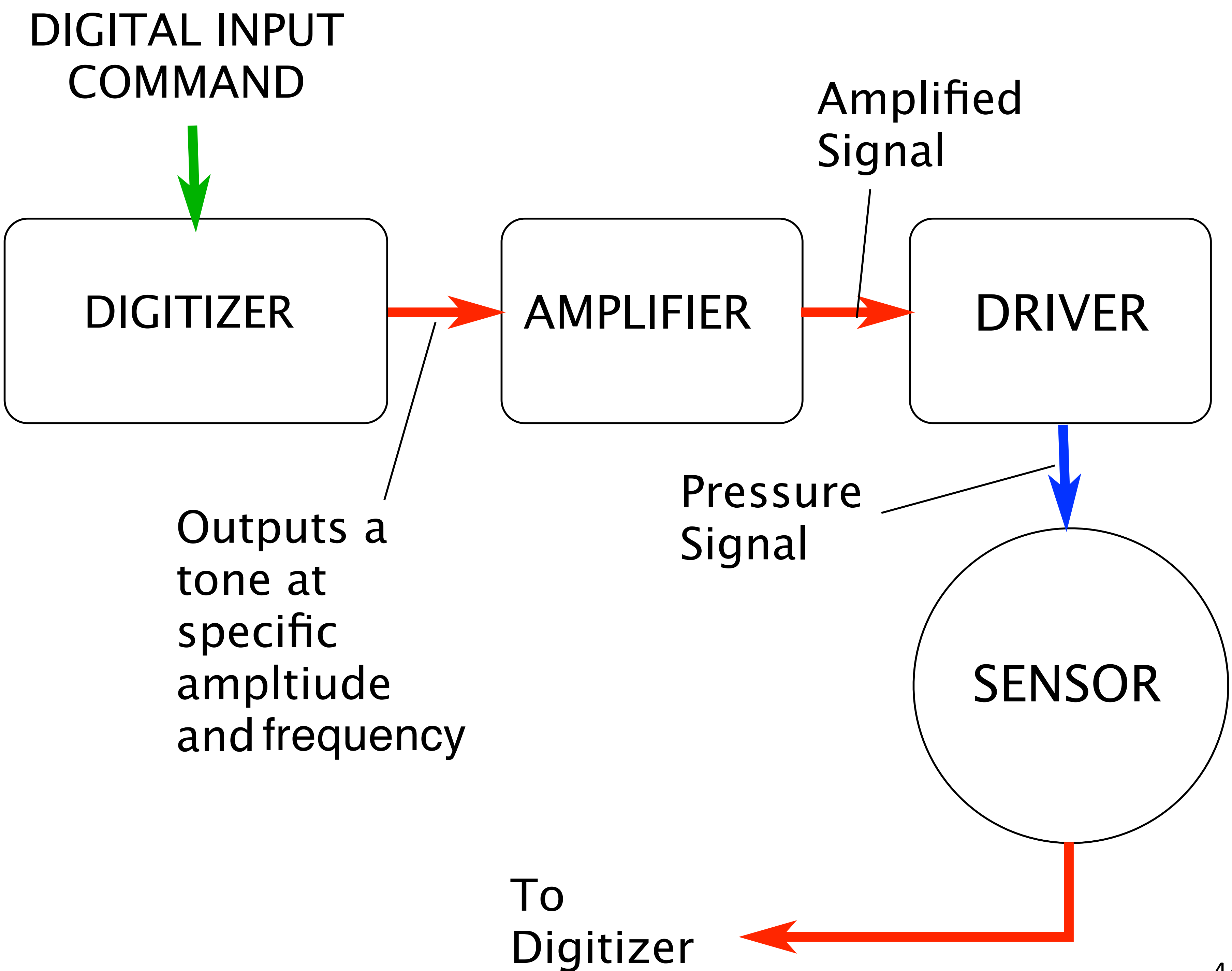
Overview

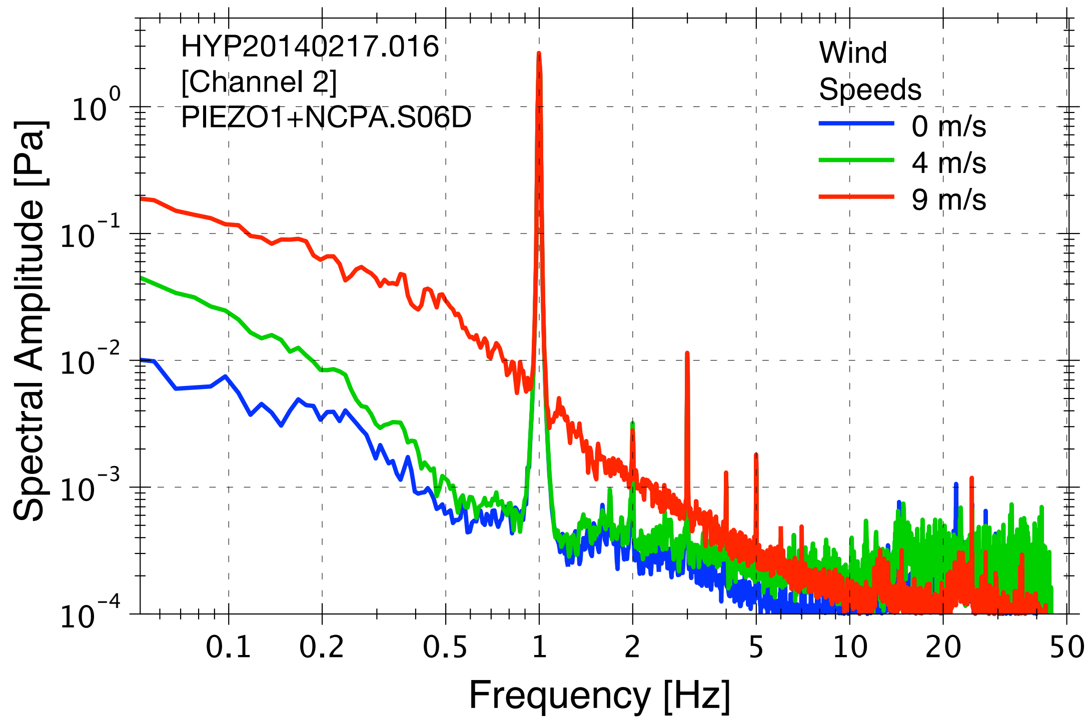
- Main goal was to develop an external calibration system that can be attached to a Hyperion sensor, in order to provide a calibrated sensor response.
- This system should be integrated into the sensor, so for field deployments, it acts as one physical unit.
- System should not require special knowledge on the part of the operator other than knowing how to generate a standard calibrated voltage signal.
- With knowledge of the amplitude of this signal, the sensitivity of the calibrator (relationship between input voltage and pressure induced in the sensor) and the measured amplitude of the sensor response, the operator will be able to infer the pressure sensitivity of the sensor.
- The calibrator operates by injecting a pressure signal in the *back volume* of the sensor. This has the advantage that it is insensitive to details about how the sensor was installed (e.g., nearly same value for bare sensor and sensor attached to a wind-noise reduction system.

Original Proof of Principle Device



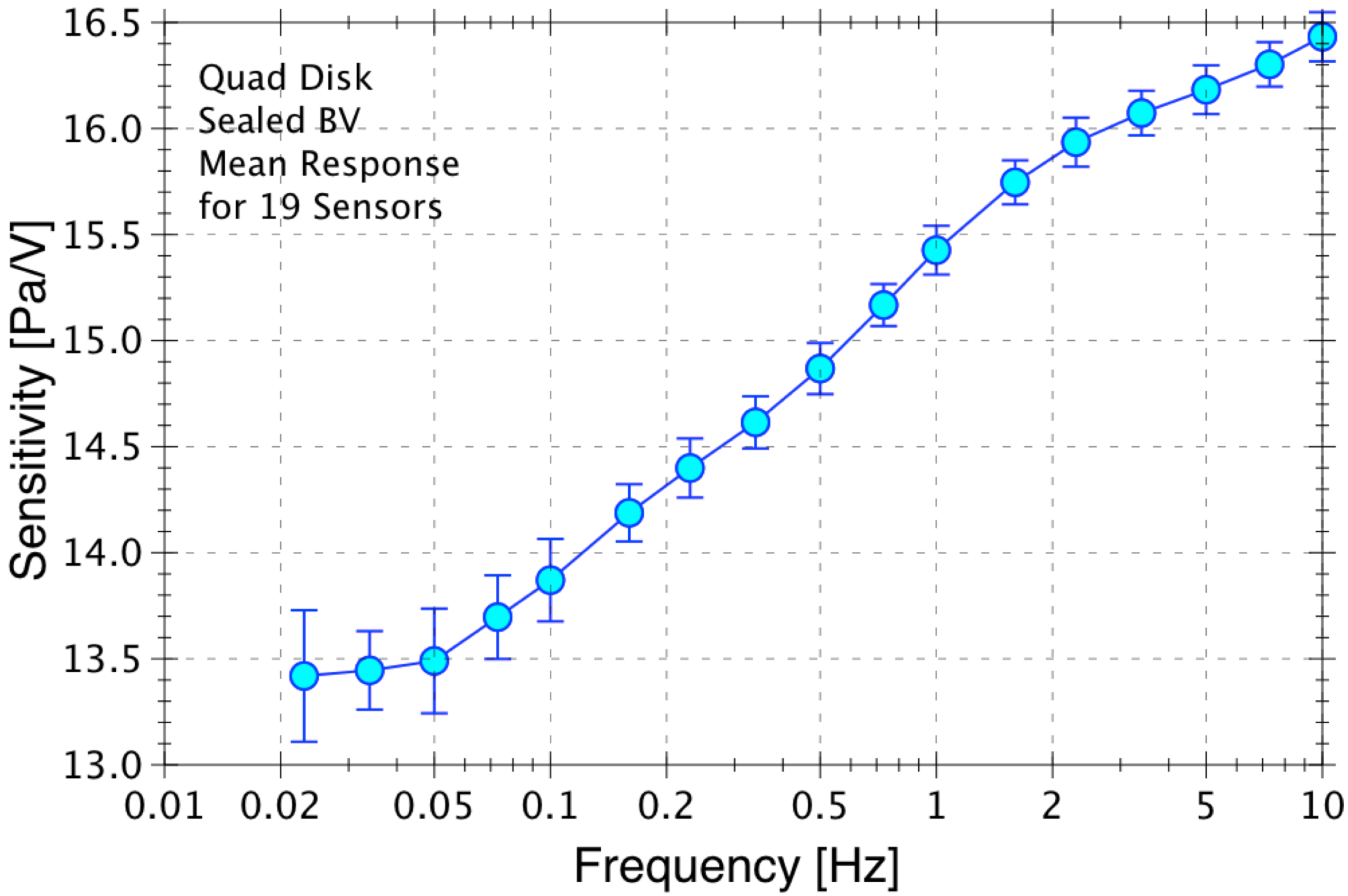

DIGITAL INPUT COMMAND
DIGITIZER
AMPLIFIER
Amplified Signal
DRIVER
Outputs a tone at specific ampltiude and frequency
Pressure Signal
SENSOR
To Digitizer

Initial Field Test At Fact Site



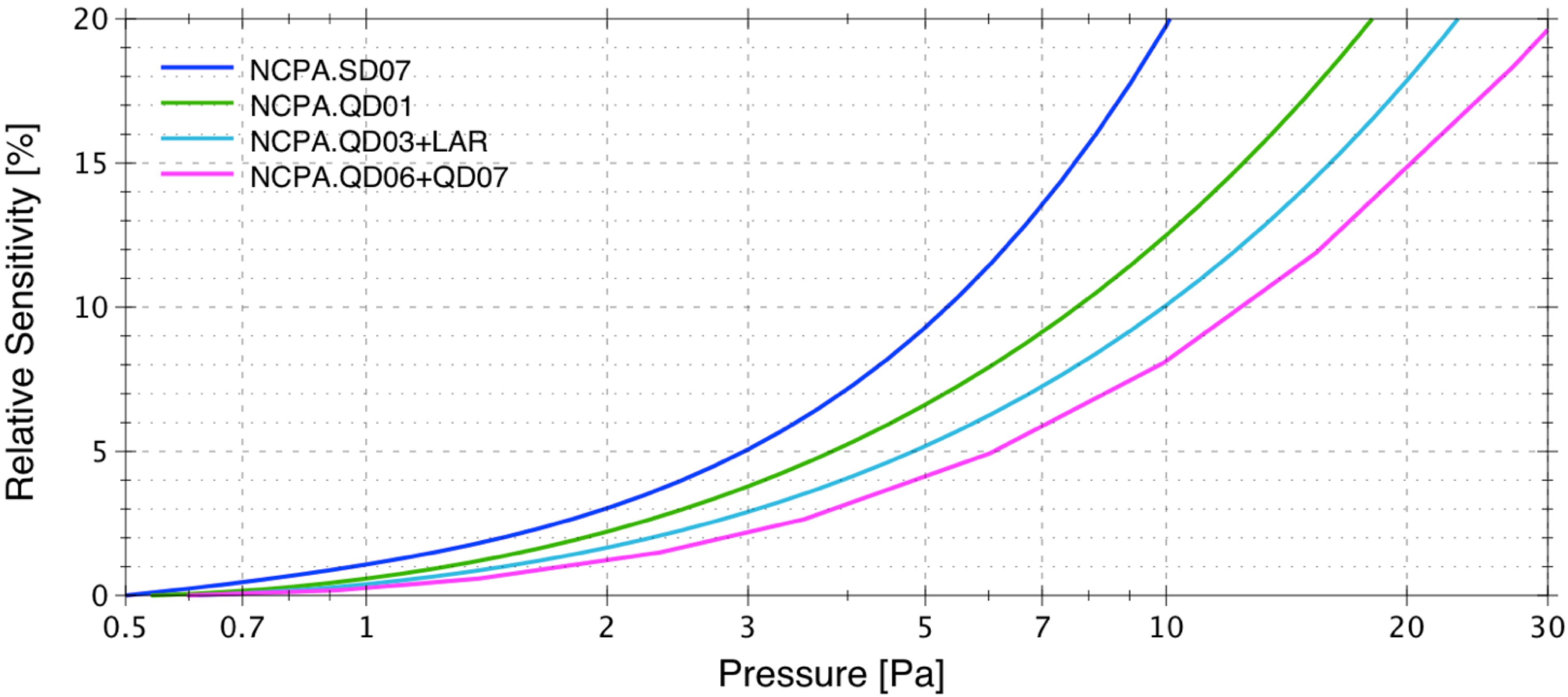
Measurements over three days—able to go from 0 m/s to as high as 9 m/s! Amplitude of 3 Pa—newer systems ≥ 10 Pa.

ISSUES: Non-Uniform Frequency Response

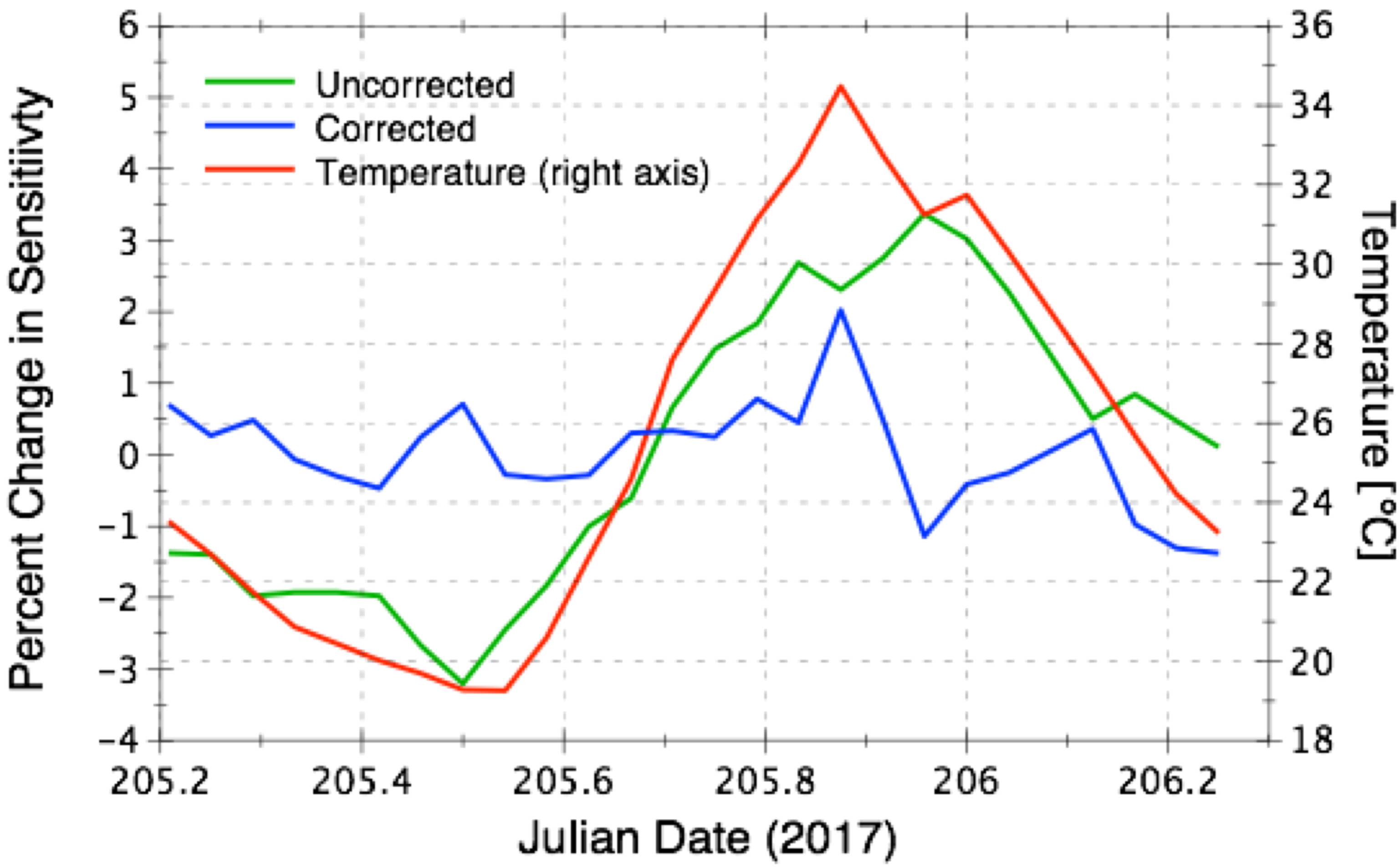


Mean & Standard Deviation of Frequency Response over 19 Sensors

ISSUES: Level Nonlinearity



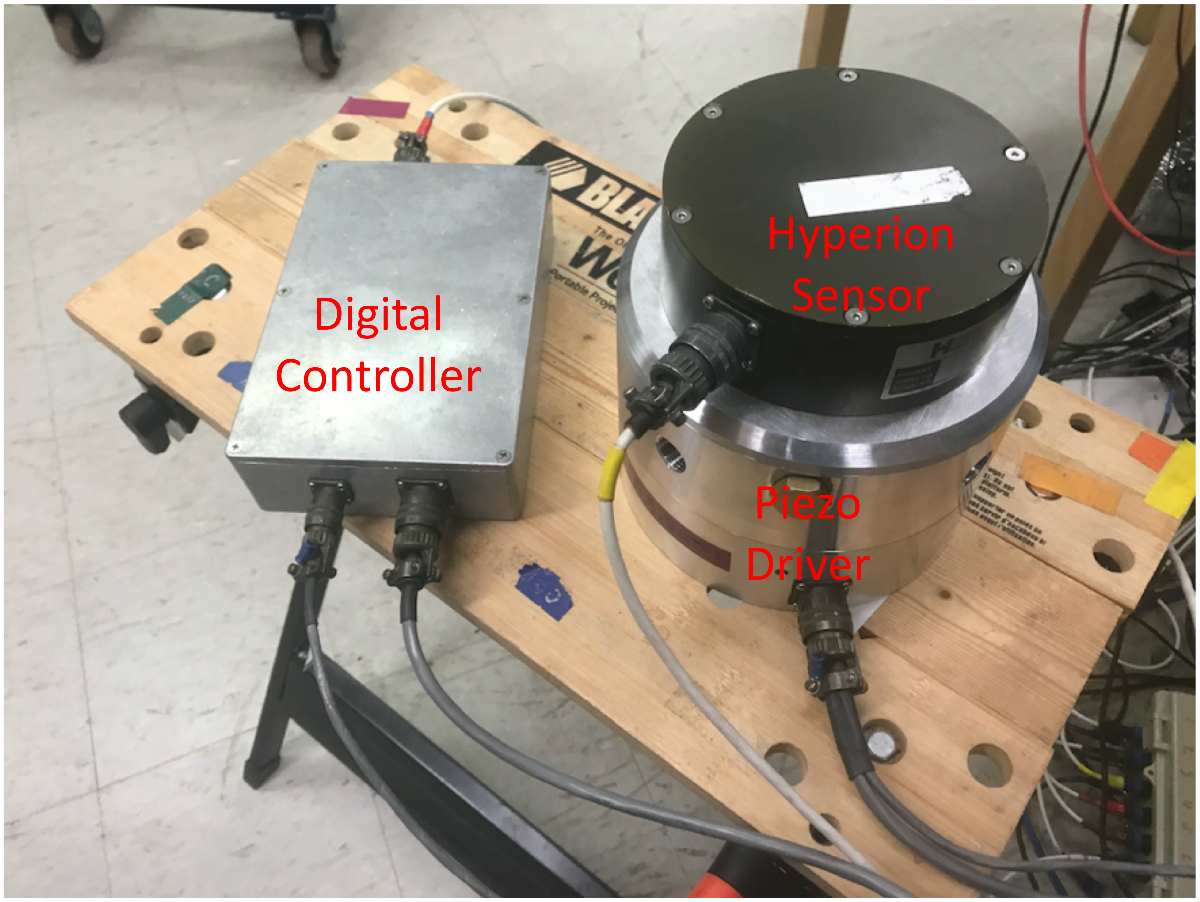
ISSUES: Temperature Effect



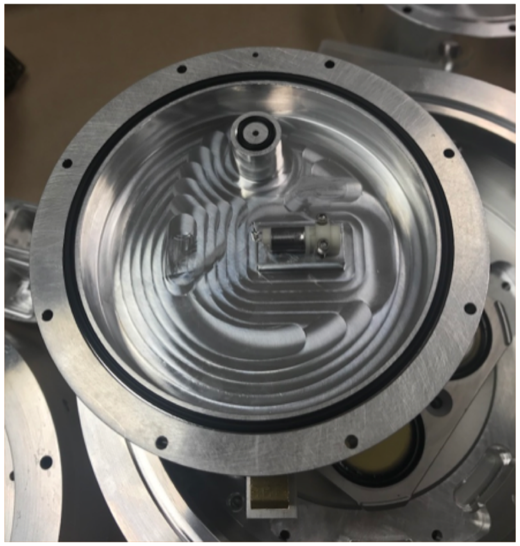
$\boldsymbol{p(t)} = -\gamma_a \boldsymbol{P_0} \frac{v_s(t)}{V_{bv}}$

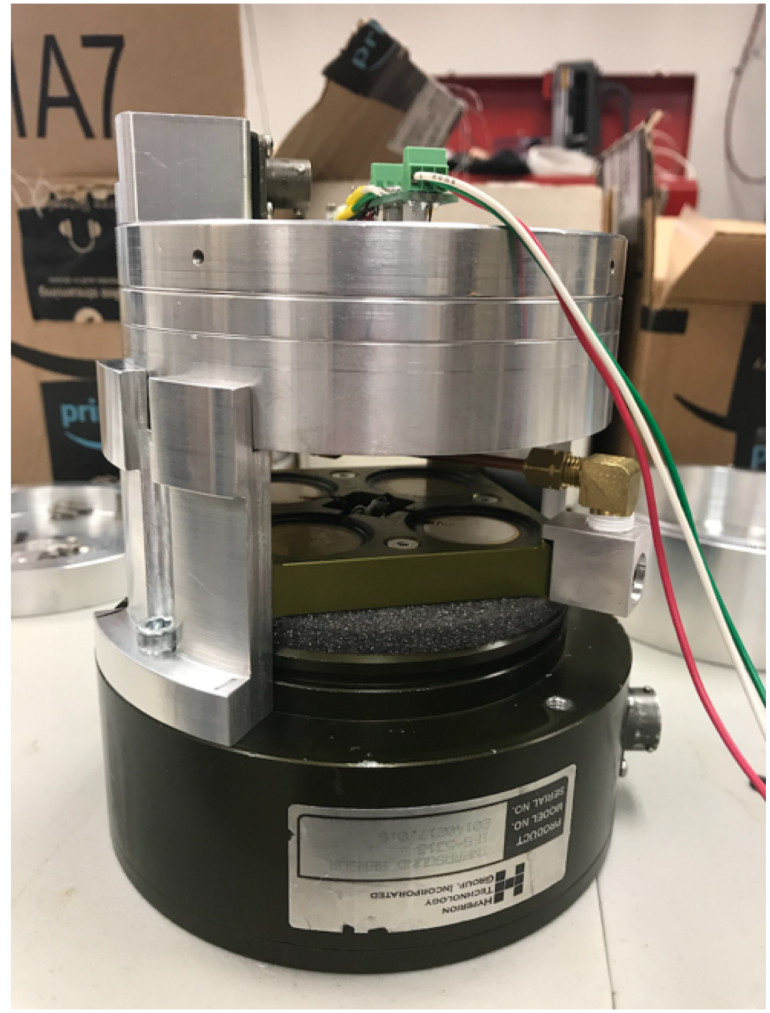
For a sealed volume, $\boldsymbol{P_0}$ depends on temperature.

Piezo Driver Now Couples to Sensor as One Unit

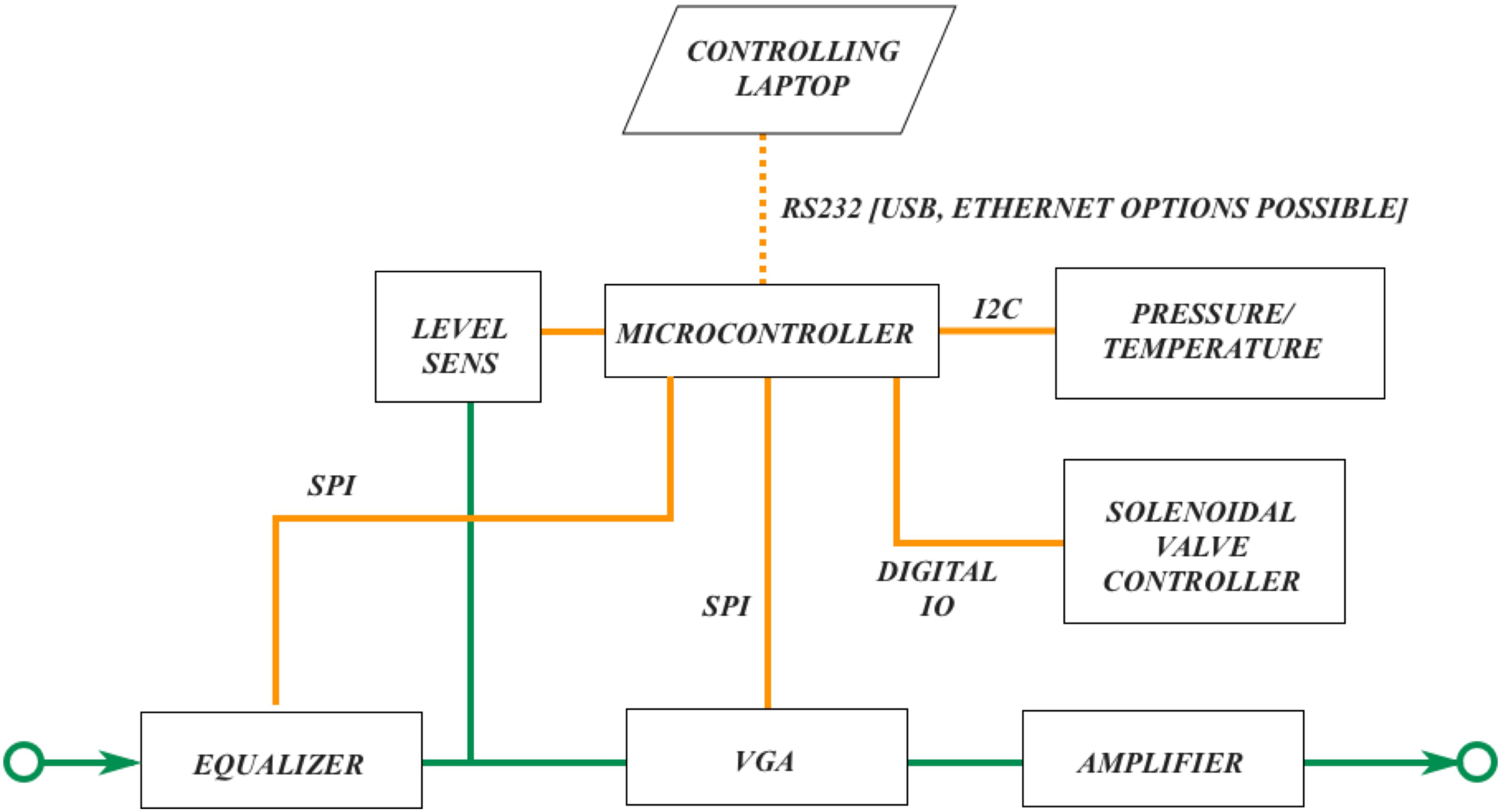


Integrated Piezo Driver Design





Integrated Digital Controller



Algorithm for Correcting for P, T & V

$$S(P,T,V) = S_0\, G_P(P) G_T(T) G_L(P,T,V)$$

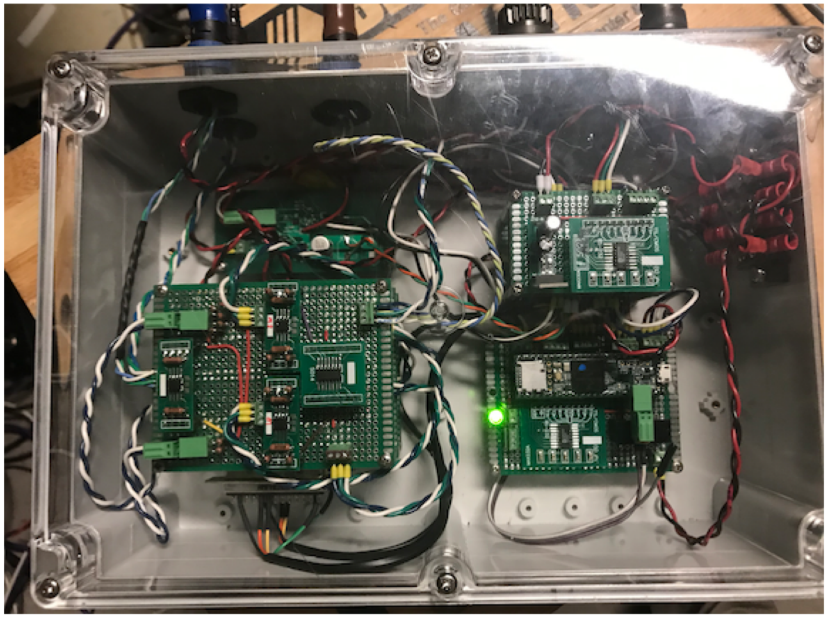
$$G_P(P) = 1 + \alpha_P(P/P_0 - 1).$$
$$G_T(T) = 1 + \alpha_T * (T - T_0)$$
$$G_L(P,T,V) = G_{L0}(G_P(P)G_T(T)V)$$
$$G_{L0}(V) = 1 + a_1 V + a_2 V^2$$

$$\alpha_P = -1.004$$
$$\alpha_T = 0.00378$$
$$a_1 = 0.2525\ \mathrm{V}^{-1}$$
$$a_2 = -0.04268\ \mathrm{V}^{-2}$$
$$P_0 = 10^5\mathrm{Pa}$$
$$T_0 = 25°C$$

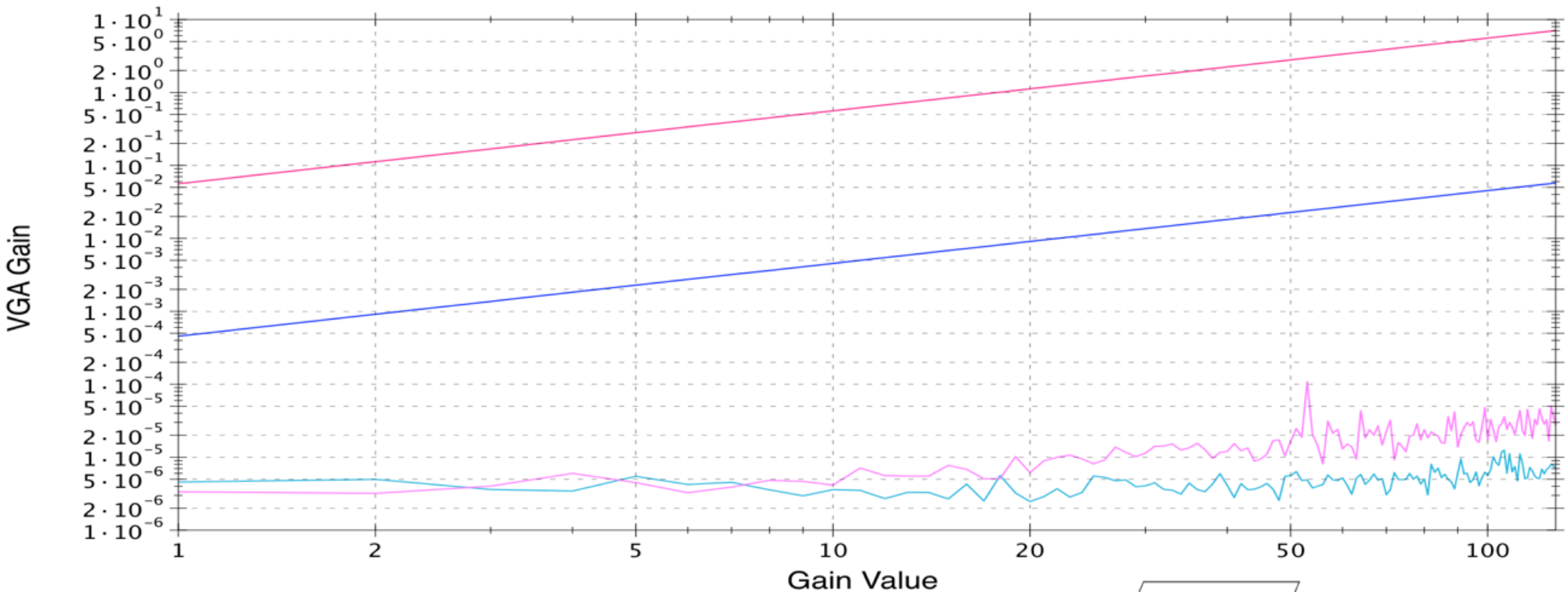
$$\mathrm{VGA(P,T,V)} = \frac{1}{G_P(P) \bullet G_T(T) \bullet G_L(P,T,V)}$$

$$VGA(P_0, T_0, 0V) \equiv 1.$$

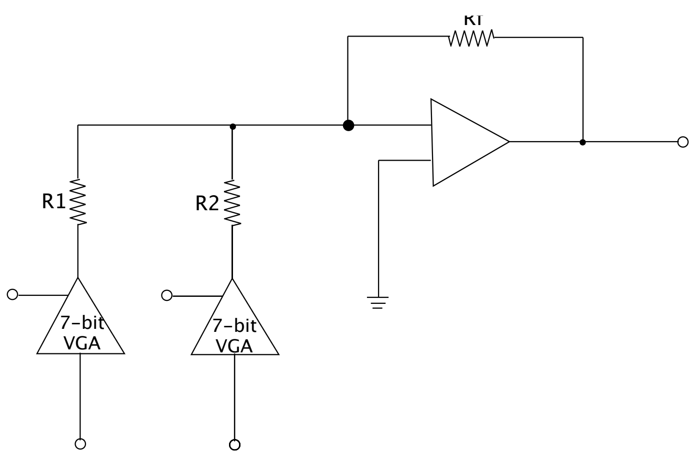
```
double gainFactor(double p, double T, double amp){
    double pfact = 1 + 1.004 * (p/1e5-1);
    double Tfact = 1 + 0.00378 * (T-25);
    double G0 = 1/(pfact * Tfact);
    double amp1 = amp * G0;
    double Afact = 1 + amp1 * (0.245 - 0.0456 * amp1);
    return 1/(pfact * Tfact * Afact);
}
```



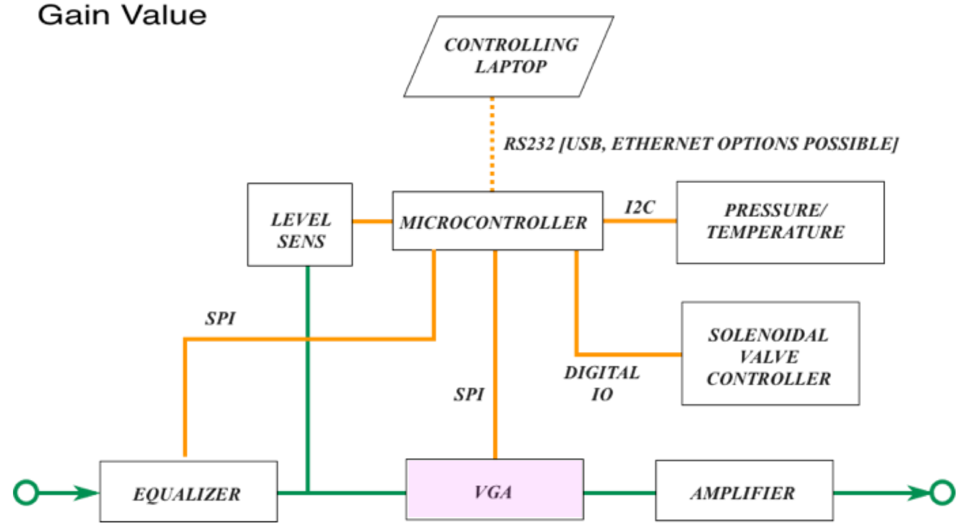
14-bit VGA



VGA Gain
Gain Value

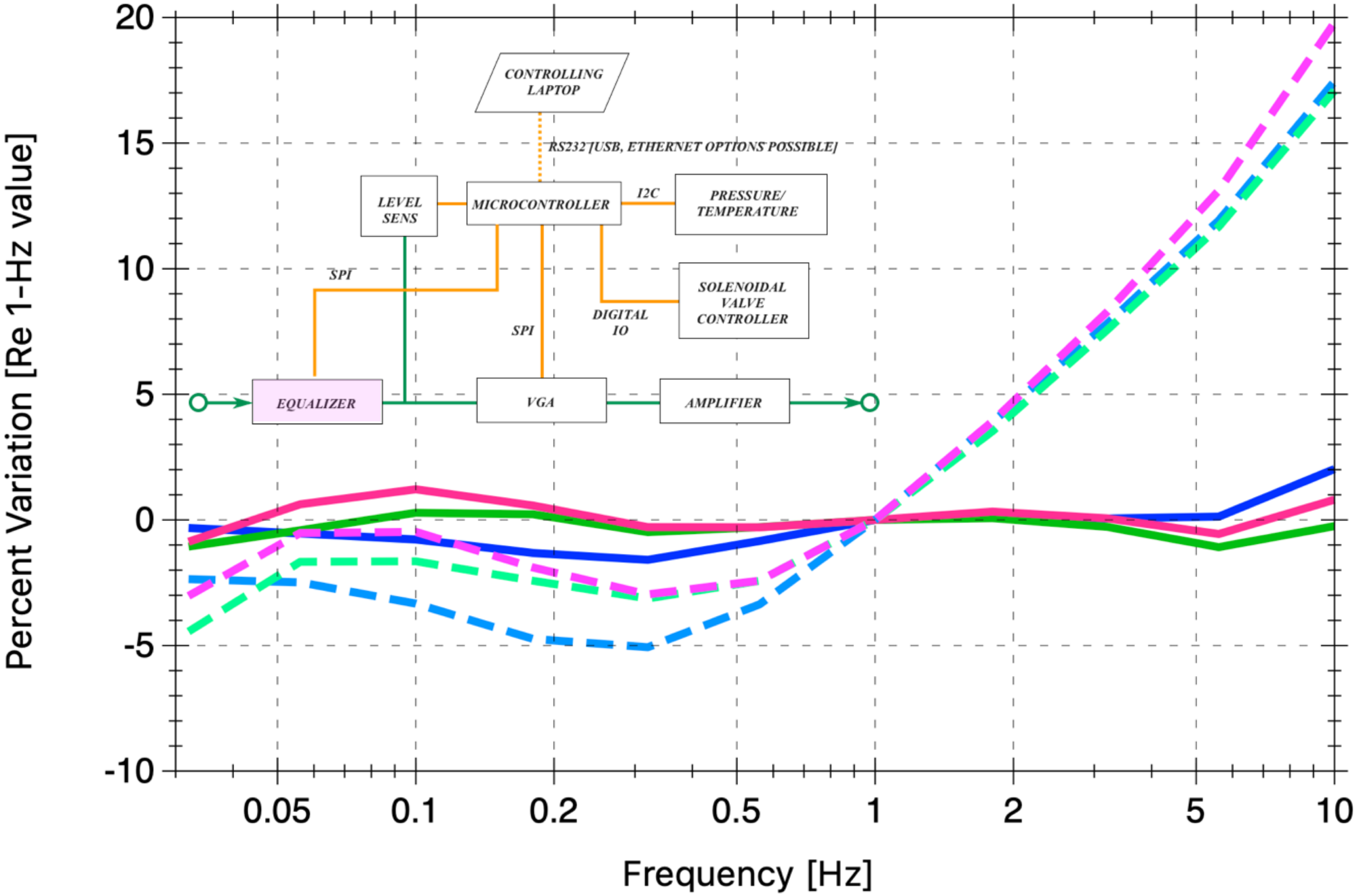


Rf
R1
R2
7-bit
VGA
7-bit
VGA

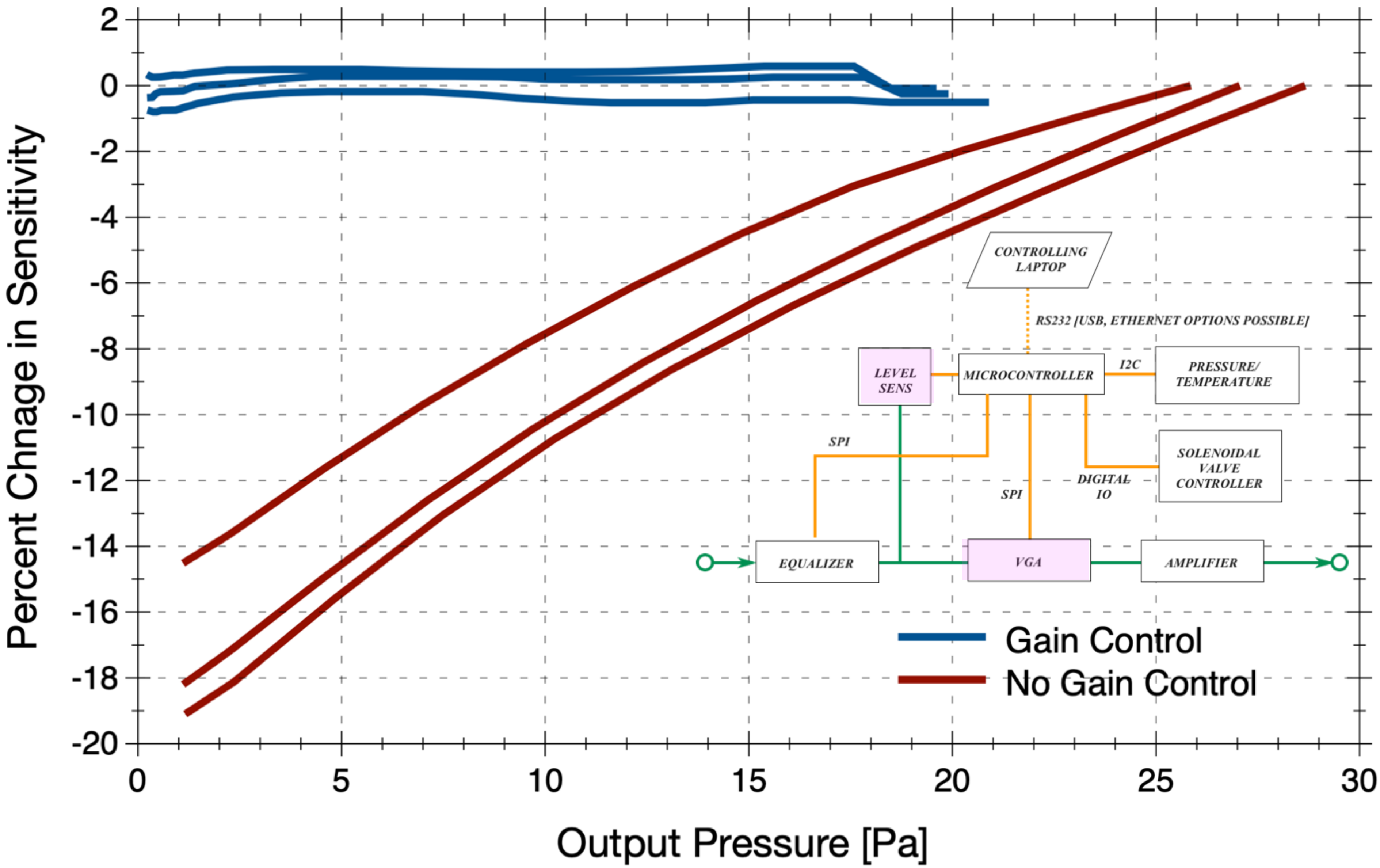


CONTROLLING LAPTOP
RS232 [USB, ETHERNET OPTIONS POSSIBLE]
LEVEL SENS
MICROCONTROLLER
I2C
PRESSURE/ TEMPERATURE
SPI
SPI
DIGITAL IO
SOLENOIDAL VALVE CONTROLLER
EQUALIZER
VGA
AMPLIFIER

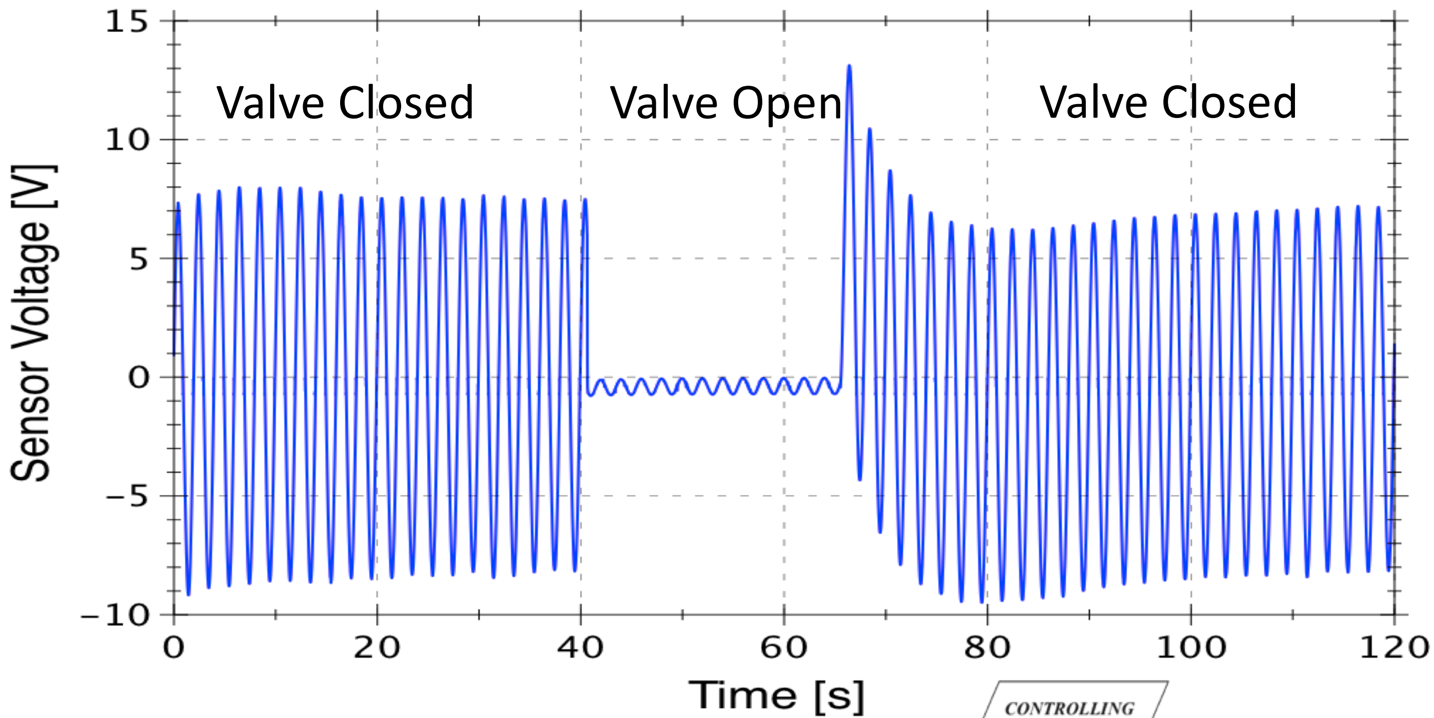
Tilt Equalizer [Frequency Compensation]

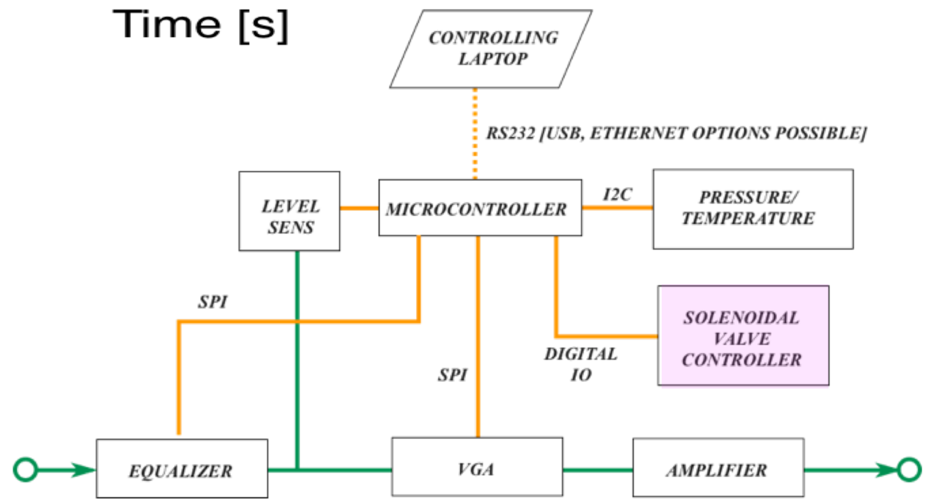


Correcting for Level Effect (Level Sense)

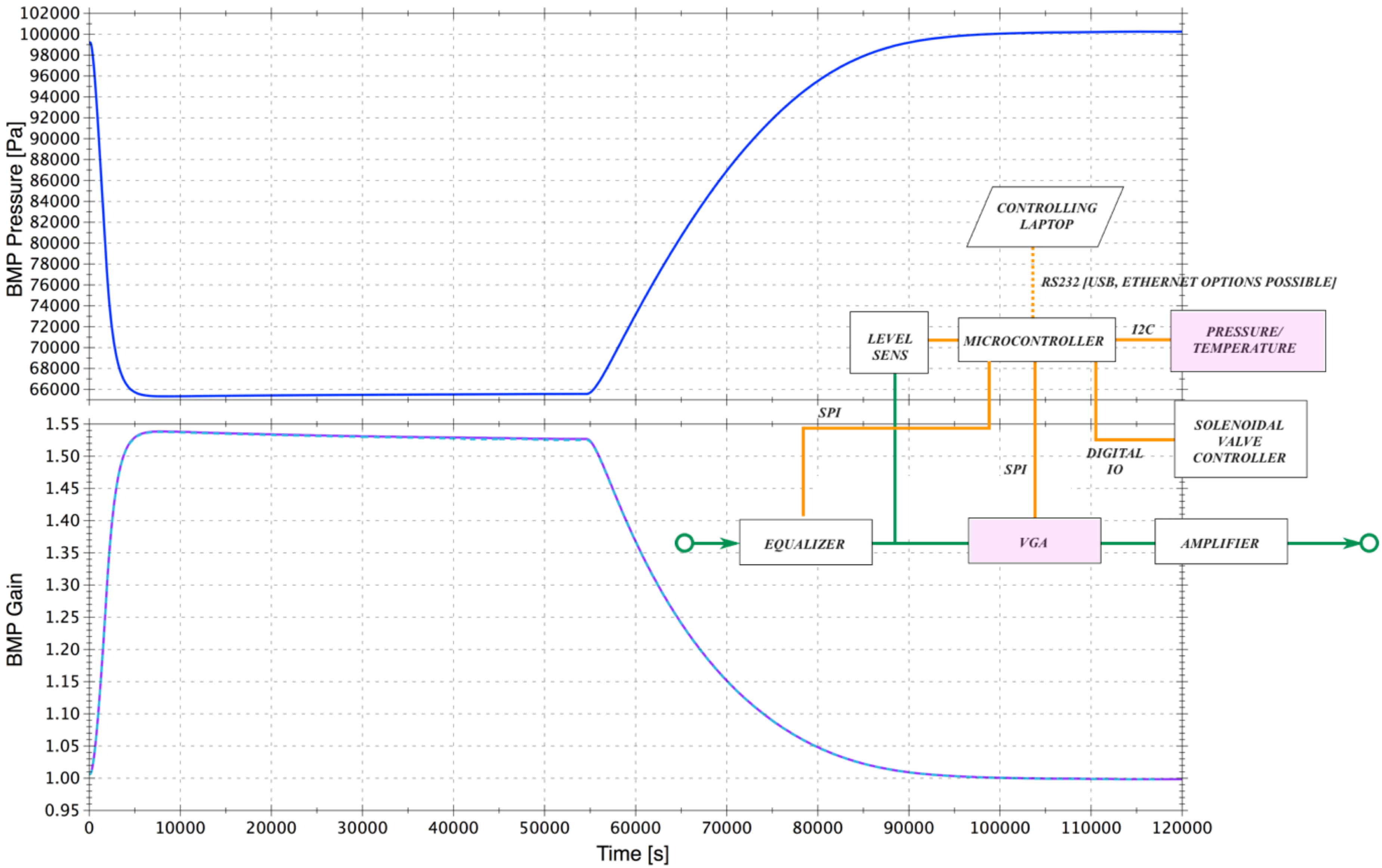


Operation of the Solenoidal Valve

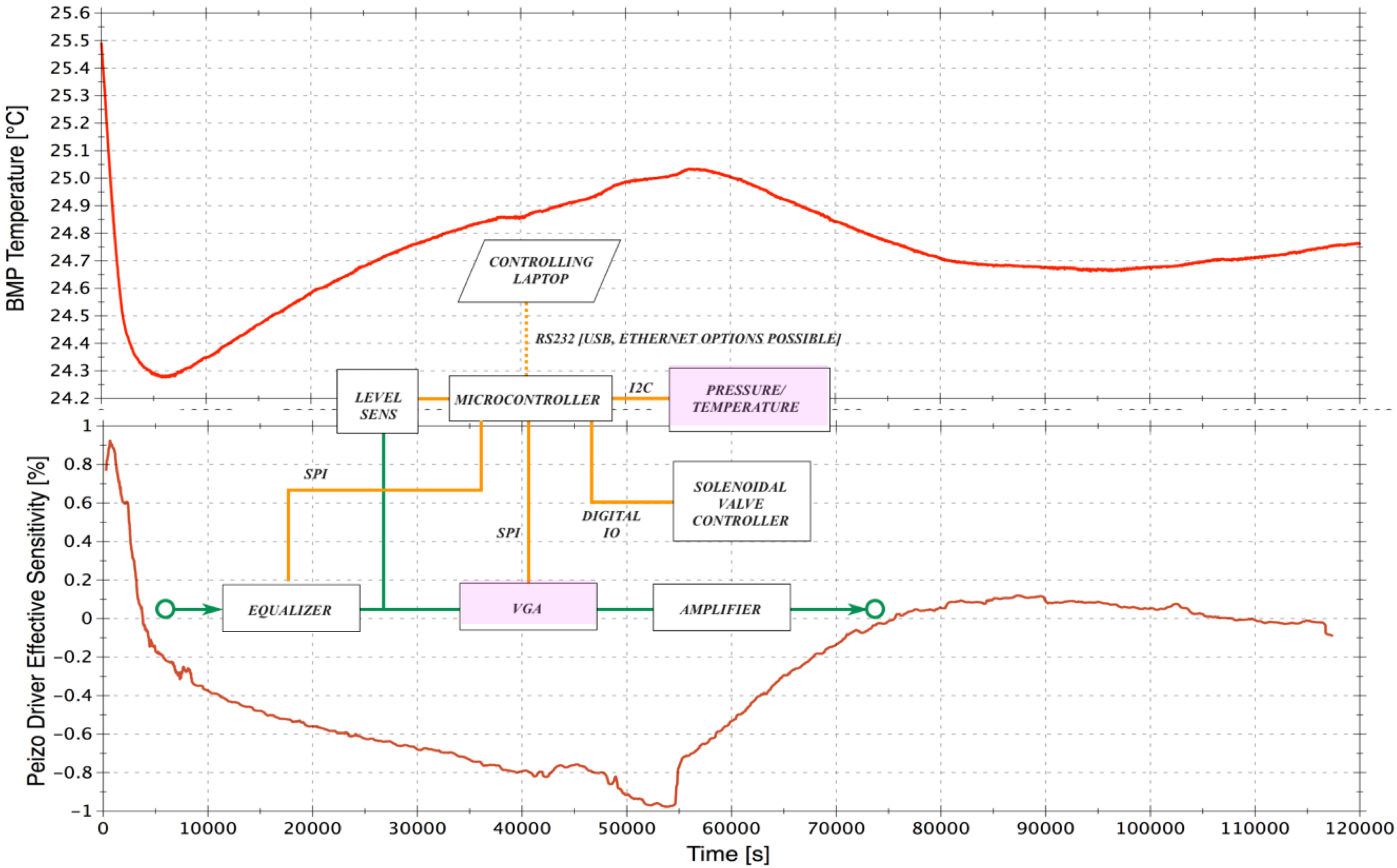




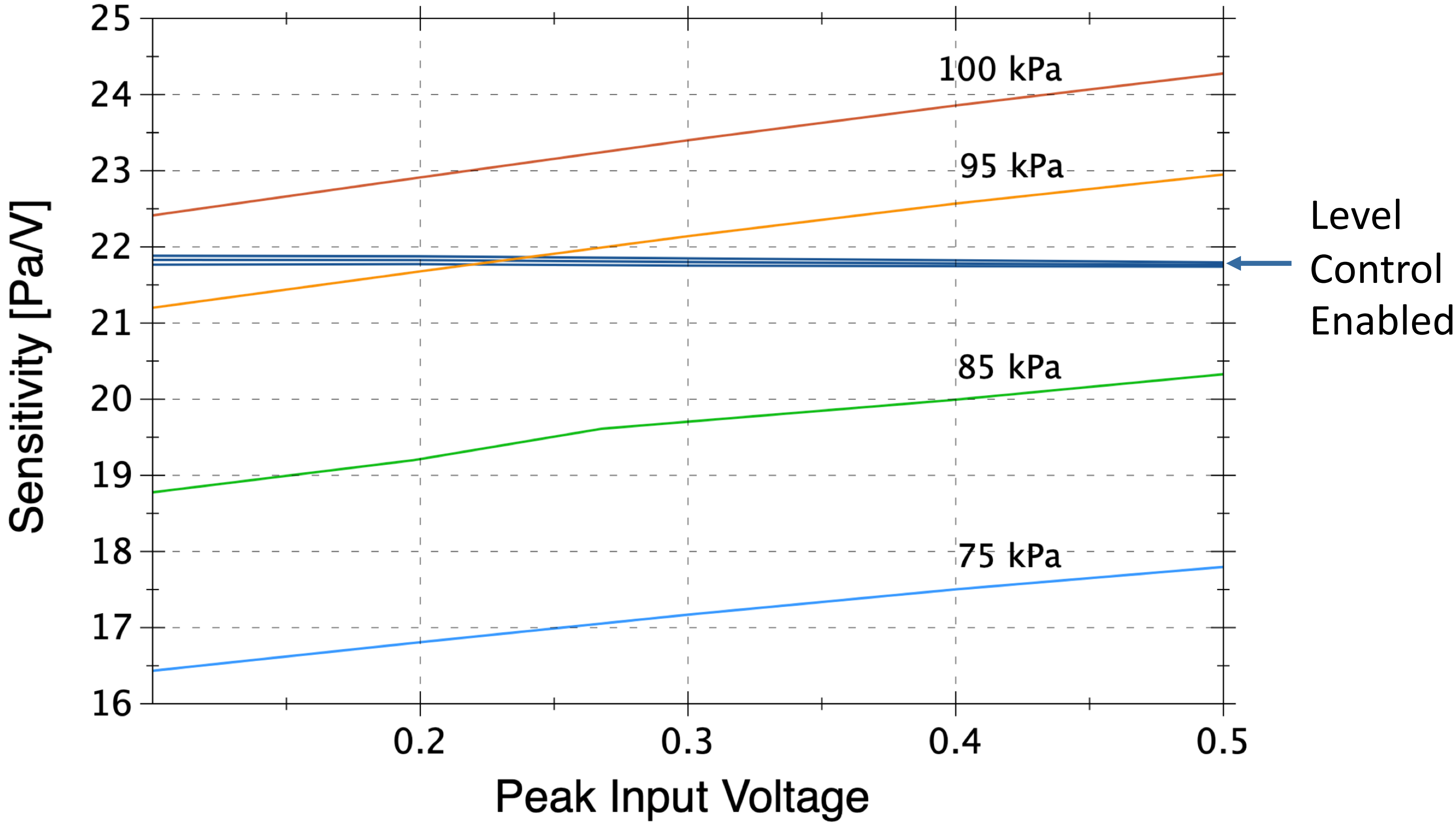
Pressure Gain Control



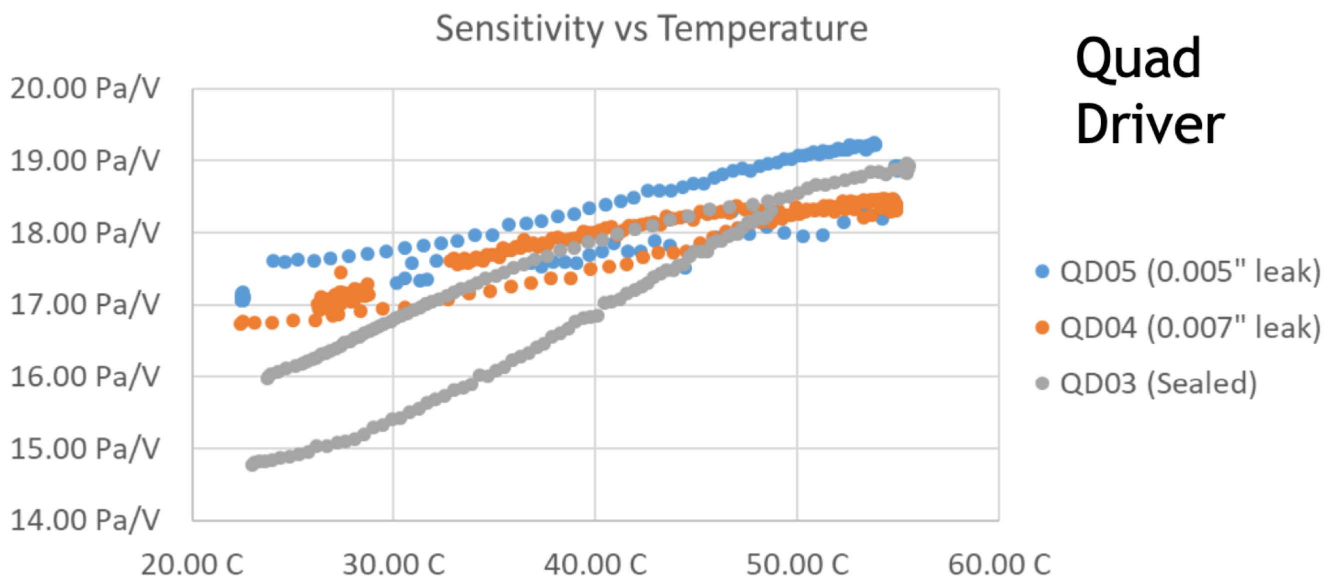
Temperature Gain Control



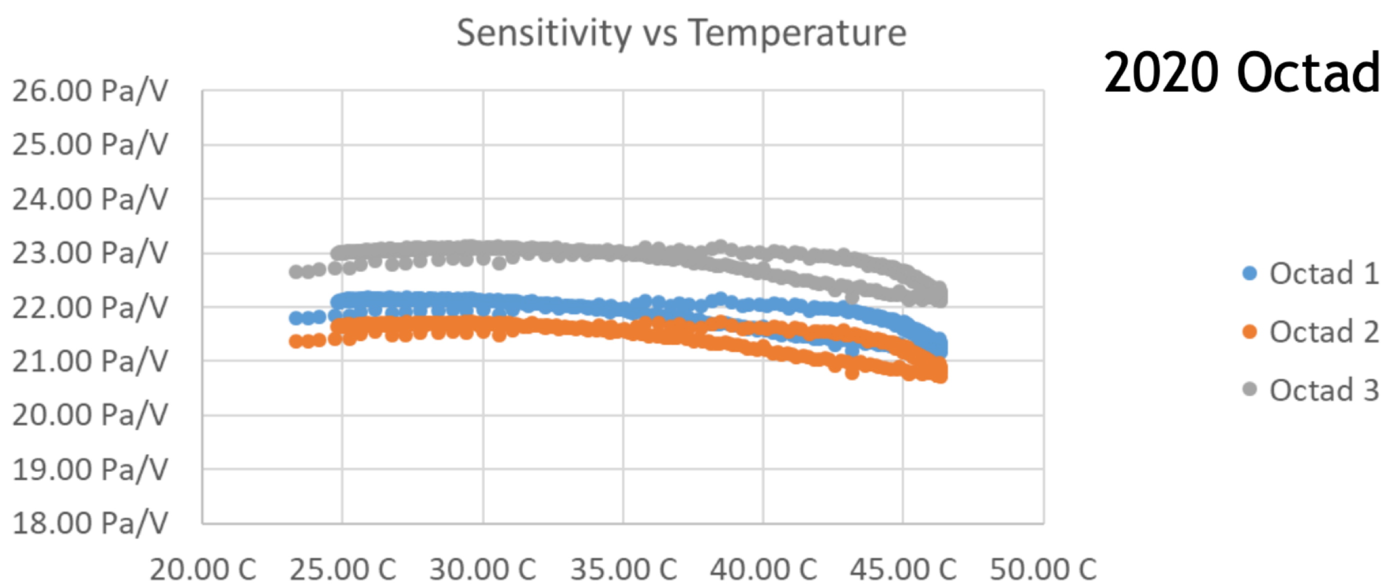
Results for Multiple Static Pressures



Sandia Tests for Temperature Correction



Quad Driver



2020 Octad

Upgrades, Tweaks and Future Work

- Digital On/Off Switch (reduce power consumption)
- Configure Solenoidal Controller ("normally closed" when powered off)
- Refined Gain Control Model (~ 20% increase in sensitivity; refined nonlinearity models; refined tilt equalization calibration; etc)
- After completion of the these upgrades, SNL will commence long term field deployment.
- Following this stage, the system behavior will be evaluated for possible acceptance into the International Monitoring System stations for the Comprehensive Test Ban Treaty Organization.