Silicon Audio Optical Seismometer

Model 213P

Contents

Introduction

The Silicon Audio Optical Seismometer is a low noise force-balanced seismometer offering a flat velocity response from 0.005Hz to 80Hz in a rugged design which is free of mass locking. The post-hole packaging of the sensor is available in water resistant (IP68) enclosure designed for direct burial. These features, combined with its small size, make it an ideal replacement for geophones and traditional force balanced seismometers in applications where both performance and ruggedness are required.

Quick start guide

Silicon Audio recommends the user familiarize themselves with the sensor operation using an evaluation setup described in the following section. Quick start instructions are provided in the table below for reference.

- Connect cable to sensor
- Install securely with attention to insulation and cable routing
- Plug into digitizer to power sensor
- After about 30 seconds the first channel will calibrate and start operating
- After about 5 seconds the next channel will calibrate and start operating
- After about 5 seconds the final channel will calibrate and start operating
- You will see a settling tail for each of the channels until the temperature is stabilized

Theory of Operation

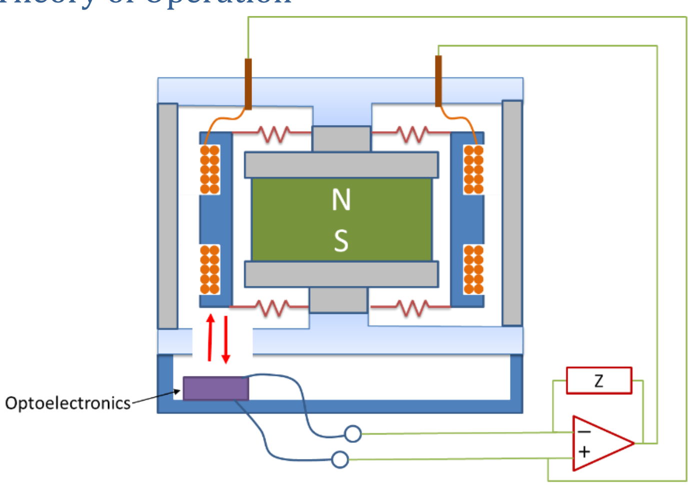

Figure 1: Simplified Model

The Silicon Audio 213P is a seismometer based around a very sensitive optical interferometric displacement sensor. It utilizes a proof mass similar to a traditional exploration geophone but replaces the induction output with a high-performance coil actuator to make a force balanced seismometer.

The sensor uses both the optical and mechanical systems to calibrate to the operating environment. The 213P will adjust its parameters to allow for large tilt ranges as well as various temperatures. The self-calibration feature allows the sensor to perform consistently in a variety of environments.

One feature of the optical sensor is the clipping point of the sensor is electrical instead of mechanical. If the sensor outputs a signal larger than the max level the sensor detects this and shuts down the output. It will then recalibrate and resume normal operation about 1 second later.

Instrument response

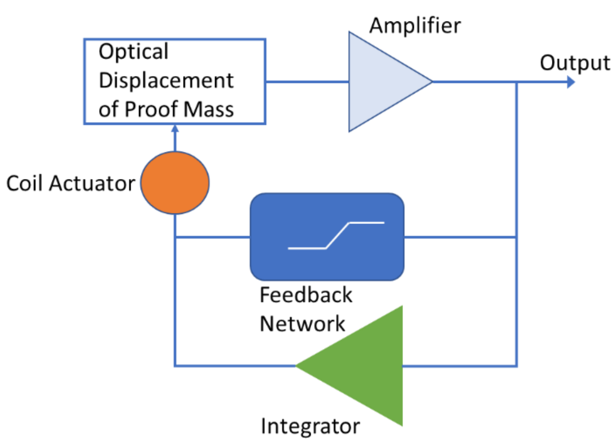

Figure 2: Block Diagram

The in-band instrument response is determined by the feedback network. The feedback network includes a high frequency proportional control, and a high pass filter to make the output flat to velocity over the pass band.

The simplified output response in velocity is given by the below equation. The other poles and zeros are above 500 Hz.

$$H(s) = \frac{Sensitivity * Normalization * s * (s + HF_c)}{(s + LC_1) * (s + LC_2)}$$

HF_c is the high frequency corner established by the feedback network. LC_1 is the low frequency corner established by the feedback network. LC_2 is the lower frequency corner set by the integrator. These are both single pole filters, so the low frequency damping is 0.7.

Installation and Handling

The 213P sensor is free of any mass-locking mechanisms. For optimal ruggedness, the sensors should be transported in the powered off state.

The posthole package is watertight and designed for direct burial. When unpacking the sensor and getting ready to install the unit, connect the cable after you remove the sensor from the case to minimize contamination of the connector pins.

The cable is flexible to minimize forces on the sensor that will disturb the installation.

Place sensor in its final position before powering up. Alternately, power cycle the sensor once the installation is complete to allow the sensor to recalibrate in place.

Before power is applied to the sensor, ensure that all other connections have been made. This guards not only against electrical inrush but also mitigates against the influence of excessive disturbance during the startup sequence which may interfere with sensor calibration. Once the sensor is powered on, a calibration sequence is automatically carried out before normal output begins.

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Calibration & Reset

Calibration occurs during the sensor's startup sequence although calibration events may also be issued directly via the mass recenter logic line. In addition to setting the sensitivity of the sensor, the calibration routine also removes the DC component of acceleration due to gravity. The length of the start-up calibration has an extra delay (approximately 30 seconds) to allow the power supplies to settle before the sensor calibrates. A decaying offset marks the start of normal operation.

In the event that operating conditions are exceeded, the sensor automatically issue a reset command which returns the sensor to its preferred operating point. The automatic reset algorithm is controlled by firmware and lasts approximately 1 second depending on ambient vibration amplitude. Excessive temperature drift is one example where the sensor may automatically issue a reset sequence. Temperature drift at the output of the SA sensor prototype is filtered out so that the DC component of the sensor remains at 0V. In the event that the temperature drift threshold is reached, a reset command is issued. A complete list of reset conditions are listed in the below table.

Table 1. Reset events controlled by sensor logic

Reset Event	Logic Trigger	Output Pulses
1. Startup Reset	Completion of Calibration Sequence	0
2. Overload Reset	Output voltage exceeding 30V peak	1
3. Temperature Reset	Too large a change in temperature since last calibration	2
4. Offset Drift Reset	Drift correction circuit exceed set-point threshold	3
5. Commanded Reset	ReCenter Logic line toggled	4

Each of these reset events has a separate code that the sensor inserts into the output to indicate the reason for the recalibration. If there is an overscale event were the sensor clips, you will see a single positive pulse after the recalibration.

Tilt

The 213P has a tilt tolerance of +/-15degrees while the instrument is installed and calibrated. Once in operation, much smaller tilts can cause the instrument to overscale. If the instrument overscales, it will recalibrate for this new tilt. This allows the instrument to recover in situations where there is slow shifting.

Recenter input

There is a logic input that allows a user to remotely call a sensor calibration. A voltage lower than 2 V on this line causes the sensor to recalibrate. This is often hooked to the digitizer mass recenter logic line. While the Silicon Audio seismometer does not have a traditional recentering motor, this command is functionally equivalent. There are no mass position outputs available from the instrument.

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Coil Calibration Input

There is also a calibration input available. These signals can be hooked up to a digitizers calibration logic line and signal outputs.

Holding the calibration enable signal below 2V puts the sensor in coil calibration mode. While in calibration mode, any signals on the calibration signal line are fed into the sensor calibration coil.

Putting a signal directly onto the calibration coil is the equivalent to input ground acceleration. To reference this input to velocity we have put a high pass filter in series with the input calibration coil. You can see the equivalent input circuit in Figure 3: DAS coil input circuit.

The nominal coil constant for the sensors is listed with the response. (nominally 58.8 mV/V for 213P-40s)

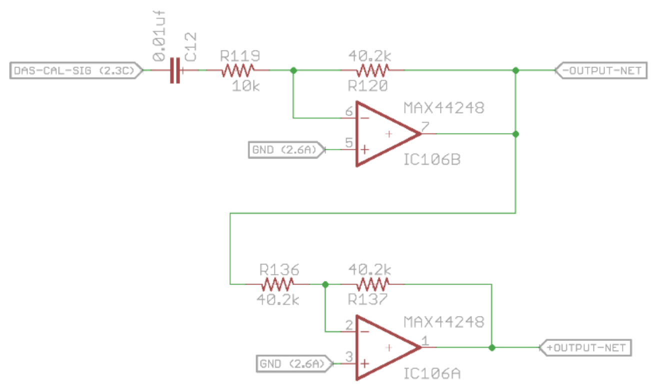
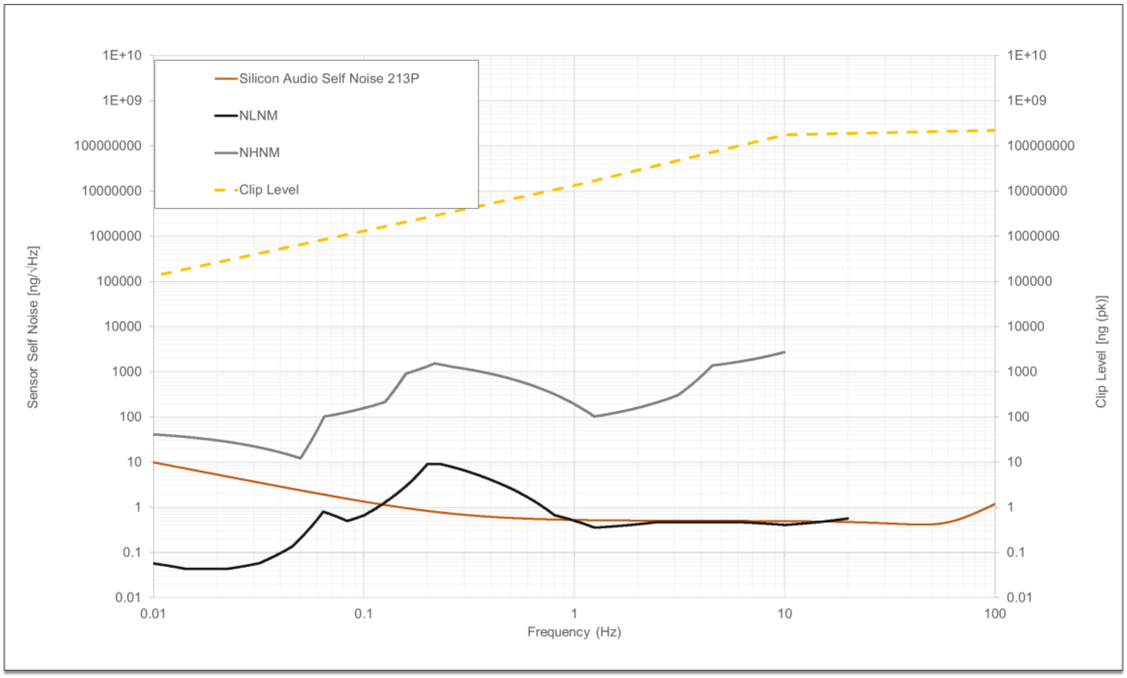


Figure 3: DAS coil input circuit

Specs

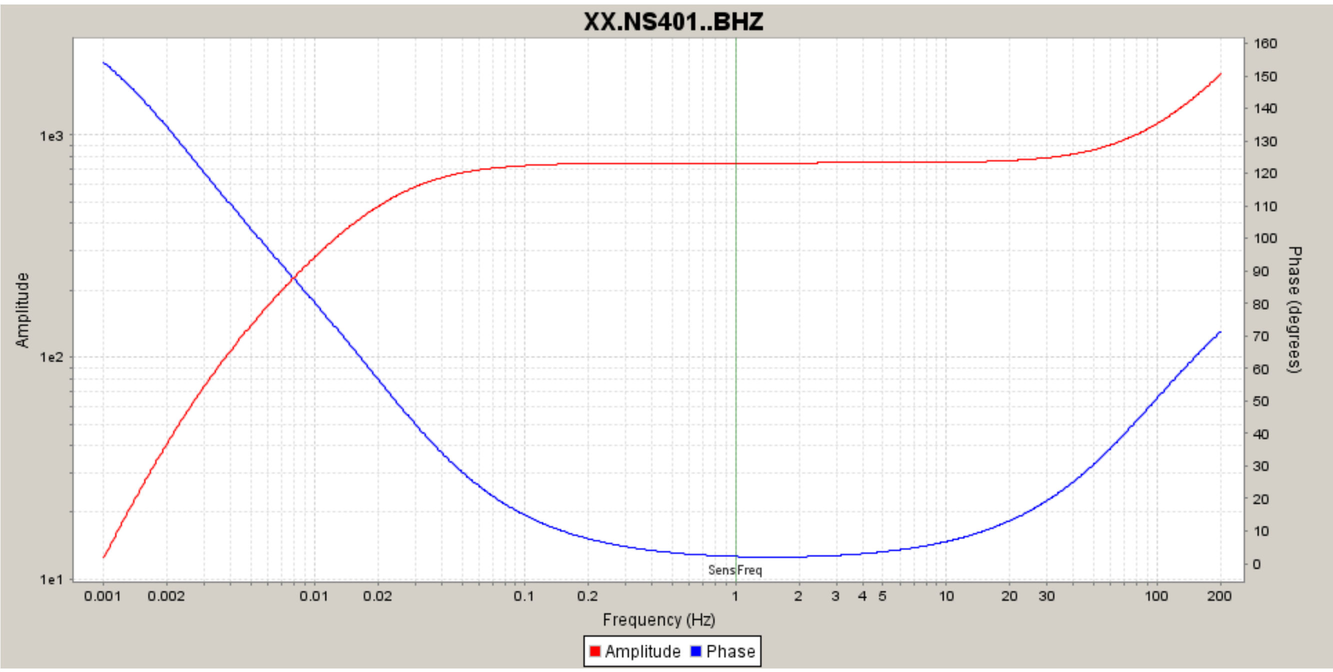
Dynamic Range Window



SENSOR PERFORMANCE	213P
Passband (flat to velocity)	**213P-40** 0.025 Hz – 90 Hz (-3db / +3db) **213P-120** 0.008 Hz – 60 Hz (-3db / +3db)
Noise	0.5ng/√Hz [@ 10Hz]
	0.8ng/√Hz [@ 1Hz]
	3ng/√Hz [@ 0.1Hz]
	10ng/√Hz [@ 0.01Hz]
Clip Level	±0.040 m/s
Dynamic Range	>154dB @ 1Hz over 1Hz BW
Sensitivity *(custom settings available)*	750 V/m/s
Max Vout	60V pk-pk
Tilt tolerance	±15°
Distortion	<0.03% @ 12Hz and 0.7in/s p-p
POWER	
Power	150mW
Supply Voltage	6-24V DC
HANDLING	
Transport	No mass lock required for transport
Shock tolerance	>1500g (0.5ms ½ sine)
Operating Temperature	-30°C to 75°C
GENERAL	
Dimensions	3.24"Diameter x 4.7"Length posthole 3 component package
Configuration	3-axis
Sensing Method	Force balance with interferometric transducer

Sensor Response

213P-40



Response function

Sensitivity	750	*V/m/s*
Coil input sensitivity	0.0588	*Vout / Vin*
Normalization factor	1.6369843e+06	
Normalization frequency	1.0	*Hz*
Number of zeroes	4	
Number of poles	5	
Complex zeroes	*real*	*imag*
0	0.000000e+00	0.000000e+00
1	0.000000e+00	0.000000e+00
2	-5.661140e+02	0.000000e+00
3	-4.398220e+03	0.000000e+00
Complex poles		
0	-1.502474e-01	0.000000e+00
1	-1.440085e-02	0.000000e+00
2	-7.539822e+03	0.000000e+00
3	-3.487822e+03	2.29850e+04
4	-3.487822e+03	-2.29850e+04

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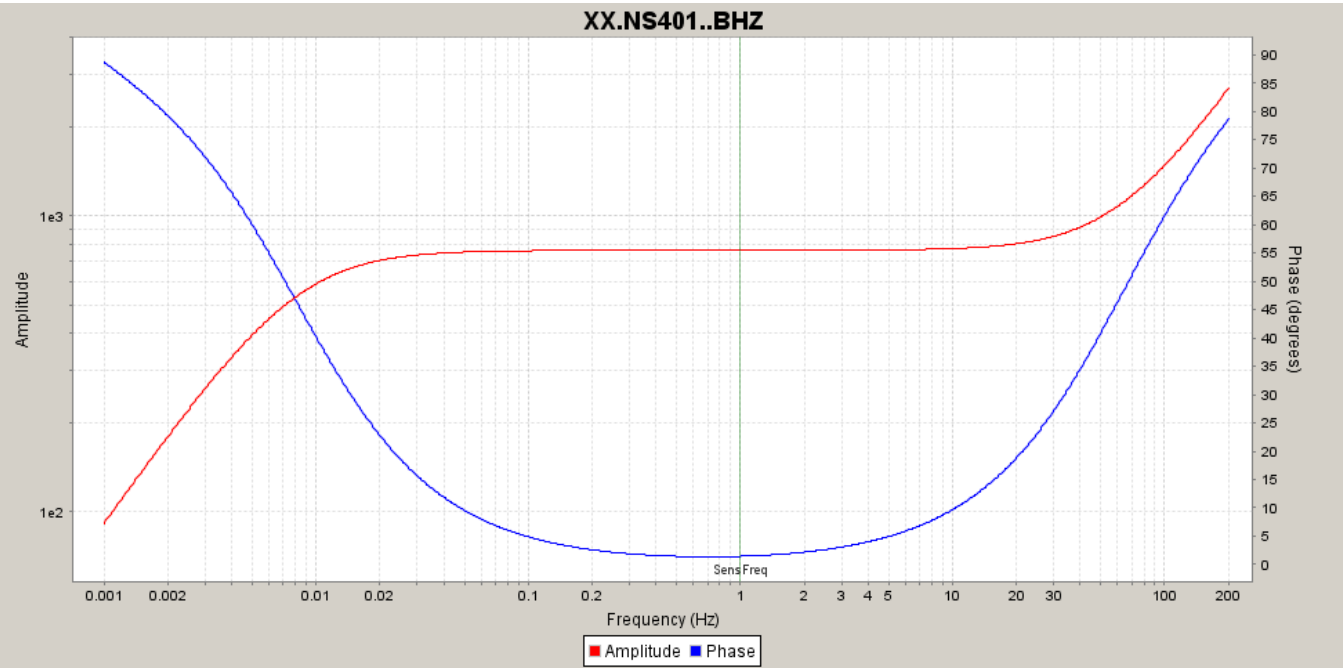
213P-120



Response function

Sensitivity	765	*V/m/s*
Coil input sensitivity	0.060	*Vout / Vin*
Normalization factor	2.421113E+06	
Normalization frequency	1.0	*Hz*
Number of zeroes	4	
Number of poles	5	
Complex zeroes	*real*	*imag*
0	0.000000e+00	0.000000e+00
1	0.000000e+00	0.000000e+00
2	-3.826450e+02	0.000000e+00
3	-4.398220e+03	0.000000e+00
Complex poles		
0	-6.175742e-04	0.000000e+00
1	-5.196194e-02	0.000000e+00
2	-7.539822e+03	0.000000e+00
3	-3.487822e+03	2.29850e+04
4	-3.487822e+03	-2.29850e+04

Sensor Pin-Out

The recommended mating connector for the 213P is a Souriau UTS6JC14E19S.

Silicon Audio
213P *cable*

Cable	Sensor Function	Silicon Audio 213P 14-19S	Cable color / label Harting 09456000332
Twisted Pair	6-24 v DC	H	2
	Power GND	J	1
Overall Shield	Shield GND	G	drain wire
Twisted Pair	digital GND	T	3
	re-center +	U	4
Twisted Pair	Output: Z+	A	blue
	Output: Z-	B	white-blue
Twisted Pair	Output: Y+	C	brown
	Output: Y-	D	white-brown
Twisted Pair	Output: X+	E	orange
	Output: X-	F	white-orange
Twisted Pair	calibration enable +	L	white-green
	calibration signal	N	green

Sensor Drawing