Test Report: Wave Energy Converter Device for SEWEC
Department of Energy Wave Energy Prize 2015

Test dates: December 7 - 11, 2015

University of Michigan
Marine Hydrodynamics Laboratory
Department of Naval Architecture and Marine Engineering

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Description of Test Facilities

The UM MHL and its Physical Modeling Basin (PMB) have a long history at UM and as a strategic asset in Midwest. Initial construction in the West Engineering Building (now West Hall) was completed in 1904 to support both the Naval Architecture and Marine Engineering department and Civil Engineering department. The PMB has had numerous upgrades through the decades and has been in continuous operation since its founding, supporting education, research and commercial activity.

Physical Model Basin

The Physical Model Basin (towing tank) is nominally 360 feet long, by 21.5 feet wide, by 9.5 feet deep. The length of basin available for free-surface operations is nominally 300 feet, due to the size and position of the wavemaker and wave-absorbing beach. Figure 1, shown below, is a view along the length of the basin from the wavemaker toward the beach. The carriage can be seen in the far end of the towing basin. The foreground shows the ballast well and wavemaker.

Figure 1: View of the Physical Model Basin looking from the wavemaker toward the beach.

The basin has a curved floor and a trench along the center that is nominally 4 feet wide, 3 feet deep, and running the length of the tank, as shown in Figure 2. This feature has a neutral impact on normal free-surface testing operations.

The PMB has four doors along its west wall and is completely secured; only select staff have keyed access. It is climate controlled with HVAC systems, etc., and is relatively comfortable to work in year-round. The PMB is relatively well lit by florescent lighting and large glass block windows along its length to the east (good diffuse light, but no visibility from outside). A few windows do allow visibility along a portion of the west wall to a public access hallway; these windows can be covered or remain uncovered. The basin (lower) walls are painted white and the floor coating is a medium-shade green-

grey; optical conditions in the water is decent and additional lighting will be used if necessary.

The water quality is excellent, being chlorinated (Ann Arbor city) fresh potable water. The water is continuously processed with a fine-mesh filtration system and regularly refreshed. The water temperature is nominally 65 degrees Fahrenheit +/- 3 degrees year round; the temperature is measured to within 0.1 degree Fahrenheit during testing.

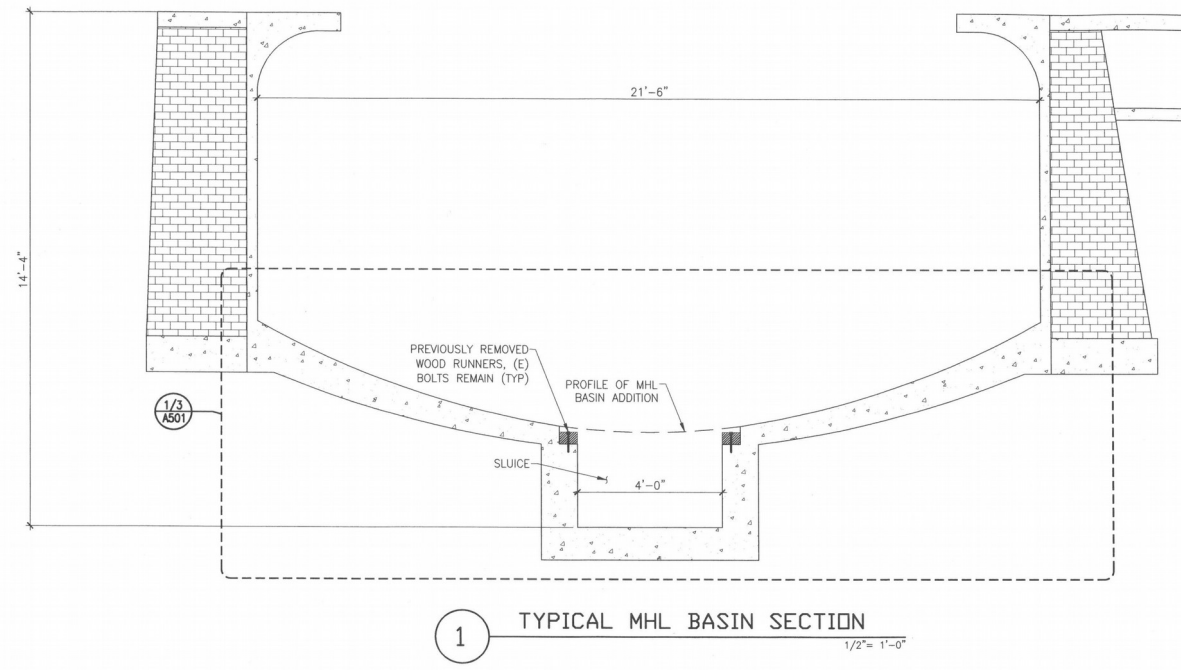


Figure 2: Cross-sectional view of the Physical Model Basin.

Wavemaker

The wavemaker consists of a vertically plunging wedge that runs on linear rails, as shown in Figures 3 and 4.

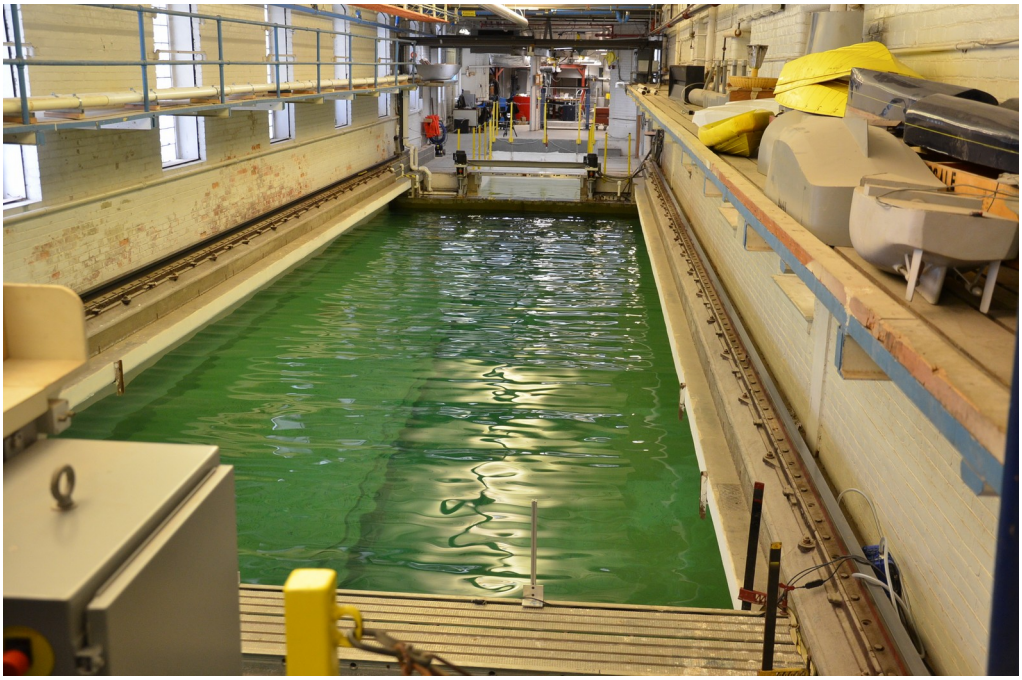


Figure 3: Wavemaker in operation, producing irregular wave conditions.

It is capable of producing regular plane waves and irregular plane waves for a variety of standard wave spectra. It can be locally or remotely controlled by computer. The wavemaker generally operates between frequencies of 0.4 Hz to 3.0 Hz.

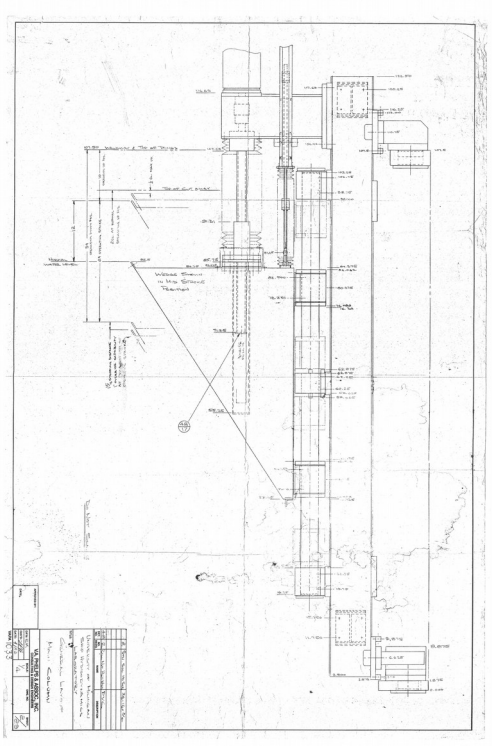
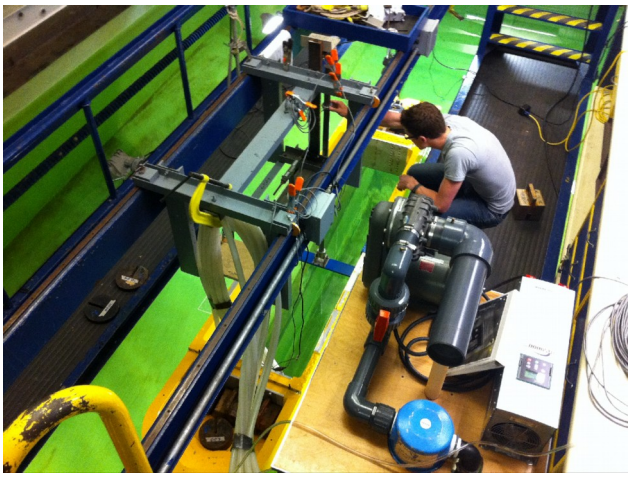


Figure 4: Profile view of the basin wavemaker.

Carriage (powered)

The tank carriage spans the width of the tank and can traverse the length of the tank between the wavemaker and beach. It is self-powered and equipped with a variety of support equipment and platforms. Two views of the carriage are shown in Figure 5. It is primary designed for towed-model testing, and also makes an excellent platform for fixed model testing. The carriage is capable of testing models at speeds up to 20 feet/second; the higher the speed the shorter the steady-state duration at that speed.

The carriage also supports the data acquisition system and the ability to initiate wavemaker control and other external systems such as remote video, wave height sensors, etc.



a) Testing on-board the carriage

b) Carriage view from aft

Figure 5: Tank carriage system

Description of Test Setup

For the Wave Energy Prize testing campaign, the carriage was secured in-place, and augmented with additional platforms to enhance the ergonomics of setting up and adjusting the WEC devices. Figure 6 is a view from the wavemaker end of the basin, west side. In the foreground a cross-structure is visible where three ultrasonic wave probes (WP1, WP 2 and WP3) are located. These probes measure the undisturbed wave coming from the wavemaker to the WEC device.

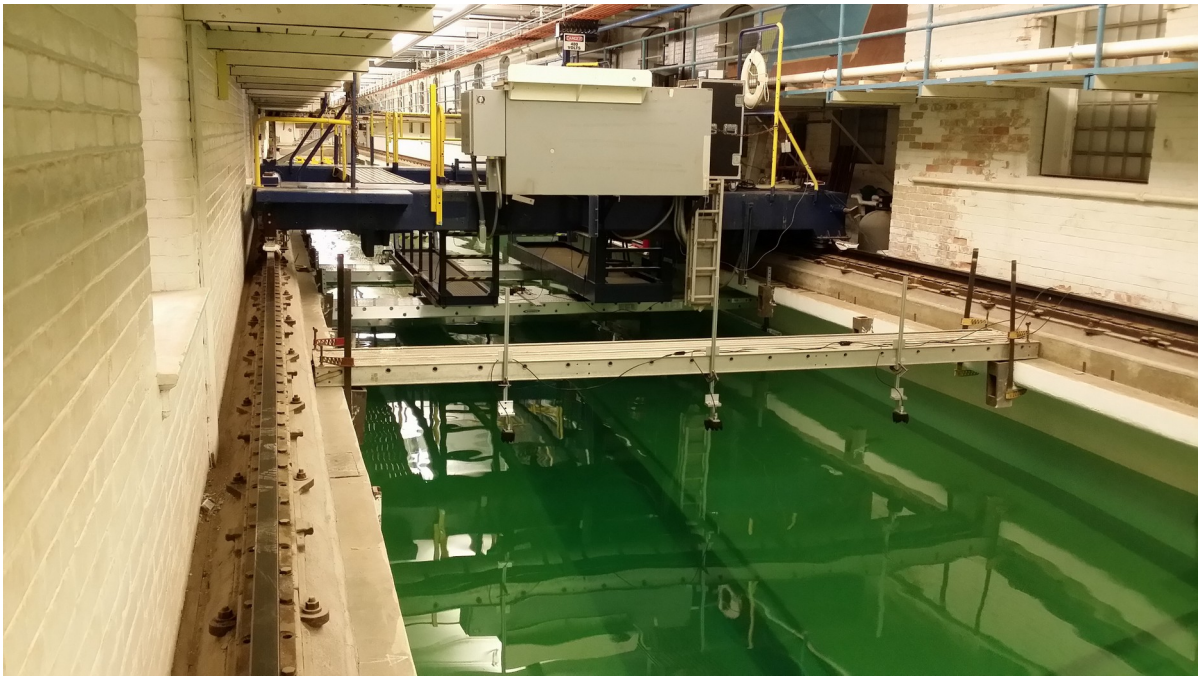


Figure 6: Carriage in WEC testing configuration and upstream wave probes

Figure 7 shows the area for testing the WEC devices between the carriage walkways (blue and black with yellow handrails). Additional cross-structure (aluminum scaffolding) is visible, passing beneath the carriage walkways. A set of c-channel rails (blue) pass longitudinally above the open water area; these are used to support instruments and cameras, etc.

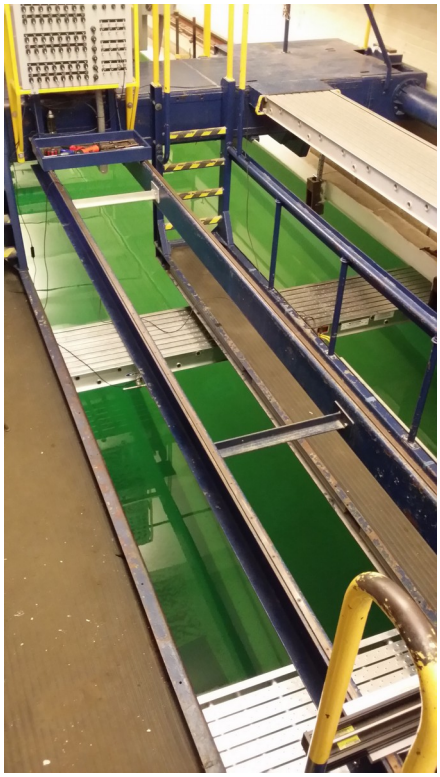


Figure 7: Open area between walkways on the carriage where the WEC devices are tested.

A top-view sketch of the Physical Model Basin equipment arrangement for testing the WEC devices is shown in Figure 8. The sketch is not drawn to scale, however, key dimensions are identified.

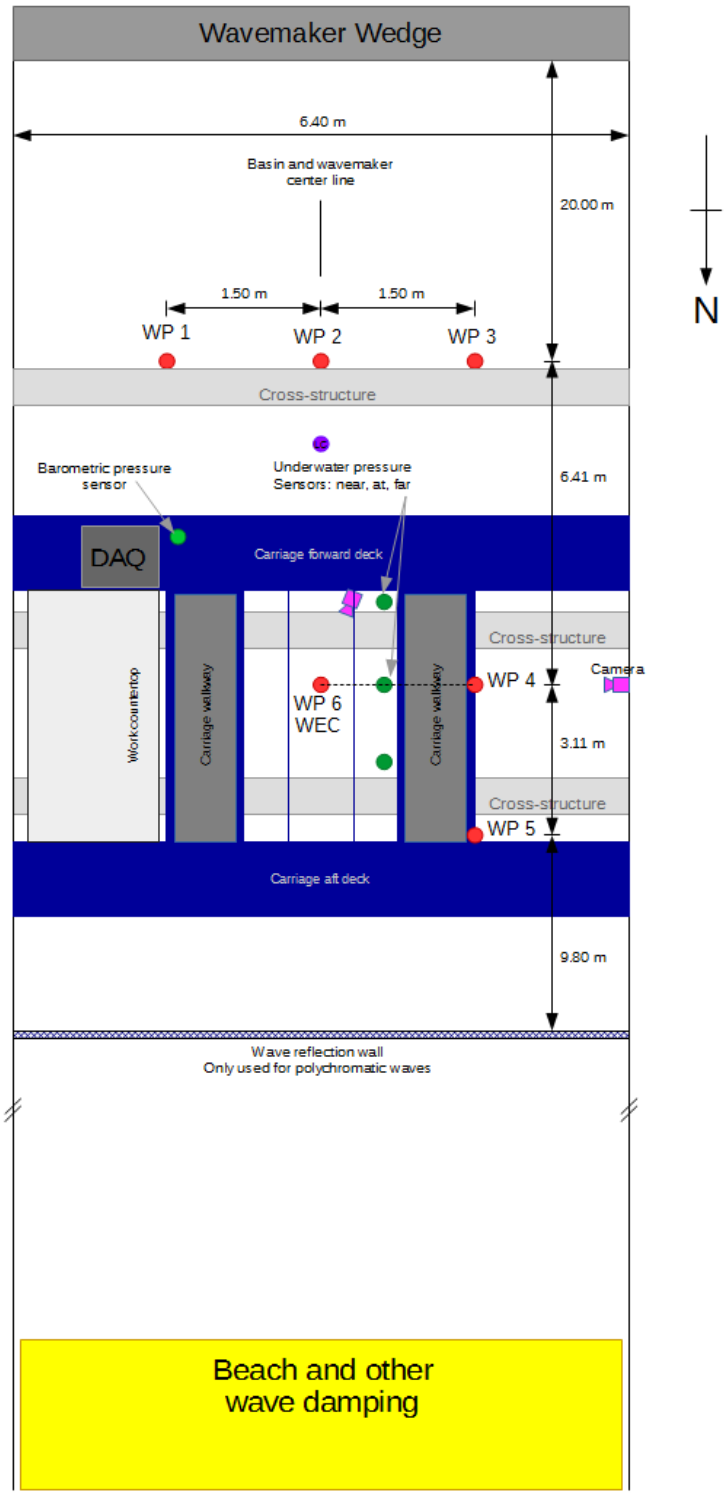


Figure 8: Top-view conceptual diagram of the testing equipment layout along with key dimensions

The array of instruments used for each of the WEC tests, as shown in Figure 8, includes the following instruments, listed in Table 1.

Instrument Function	Symbol	Make	Model
Wave probes – ultrasonic	Red circle	Senix	ToughSonic 30
Underwater pressure sensor	Green circle	Impress Sensors	IMCL-G0360
		Omega Engineering	PX2300-10DI
Barometric air pressure	Light green circle	Omega Engineering	PX409-26BI
Load cell	Purple circle	Cooper Instruments	LFS-250
Digital camera	Magenta square/triangle		
3D Motion Tracking	Not shown	OptiTrack	Prime 41 cameras

Table 1: UM MHL supplied instrumentation

The location of the wave probes with respect to the front edge of the wavemaker is identified in Figure 8. Wave probe number 6 (WP6) was used for characterizing the wave conditions in the basin before the testing program started. This probe was located where the WEC devices were tested for each case. For the monochromatic wave cases, wave probe number 4 (WP4) was used to identify the timing between the incoming waves and the behavior of the WEC device. Since WP6 would not be available to record the data when the WEC was located there, the values from other wave probes were used to estimate the wave conditions at the WEC device.

A mapping between the average of the wave conditions at WP1, WP2, WP3 and WP4 and those at WP6 was developed for each of the monochromatic cases and used for data analysis. The results are shown in the following table:

Wave case	WP6 – WP1,2,3,4	WP6 – WP1,2,3,4
	Avg Amplitude (%)	Avg Frequency (%)
M1 s 80	4.68	0.04
M2 s 80	7.00	0.13
M3 s 80	1.20	-0.09
M4 s 80	1.57	-0.01
M5 s 80	-4.84	-0.04
M6 s 80	-29.50	0.02
M7 s 80	1.51	0.03
M1 s 40	-0.95	0.10
M2 s 40	3.49	0.03
M3 s 40	0.14	-0.07
M4 s 40	0.69	-0.05
M5 s 40	-3.52	-0.04

Table 2: Average wave amplitude correlation at WEC

Monochromatic test case M6_s_80 stands out for being so different in average wave amplitude. This condition is due to a resonance near this frequency in the basin. It is dealt with by performing longer wavemaker runs for this case, getting the wave phenomena to 'lock-in' after 15 periods, and utilizing the data from that point afterward. The typical monochromatic wave test run consisted of operating the wavemaker for a duration of 25 periods plus 10 seconds (to account of 5 seconds of ramp-up and ramp-down time). The exceptions were cases M6s80 where the wavemaker was run for 40 periods plus the ramp-up/down time, and M1s80 where the wavemaker was run for 50 periods plus ramp-up/down time.

For the polychromatic test cases, the WEC was required to be exposed to the prescribed irregular wave conditions for the equivalent of 30 minutes full-scale time (4.24 minutes duration model-scale time). Running the wavemaker for this duration would obviously result in reflected energy, since the beach system is not a perfect absorber. Given the fact that reflection was going to be present, it was decided to influence the reflection conditions by installing a wave reflector wall approximately 14.4 meters from the WEC device. The wavemaker parameters were tested and determined assuming a relatively high degree of wave reflection. For the polychromatic cases, the wave data from wave probe number 2 (WP2) was used, assuming the conditions would be similar at the WEC location.

For both the monochromatic and polychromatic wave cases, the wavemaker motion control signals were defined and stored for repeated use. Each prescribed test case was run with an identical input signal, regardless of when it was run, or which WEC team it was run for. This strategy was instituted in order to minimize the differences between identical test cases.

The instrumentation data sheets and calibration records for the load cells and the wave probes are included in Appendix A. The factory calibration values were used for the three pressure sensors used underwater and for the barometric air pressure sensor.

Instrumentation and Data Channel Lists

The data was collected on a National Instruments M-Series USB-6225 data acquisition unit coupled with the SC-2345 signal conditioning system and other input devices, which allow for the use of voltage, current, strain, digital and frequency input and output (control). National Instruments LabVIEW 2015 software was used to control the data acquisition system and collect the data. The data is stored in the LabVIEW native TDMS file format, which is more flexible than a traditional flat-file spreadsheet. The TDMS files may be easily read by LabVIEW software, or exported to a spreadsheet format for viewing/analysis.

The following file naming convention was used for data collection:

- Raw numerical: R_M/PX_s_Y0_Z_TeamName_DataRun#
- Raw numerical gain and offset: R_M/PX_s_Y0_Z_TeamName_ParametersRun#
- Raw 3D motion: M_M/PX_s_Y0_Z_TeamName_run#
- Video: V_M/PX_s_Y0_Z_TeamName_DataRun#
- Processed: P_M/PX_s_Y0_Z_TeamName_DataRun#

The M/P value refers to the monochromatic and polychromatic wave cases, respectively. The X refers to the M or P run identifier. The Y is the steepness identifier (either '4' for 40, or '8' for 80). The Z is the wave direction identifier (either 0, 20 or 50). The DataRun# or run# suffix was utilized to keep track of repeat runs for a given condition.

For the processed data files, the raw numerical and motion data are integrated into the file in order to be processed by the LabVIEW DiaDEM data analysis and reporting tool.

The raw data channel list is shown in table 3, below:

Data File	Channel Name	Description	Unit	Sensor	Sample Rate
R_M/PX_s_Y0_Z	Wave Probe 1	WP 1 water level	cm	Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Wave Probe 2	WP 2 water level	cm	Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Wave Probe 3	WP 3 water level	cm	Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Wave Probe 4	WP 4 water level	cm	Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Wave Probe 5	WP 5 water level	cm	Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Wave Probe 6	Not used - WEC location		Senix ToughSonic 30	200 Hz
R_M/PX_s_Y0_Z	Underwater Pressure Near	Pressure at basin floor - nearest to wavemaker	Pa	Impress IMCL-G0360	200 Hz
R_M/PX_s_Y0_Z	Underwater Pressure At	Pressure at basin floor - at WEC device	Pa	Impress IMCL-G0360	200 Hz
R_M/PX_s_Y0_Z	Underwater Pressure Far	Pressure at basin floor - furthest from wavemaker	Pa	Omega PX2300-10DI	200 Hz
R_M/PX_s_Y0_Z	Barometric	Barometric air pressure	inHg	Omega PX409-26BI	200 Hz
R_M/PX_s_Y0_Z	Mooring LC 1	Mooring force	N	Cooper LFS-250	200 Hz
R_M/PX_s_Y0_Z	Mooring LC 2	Not used			
R_M/PX_s_Y0_Z	Mooring LC 3	Not used			
R_M/PX_s_Y0_Z	Mooring LC 4	Not used			
R_M/PX_s_Y0_Z	WECVI1	PTO Internal water position 1	Volts	Resistance probes	200 Hz
R_M/PX_s_Y0_Z	WECVI2	PTO Internal water position 2	Volts	Resistance probes	200 Hz
R_M/PX_s_Y0_Z	WECVI3	PTO air diff. pressure	Pa	RS 395-263	200 Hz
R_M/PX_s_Y0_Z	WECVI4	Not used			
R_M/PX_s_Y0_Z	WECVI5	Not used			
R_M/PX_s_Y0_Z	WECVI6	Not used			
R_M/PX_s_Y0_Z	WECSG1	Not used			
R_M/PX_s_Y0_Z	WECSG2	Not used			
R_M/PX_s_Y0_Z	WECVI3	PTO air diff. pressure	Pa	Micro Switch 143PC03D	200 Hz
M_M/PX_s_Y0_Z	Time	Time	s	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	X	Pitch	deg	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	Y	Yaw	deg	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	Z	Roll	deg	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	X1	Sway	cm	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	Y1	Heave	cm	Optitrack 3D motion	100 Hz
M_M/PX_s_Y0_Z	Z1	Surge	cm	Optitrack 3D motion	100 Hz

Table 3: Data channel list for raw numerical and motion data

The processed data channel lists are shown in the following tables: the monochromatic wave data format is shown in Table 4 and the polychromatic wave data format is shown in Table 5.

Data File	Channel Name	Description	Unit	Sensor	Sample Rate
P_MX_s_Y0_Z	WEC Wave	Summary statistics	m		
P_MX_s_Y0_Z	FilteredSignalCopyYWave Probe 1	WP 1 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_MX_s_Y0_Z	FilteredSignalCopyYWave Probe 2	WP 2 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_MX_s_Y0_Z	FilteredSignalCopyYWave Probe 3	WP 3 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_MX_s_Y0_Z	FilteredSignalCopyYWave Probe 4	WP 4 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_MX_s_Y0_Z	UnderwaterPressure	Summary statistics	Pa		
P_MX_s_Y0_Z	FilteredCopyYUnderwater Pressure Near	Pressure at basin floor - nearest to wavemaker - windowed, filtered	Pa	Impress IMCL-G0360	200 Hz
P_MX_s_Y0_Z	FilteredCopyYUnderwater Pressure At	Pressure at basin floor - at WEC device - windowed, filtered	Pa	Impress IMCL-G0360	200 Hz
P_MX_s_Y0_Z	FilteredCopyYUnderwater Pressure Far	Pressure at basin floor - furthest from wavemaker - windowed, filtered	Pa	Omega PX2300-10DI	200 Hz
P_MX_s_Y0_Z	Mooring	Summary statistics			
P_MX_s_Y0_Z	FilteredCopyYMooring LC 1	Mooring line force - windowed, filtered	N	Cooper LFS-250	200 Hz
P_MX_s_Y0_Z	PTO	Summary statistics			
P_MX_s_Y0_Z	PTO Power	Time series and summary statistics	W		
P_MX_s_Y0_Z	PTO Dynamic	PTO dynanic channel - pressure - windowed, filtered	Pa	Either RS 395-263 or Micro Switch 143PC03D	200 Hz
P_MX_s_Y0_Z	FilteredSignalCopyYWECVI3	PTO dynamic channel -diff press - windowed, filtered	Pa	Either RS 395-263 or Micro Switch 143PC03D	200 Hz
P_MX_s_Y0_Z	PTO Kinematic	PTO kinematic channel - volumetric flow rate	m^3/s		200 Hz
P_MX_s_Y0_Z	PTOKinematicTheta1	PTO kinematic channel - internal water position	angle	Resistance probes	200 Hz
P_MX_s_Y0_Z	PTOKinematicTheta2	PTO kinematic channel - internal water position	angle	Resistance probes	200 Hz
P_MX_s_Y0_Z	WEC Motion	Summary statistics			
P_MX_s_Y0_Z	FilteredCopyYX Pitch	Pitch - windowed, filtered	deg	Optitrack 3D motion	100 Hz
P_MX_s_Y0_Z	FilteredCopyYY Yaw	Yaw - windowed, filtered	deg	Optitrack 3D motion	100 Hz
P_MX_s_Y0_Z	FilteredCopyYZ Roll	Roll - windowed, filtered	deg	Optitrack 3D motion	100 Hz
P_MX_s_Y0_Z	FilteredCopyYX1 Sway	Sway - windowed, filtered	cm	Optitrack 3D motion	100 Hz
P_MX_s_Y0_Z	FilteredCopyYY1 Heave	Heave - windowed, filtered	cm	Optitrack 3D motion	100 Hz
P_MX_s_Y0_Z	FilteredCopyYZ1 Surge	Surge - windowed, filtered	cm	Optitrack 3D motion	100 Hz

Table 4: Data channel list for monochromatic processed numerical and motion data

Data File	Channel Name	Description	Unit	Sensor	Sample Rate
P_PX_s_Y0_Z	WP24PSDAvg	WP 2 &4 average spectrum and summary statistics	cm^2/s		
P_PX_s_Y0_Z	FilteredSignalCopyYWave Probe 1	WP 1 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_PX_s_Y0_Z	FilteredSignalCopyYWave Probe 2	WP 2 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_PX_s_Y0_Z	FilteredSignalCopyYWave Probe 3	WP 3 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_PX_s_Y0_Z	FilteredSignalCopyYWave Probe 4	WP 4 water level - windowed, filtered	cm	Senix ToughSonic 30	200 Hz
P_PX_s_Y0_Z	UnderwaterPressure	Summary statistics	Pa		
P_PX_s_Y0_Z	FilteredCopyYUnderwater Pressure Near	Pressure at basin floor - nearest to wavemaker - windowed, filtered	Pa	Impress IMCL-G0360	200 Hz
P_PX_s_Y0_Z	FilteredCopyYUnderwater Pressure At	Pressure at basin floor - at WEC device - windowed, filtered	Pa	Impress IMCL-G0360	200 Hz
P_PX_s_Y0_Z	FilteredCopyYUnderwater Pressure Far	Pressure at basin floor - furthest from wavemaker - windowed, filtered	Pa	Omega PX2300-10DI	200 Hz
P_PX_s_Y0_Z	Mooring	Summary statistics			
P_PX_s_Y0_Z	FilteredCopyYMooring LC 1	Mooring line force - windowed, filtered	N	Cooper LFS-250	200 Hz
P_PX_s_Y0_Z	PTO Power	Time series and summary statistics	W		
P_PX_s_Y0_Z	PTO Dynamic	Time series and summary statistics	Pa		200 Hz
P_PX_s_Y0_Z	PTODynPSDAvg	PTO dynanic channel - average DFT spectrum	Pa^2/s	Either RS 395-263 or Micro Switch 143PC03D	200 Hz
P_PX_s_Y0_Z	PTO Kinematic	Time series and summary statistics	m^3/s		200 Hz
P_PX_s_Y0_Z	PTOKinPSDAvg	PTO kinematic channel - average DFT spectrum	$(m^3/s)^2$ /s		200 Hz
P_PX_s_Y0_Z	WEC Motion	Summary statistics	m		
P_PX_s_Y0_Z	FilteredCopyYX Pitch	Pitch - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	FilteredCopyYY Yaw	Yaw - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	FilteredCopyYZ Roll	Roll - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	FilteredCopyYX1 Sway	Sway - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	FilteredCopyYY1 Heave	Heave - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	FilteredCopyYZ1 Surge	Surge - windowed, filtered, summary statistics (m)	cm	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionPitchPSDAvg	Pitch - average DFT spectrum	dg^2/s	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionYawPSDAvg	Yaw - average DFT spectrum	dg^2/s	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionRollPSDAvg	Roll - average DFT spectrum	dg^2/s	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionSwayPSDAvg	Sway - average DFT spectrum	m^2/s	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionHeavePSDAvg	Heave - average DFT spectrum	m^2/s	Optitrack 3D motion	100 Hz
P_PX_s_Y0_Z	WECMotionSurgePSDAvg	Surge - average DFT spectrum	m^2/s	Optitrack 3D motion	100 Hz

Table 5: Data channel list for polychromatic processed numerical and motion data

Appendix A
Instrumentation and Calibration Information

ToughSonic® 30 Level and Distance Sensor

Windows PC or Button Setup, Liquid Tight, Multiple Outputs

FormerlyTSPC-15S

Button TEACH or PC Configured Non-Contact Ultrasonic Distance Measurement

Senix sensors and SenixVIEW software put the power of ultrasonics in your hands yet retain the simplicity of push-button TEACH setup. You can quickly adjust, optimize, save and clone your applications without calibration!

ToughSonic sensors contain a rugged transducer potted in a stainless steel housing for long life.

Outputs respond to measured distance and non-contact technology means nothing touches your materials.

Many applications exist in all industries. Contact Senix today to discuss your specific needs.

Features

Distance Measurements

- Long range, short dead band
- Unaffected by optical factors like color and transparency
- PC or button "teachable" setup
- Narrow beam with adjustments to optimize performance
- Temperature compensated

Packaging & Performance

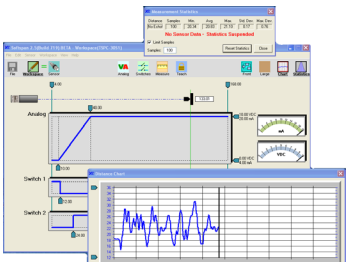
- Quick mounting
- Durable sealed housing for wet or dirty applications
- Short & overload protected I/O
- Multi-sensor synchronization
- Adjustable sensitivity
- Rear status indicators (3)

Free Functionality

Use adjustable interface features like switch hysteresis and time delays to build complete solutions such as pump or material flow controllers. Save cost by eliminating PLCs, delay circuits and time delay relays!

PC Setup Power!

Use SenixVIEW software (see separate data sheet) to select and adjust all interfaces, timing parameters, filters and modes. Then view, analyze or log data to optimize your application.



Several push-button "teach" features also provide common adjustments without the PC.

Stock, repairs, OEMs

Flexible configuration means fewer parts to stock and quick duplication! Higher volume OEM options are available.

Multiple Outputs

In addition to the model's serial data interface there are five simultaneous outputs. All have SenixVIEW configurable features including ranges, target responses and time delays.

Analog Outputs (3)

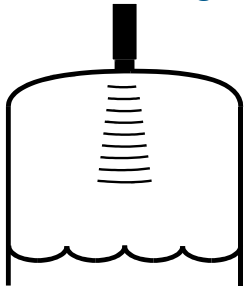
These include voltage (0-10 VDC) and two current loops (4-20 mA sinking and sourcing).

The analog slope can increase or decrease value with distance. The analog output limits can be set any distance, and have user-selected voltage/current values.

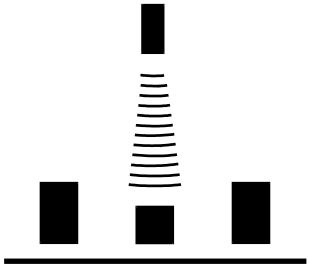
Switches (2)

Two switches are SenixVIEW configurable as either "PNP" or "NPN" type (sourcing or sinking). Each has adjustable set point, hysteresis, window, initial conditions, ON delay, OFF delay and loss of target response for ultimate flexibility.

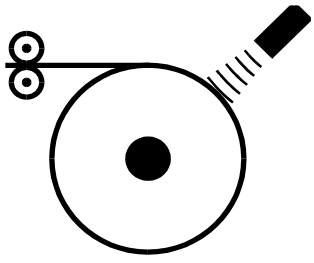
Level or Height



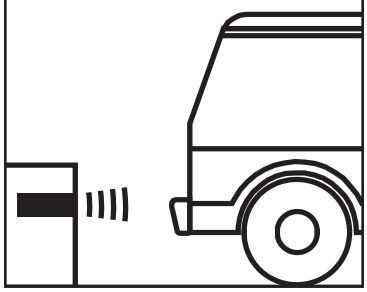
Distance-Proximity



Dimension



Object Detection



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Senix® Distance Measurement

Senix® Corporation, 10516 Route 116 Suite 300, Hinesburg, VT 05461 U.S.A.

Phone: 800-677-3649 or 802-489-7300 FAX: 802-489-7400

Web Site: http://www.senix.com e-mail: sales@senix.com

Senix ToughSonic® 30 Level and Distance Sensor

Specifications

Optimum Range	10 in.- 20 ft. (25.4 cm- 6.1m)	**Max Range**	30 feet (9.1 meters)
Case Material	316 stainless steel	**Adjustment**	Button "teach" or SenixVIEW
Temperature	-40 to 158 F (-40 to 70 C)	**Configuration**	Stored in non-volatile memory
Humidity	0 to 100% operating	**Transducer**	Ruggedized piezoelectric
Compensation	Temperature compensated	**Protection**	NEMA-4X, NEMA-6P, IP68
Resolution	Digital: 0.0068 in. (0.172 mm); Analog:4099 steps (0-10 VDC), 3279 steps (4-20 mA)		
Repeatability	Nominal 0.3% of range @ constant temp. Affected by target, distance, environment		
Update Rate	10 Hz (100 ms), SenixVIEW adjustable; affected by SenixVIEW filter selections		
Voltage Output	0-10, 0-5 VDC or PC customized; 10 mA max. (*)		
Current Loop #1	Current sourcing 4-20 mA or PC customized, max. loop 450Ω (*)		
Current Loop #2	Current sinking 4-20 mA or PC customized, max. loop 450Ω (*)		
Sinking Switch	150 mA max. @ 40 VDC max., teachable set point & polarity, fault indication		
Sourcing Switch	150 mA max. @ input voltage, teachable set point & polarity, fault indication		
RS-232, RS-485	Modbus protocol, 9600-115200 baud (selectable), 8 data bits, 1 stop, no parity		
SYNC feature	Permits up to 32 sensors to operate in close proximity without interaction		

Target Requirements

Objects	Detects flat or curved objects. Surface must reflect ultrasound back to sensor.
Max. Distance	Affected by size, shape, orientation of target (sound level reflected back to sensor)
Orientation	Flat surfaces should be oriented perpendicular to sensor output beam
Optical	Unaffected by target color, transparency, light, or other optical characteristics

Connections

Cable Connection	Wire	Description
Power	Brown	10-30 VDC @ 70 mA maximum; Typical: 45 mA @ 24 VDC (**)
Ground	Blue	Power and interface common
Voltage Output *	Violet	0-10 VDC, 0-5 VDC or custom end values between 0 and 10 VDC
Current Loop Output *	Green	4-20 mA sourcing (adjustabled end values between 4 and 20 mA)
Current Loop Output *	Orange	4-20 mA sinking (adjustabled end values between 4 and 20 mA)
Switch #1 Output	Black	Sinking ("NPN") or Sourcing ("PNP"), user selected
Switch #2 Output	White	Sinking ("NPN") or Sourcing ("PNP"), user selected
RS-232 out / RS-485-	Gray	Serial data connection (depends on model - see model selection)
RS-232 in / RS-485+	Yellow	Serial data connection (depends on model - see model selection)

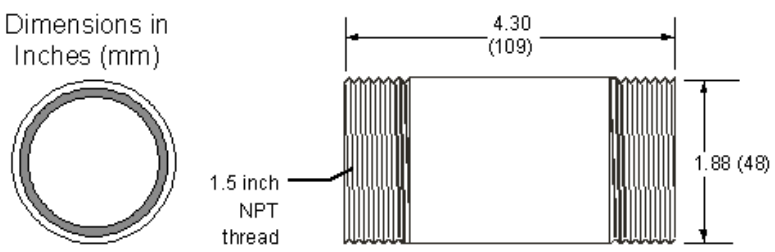
(*) Analog outputs share common distance endpoints. Both 4-20 mA outputs share the same adjustable max / min end values. The maximum loop resistance is derated below 15 VDC input voltage.
(**) At default update rate. Output currents not included. Sensitivity reduced below 15 VDC input voltage.

Part Numbers

Model Number	Description
TSPC-15S-232	Serial RS-232 interface (PC COM port compatible)
TSPC-15S-485	Serial RS-485 interface (allows addressable multi-sensor networks)

Senix also offers interconnection, communications, mounting, and display components

Dimensions



Mechanical

Mounting: 1.5 inch NPT thread, top or bottom

Attached Cable: 6.5ft (2 m)

Total Weight: 22.6 oz. (0.64 kg)

May 2015 Rev K2

WET/WET DIFFERENTIAL PRESSURE TRANSDUCER

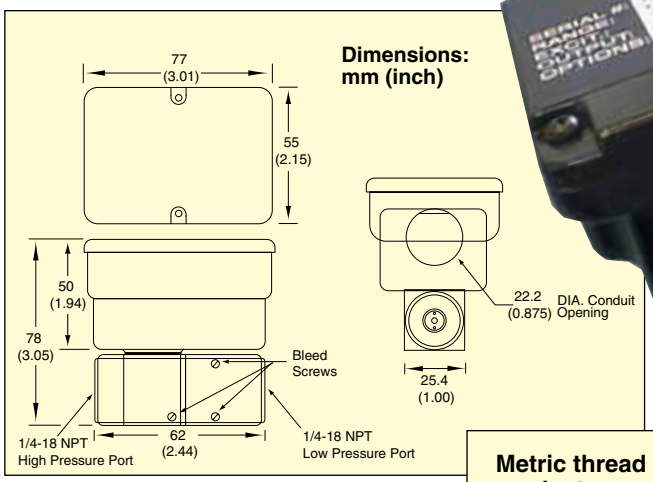
UNI-DIRECTIONAL AND BI-DIRECTIONAL RANGES

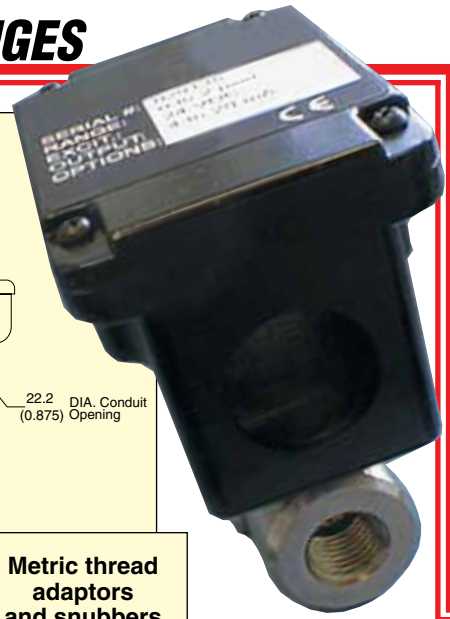
0-1 to 0-100 psid Uni-Directional
±0.5 to ±50 psid Bi-Directional

PX2300 Series

1 YEAR WARRANTY

- **0.25% Accuracy**
- **NEMA 4 (IP65) Rating**
- **Wet/Wet Corrosive Environments**
- **Ideal for Measuring Pressure Drop Across Filters**





Metric thread adaptors and snubbers available, visit us online.

PX2300-1DI, shown smaller than actual size.

OMEGA's PX2300 Series high-output, low differential pressure transducers are compatible with most media, from dry air to corrosive liquids. All wetted parts are stainless steel with elastomer seals. The electronics are housed in a NEMA 4 (IP65) enclosure. A high working pressure and high overpressure ratings ensure dependability in harsh industrial environments. These transducers are ideal for measuring pressure drop across filters and other process devices.

SPECIFICATIONS

Excitation: 24 Vdc nominal
Max: 30 + 0.004 x (loop resistance Ω) Vdc
Min: 11 + 0.02 x (loop resistance Ω) Vdc
Loop Resistance: 0 to 1000 Ω
Output: 4 to 20 mA
Accuracy: ±0.25% RSS FS at constant temperature (includes linearity, repeatability and hysteresis)
Linearity: ±0.20% FS
Hysteresis: 0.10% FS
Repeatability: ±0.05% FS
Operating Temperature Range: -18 to 80°C (0 to 176°F)
Compensated Temperature Range: -1 to 65°C (30 to 149°F)
Thermal Zero Effect: <±0.02% FS/°F
Thermal Span Effect: <±0.02% FS/°F
Sensor: Capacitive
Maximum Line Pressure: 250 psig
Maximum Overpressure:
High Side: 1 to 5 psi = 20 x FS, 10 to 25 psi = 10 x FS, 50 psi = 5 x FS, 100 psi = 2.5 x FS
Low Side: 2.5 x FS (shift recoverable)

The zero will shift slightly when high differential pressure is applied. The shift may be as much as ±10% FS with overpressure applied to the low port. (Other parameters will not shift.) The shift may be recovered by a positive overpressure or if the overpressure is always in one direction, the user may apply this pressure to pre-set the sensor. Subsequent overloads of less pressure will not cause any further shift.

Wetted Parts: Air and fluids compatible with 17-4 and 300 stainless steel, FKM, and silicone O-rings
Cavity Volume: 0.27/0.08" pos./neg. port
Case: NEMA 4 (IP65)
Pressure Port: ¼ NPT internal
Electrical Connection: Internal barrier strip with 22.2 mm (0.875") conduit opening
Response Time: 50 ms (water)
Weight: 410 g (14.4 oz)

To Order

RANGE (psid)	MODEL NO.	COMPATIBLE METERS
0 to 1	**PX2300-1DI**	DP41-E, DP25B-E, DP-7700
0 to 2	**PX2300-2DI**	DP41-E, DP25B-E, DP-7700
0 to 5	**PX2300-5DI**	DP41-E, DP25B-E, DP-7700
0 to 10	**PX2300-10DI**	DP41-E, DP25B-E, DP-7700
0 to 25	**PX2300-25DI**	DP41-E, DP25B-E, DP-7700
0 to 50	**PX2300-50DI**	DP41-E, DP25B-E, DP-7700
0 to 100	**PX2300-100DI**	DP41-E, DP25B-E, DP-7700
BI-DIRECTIONAL RANGE		
±0.5	**PX2300-0.5BDI**	DP41-E, DP25B-E, DP-7700
±1	**PX2300-1BDI**	DP41-E, DP25B-E, DP-7700
±2.5	**PX2300-2.5BDI**	DP41-E, DP25B-E, DP-7700
±5	**PX2300-5BDI**	DP41-E, DP25B-E, DP-7700
±10	**PX2300-10BDI**	DP41-E, DP25B-E, DP-7700
±25	**PX2300-25BDI**	DP41-E, DP25B-E, DP-7700
±50	**PX2300-50BDI**	DP41-E, DP25B-E, DP-7700

Comes complete with operator's manual.
Ordering Examples: PX2300-5BDI, *bi-directional range -5 to 5 psid transducer with current output.*
PX2300-1DI, *0 to 1 psid range transducer with current output.*

IMPRESS
SENSORS & SYSTEMS

Unit 6 Mercury House, Calleva Park
Aldermaston, Berkshire, RG7 8PN
Tel: +44 (0)118 981 7980
Fax:+44 (0)118 981 7990
e-mail: sales@impress-sensors.co.uk
Website: www.impress-sensors.co.uk

Pressure - Temperature - Level - Distance - Control - Indication - Data logging

Calibration Certificate

Customer Order Number Brent Cragi		Impress Sales Order IMPS-19808 Line 1	
Type IMCL-G0360-5B2-BAV-012-000		Operator Joseph Witherall	Date 23/11/15
Supply 9 - 32V dc	Range 0 - 3.6mW G	Output 4 - 20mA / 2-wire	Test Voltage 12Vdc

0 - 35300 Pa

Serial Number	Zero	FSO	Span	Non-Linearity
360870	4.030	20.000	15.970	-0.016
360871	4.010	20.040	16.030	0.016

360870

0 - 3.6 mWG => $\frac{3.6}{0.015970} = 225.4226675$

0 - 35,300 Pa => $\frac{35\,300}{0.015970} = 2,210,394.489668$

360871

0 - 3.6 mWG => $\frac{3.6}{0.016030} = 224.5789145$

0 - 35,300 Pa => $\frac{35\,300}{0.016030} = 2,202,121.023081$

Note: Non-Linearity = % of Span BFSL

Wiring Designation

		PUR Sheath	PVC Sheath	FEP Sheath
2-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	Housing	White	Pink	Pink
	Cable Screen	Green	Green	Green
3-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	+ve Output	Yellow	Yellow	Yellow
	Housing	White	Pink	Pink
	Cable Screen	Green	Green	Green
4-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	+ve Output	White	Pink	Pink
	-ve Output	Yellow	Yellow	Yellow
	Cable Screen	Green	Green	Green

HIGH ACCURACY TRANSDUCERS
MICRO-MACHINED SILICON FOR BAROMETRIC PRESSURE MEASUREMENT

Barometric Pressure Absolute Pressure
Outputs: mV/V, 0 to 5V, 0 to 10V or 4 to 20 mA
0 to 32, 16 to 32 or 26 to 32 inHg
0 to 1100, 550 to 1100, 880 to 1100 hPa

PX409 Series

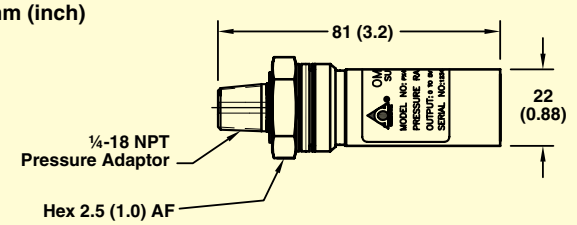
NIST CE RoHS
Standard

- **High Accuracy ±0.08% BSL Includes Linearity, Hysteresis, and Repeatability**
- **Broad Temperature Compensated Range -18 to 85°C (0 to 185°F)**
- **Premium Temperature Performance Span: ±0.5% Over Compensated Range**
- **5-Point NIST Traceable Calibration Included**
- **All Stainless Steel Wetted Parts**
- **Fast Response Time**
- **Solid State Reliability and Stability**
- **400% Proof Pressure**

All shown actual size.

OMEGA's PX409 series electronic barometers are high-accuracy barometers available in three ranges: 16 to 32 inHg, 26 to 32 inHg, or 0 to 32 inHg (absolute pressure) for laboratory or industrial test applications. Models with integral cables (PX409) are IP67 while connector styles (PX419 and PX429) are IP65 rated. They feature all stainless steel construction, which makes them ideal for harsh industrial environments. Their high operating temperature, broad compensated range, and excellent temperature compensation allow stable readings in applications with fluctuating temperatures commonly found where barometric pressure must be monitored. Models are available with millivolt, voltage or current outputs.

Dimensions: mm (inch)



SPECIFICATIONS

Output:
Millivolt: 10 mV/V (100 mV @ 10 Vdc)
Amplified Voltage: 0 to 5 Vdc or 0 to 10 Vdc
Current Loop: 4 to 20 mA

Power Requirements:
Millivolt: 5 to 10 Vdc (5 mA @ 10 Vdc)

Amplified Voltage:
0 to 5 Vdc Supply Voltage: 10 to 30 Vdc @ 10 mA
0 to 10 Vdc Supply Voltage: 15 to 30 Vdc @ 10 mA
Current Loop: 9 to 30 Vdc [max loop res = (Vs-9) x 50]; [9 to 20 Vdc above 105°C (229°F)]

Accuracy (Combined Linearity, Hysteresis and Repeatability): ±0.08% BSL

Zero Balance: ±0.5% FS typical, 1% max

Span Setting: ±0.5% FS typical, 1% max; calibrated in vertical direction with fitting down

HIGH ACCURACY, MICRO-MACHINED SILICON TRANSDUCERS

All models shown smaller than actual size.

IP67 rated
PX409-32BV

IP65 rated
PX419-16B5V

IP65 rated
PX429-26BI

PX409 and PX409C CABLE CONNECTION			
COLOR	mV	5/10V	mA
Black	– EXC	Common	– Supply
White	+ SIG	+ Output	NC
Green	– SIG	NC	NC
Red	+ EXC	+ EXC	+ Supply

PX419 and PX459 PIN OUT			
PIN	mV	5/10V	mA
1	+ EXC	+ EXC	+ Supply
2	– EXC	Common	– Supply
3	+ SIG	+ Output	NC
4	– SIG	NC	NC

PX429 TWIST LOCK PINOUT			
PIN	mV	5/10V	mA
A	+ EXC	+ EXC	+ Supply
B	– EXC	Common	– Supply
C	+ SIG	+ Output	NC
D	– SIG	NC	NC
E	NC	NC	NC
F	NC	NC	NC

Operating Temperature Range: -45 to 121°C (-49 to 250°F) [-45 to 115°C (-49 to 240°F) for voltage or current outputs]

Compensated Temperature:
Ranges > 5 psi: -29 to 85°C (-20 to 185°F)
Ranges ≤ 5 psi: -18 to 85°C (0 to 185°F)

Thermal Effects Span (Over Compensated Range):
Ranges > 5 psi: ±0.5% span
Ranges ≤ 5 psi: ±1% span

Long Term Stability (1-Year): ±0.1% FS typical

Shock: 50 g, 11 mS half sine, vertical and horizontal axis

Vibration: 5-2000-5 Hz, 30 minute cycle, Curve L, Mil-Spec 810 figure 514-2-2, vertical and horizontal axis

Response Time: <1 ms

Bandwidth: DC to 1 kHz typical

Proof Pressure: 400% of span

Burst Pressure: 1000 psia

Electrical Termination:
PX409: Integral 2 m (6') cable
PX419: mini DIN
PX429: Twist-lock

Mating Connectors:
PX419: CX5302 (included)
PX429: PT06F10-6S (sold separately)

Environmental Protection:
PX409: IP67
PX419: IP65
PX429: IP65
PX459: IP65

Wetted Parts: 316 SS

Pressure Port: ¼-18 NPT male

Weight: 115 to 200 g (4 to 7 oz) depending upon configuration

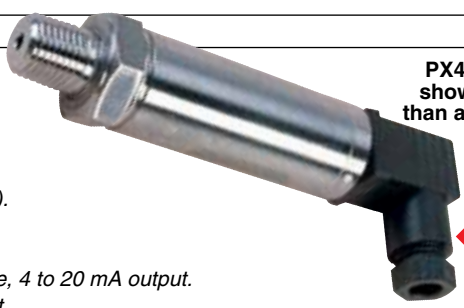
To Order

CALIBRATED RANGE		mV/V OUTPUT	5 Vdc** OUTPUT	4 to 20 mA OUTPUT
inHg	hPa			
BAROMETRIC RANGES (Absolute Pressure)				
0 to 32 inHg	—	PX4[*]9-32BV	PX4[*]9-32B5V	PX4[*]9-32BI
16 to 32 inHg	—	PX4[*]9-16BV	PX4[*]9-16B5V	PX4[*]9-16BI
26 to 32 inHg	—	PX4[*]9-26BV	PX4[*]9-26B5V	PX4[*]9-26BI
—	0 to 1100 hPa	PX4[*]9-32HBV	PX4[*]9-32HB5V	PX4[*]9-32HBI
—	550 to 1100 hPa	PX4[*]9-16HBV	PX4[*]9-16HB5V	PX4[*]9-16HBI
—	880 to 1100 hPa	PX4[*]9-26HBV	PX4[*]9-26HB5V	PX4[*]9-26HBI

ACCESSORIES

MODEL NO.	DESCRIPTION
PT06F10-6S	Mating connector for PX429 series, sold separately
CX5302	Spare mating connector for PX419 series; one included with each unit
M12C-PVC-4-S-F-5	PVC cable, straight 4-pin M12 female connector one end, flying leads one end, 5 m (16.4') long, fits PX459
M12C-PVC-4-R-F-5	PVC cable, right angled 4-pin M12 female connector one end, flying leads one end, 5 m (16.4') long, fits PX459
-MB	Mounting bracket, factory installed

*** For 0 to 10 Vdc output replace "5V" with "10V" in model number.*
[*] Select Electrical Termination (no extra charge).
Insert "0" for 2 m (6') cable with flying leads.
*For ½ NPT conduit connector order **PX409CS.***
Insert "1" for Mini DIN connector (mating connector included).
*Insert "2" for Twist-lock connector (mating connector **PT06F10-6S** sold separately).*
Insert "5" for M12 connector, M12 cables sold separately.
Custom configurations also available.
***Ordering Examples: PX409-32BI,** cable termination, 0 to 32 inHg barometric range, 4 to 20 mA output.*
***PX459-32HB5V,** M12 connector, 0 to 1100 hPa barometric range, 0 to 5 Vdc output.*
***PX419-16HBV** mini DIN termination, 550 to 1100 hPa barometric range, mV/V output.*



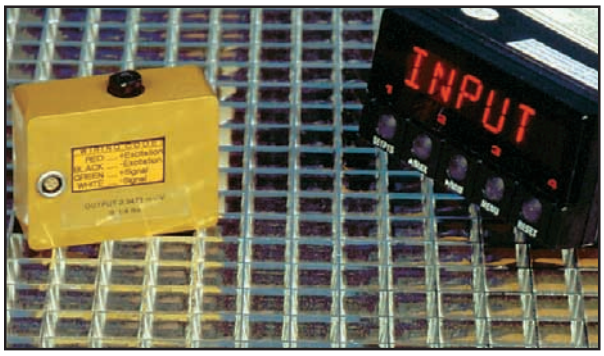
PX419-26B5V, shown smaller than actual size.

mini DIN style

LFS 242 - TENSION/COMPRESSION CELL

The LFS 242 is a low range load cell, which provides high accuracy for weighing or force measurement applications. This cell is made of aluminum, but is durable enough for most applications. The LFS 242 has 10-32 UNC threads on both ends of the transducer for easy installation.

- **ALUMINUM CONSTRUCTION**
- **COMPACT SIZE**
- **HIGH ACCURACY**



SPECIFICATIONS

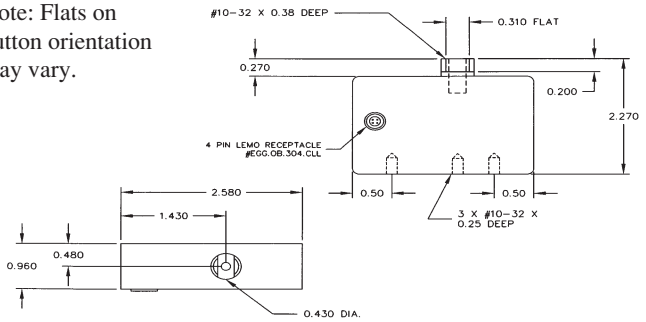
LOAD RANGES:	.25 lb to 100 lb
LINEARITY	±0.05%
HYSTERESIS:	±0.05%
REPEATABILITY:	±0.05%
MATERIAL:	Aluminum
TEMPERATURE RANGE:	60° to 160° F
OUTPUT:	2 mv/v
BRIDGE RESISTANCE:	1000 ohm
EXCITATION:	18Vdc Max
SAFE OVERLOAD:	150% of capacity
CABLE:	Connector & cable assembly optional - 10 Ft standard

AVAILABLE RANGES

.25, .5, 1, 2.2, 5, 10, 25, 50, 100 lbs.

10 gram range unit available, consult Cooper for specifications.

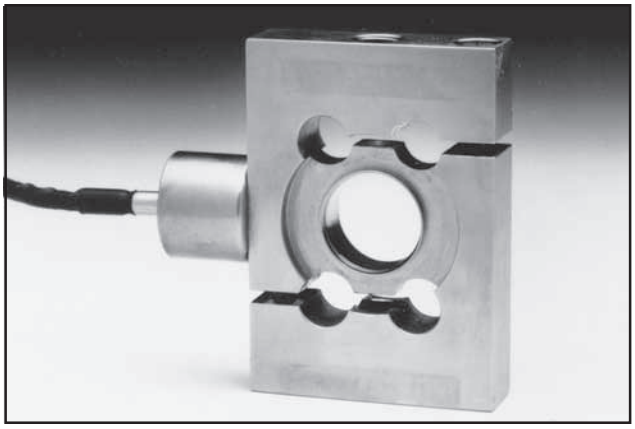
Note: Flats on button orientation may vary.



LFS 250 - HERMETICALLY SEALED S-BEAM

The LFS 250 is a dual cantilevered, hermetically sealed, stainless steel beam load cell. This cell is designed for both tension and compression and harsh environments, where other cells will not work. It is capable of withstanding significant sideload without physical damage. The LFS 250 uses proven sealing techniques that provide superior waterproofing and combines welded metal seals and a water block cable entry system which will resist leakage.

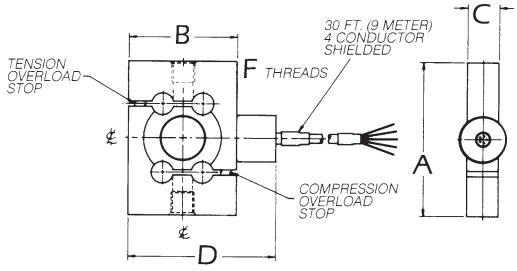
- **100 TO 10,000 LBS**
- **WELDED STAINLESS STEEL**
- **EXCEEDS NEMA 6 FOR WASHDOWN**



SPECIFICATIONS

LOAD RANGES:	100 to 10,000 lbs
ACCURACY:	0.03% F.S.
REPEATABILITY:	0.01% F.S.
MATERIAL:	Stainless Steel
TEMPERATURE RANGE:	0° to 150° F
OUTPUT:	3 ±.003 mv/v
BRIDGE RESISTANCE:	350 ohm
EXCITATION:	15Vdc Max
SAFE OVERLOAD:	150% F.S.
CABLE:	30 Ft

AVAILABLE RANGES	A"	B"	C"	D"	F"
100, 250 lb	3.32	2.48	0.94	3.36	3/8-24 UNF
500 lb	3.50	2.44	0.71	3.32	1/2-20 UNF
1000 lb	3.50	2.94	0.71	3.81	1/2-20 UNF
2500 lb	3.75	2.44	0.95	3.31	1/2-20 UNF
5,000, 10,000 lb	4.75	2.44	1.44	3.31	1-14 UNS



LOW PROFILE LOAD CELLS
WATERPROOF FOR WET OR WASHDOWN APPLICATIONS

5 to 500,000 lb Capacities
2.3 kgf to 225T Capacities

LSHD Series Compression

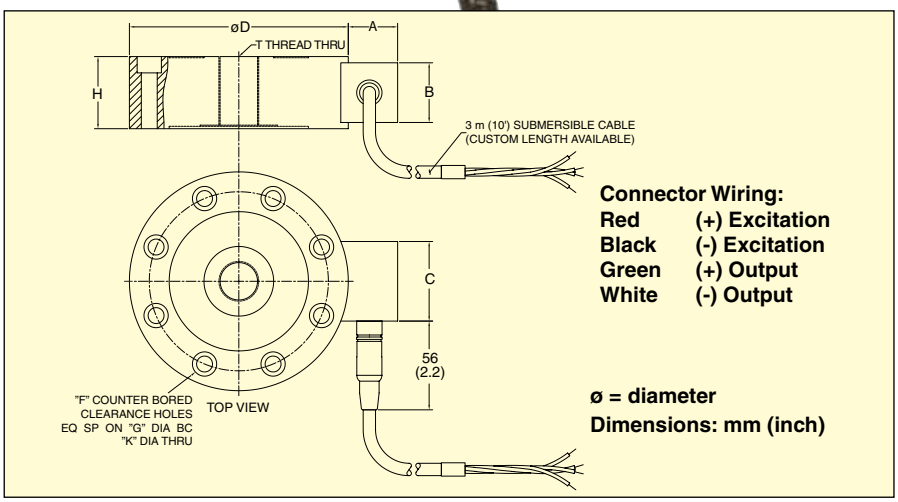
NIST Standard

LSHD

Waterproof high pressure molded cable connection.

- **High Accuracy**
- **5-Point NIST Traceable Calibration Included**
- **Hermetically Sealed for Wet and Submerged Applications**
- **All Stainless Steel Construction for Harsh Industrial Environments**
- **1% Interchangeability for Scale Applications**
- **High Capability to Resist Side Loads**
- **Low Profile for Easy Installations**
- **3 m (10') Waterproof Cable Standard**

The LSHD Series load cells are hermetically sealed and have a high pressure, high temperature molded cable seal to assure long life in wet or submerged applications such as truck or rail scales. They are supplied with a standard length of 3 m (10') of cable, however longer lengths are available. Many standard lengths are stocked plus custom lengths are also available.



SPECIFICATIONS

Excitation: 10 Volts, 15 Vdc maximum
Output Ranges ≤ 25 lb: 2 mV/V ± 1%
Ranges > 25 lb: 3 mV/V ± 1%
Calibration: 5 points in tension
0%, 50%, 100%, 50%, 0% capacity
Linearity ≤ 25 lb: ± 0.2% FSO
Ranges > 25 lb: ± 0.1% FSO
Hysterisis ≤ 25 lb: ± 0.1% FSO
Ranges > 25 lb: ± 0.08% FSO
Repeatability ≤ 25 lb: ± 0.1% FSO
Ranges > 25 lb: ± 0.03% FSO
Zero Balance: ±1% FSO
FS Deflection: 0.025 to 0.075 mm (0.001 to 0.003")
Operating Temperature: -18 to 82°C (0 to 180°F)
Compensated Temperature: 15 to 71°C (60 to 160°F)
Thermal Effects:
Span: ± 0.0036% rdg/°C
Zero: ± 0.0036% FSO/°C
Safe Overload: 150% Capacity
Ultimate Overload: 300% Capacity

CAPACITY (LBS)	Dimensions: mm (inch)								
	D	H	K	G	F	T-THREADS	B	C	A
5 to 25	64 (2.50)	20 (0.80)	4.6 (0.18)	51 (2.00)	6	¼ – 28UNF–2B	19 (0.75)	32 (1.25)	23 (0.92)
50 to 1000	76 (3.00)	25 (1.00)	7 (0.28)	57 (2.25)	6	⅜ – 24UNF–2B	19 (0.75)	32 (1.25)	23 (0.92)
2000 to 5000	89 (3.50)	25 (1.00)	9 (0.34)	67 (2.63)	6	½ – 20UNF–2B	19 (0.75)	32 (1.25)	23 (0.92)
7500 to 15,000	140 (5.50)	46 (1.80)	10 (0.40)	114 (4.50)	8	1 – 14UNS–2B	38 (1.50)	51 (2.00)	32 (1.24)
20,000 to 50,000	152 (6.00)	46 (1.80)	13 (0.53)	124 (4.88)	8	1½ – 12UNF–2B	38 (1.50)	51 (2.00)	32 (1.24)
75,000 to 100,000	229 (9.00)	64 (2.50)	17 (0.66)	197 (7.75)	12	2 – 12UN–2B	38 (1.50)	51 (2.00)	32 (1.24)
150,000 to 200,000	279 (11.00)	76 (3.00)	20 (0.78)	241 (9.50)	12	2½ – 12UN–2B	38 (1.50)	51 (2.00)	32 (1.24)
300,000 to 500,000	356 (14.00)	108 (4.25)	25 (1.00)	298 (11.75)	12	3½ – 8UN–2B	38 (1.50)	51 (2.00)	32 (1.24)

WATERPROOF LOAD CELLS

Bridge Resistance: 350 Ω nominal
Protection Level: IP68
Electrical Connection: 3 m (10') submersible cable
Other lengths available see table
Construction: 17-4 pH stainless steel
Submersible Depth:
5 to 10K Range: 3 m (10')
20 to 50K Range: 6 m (20')
75 to 500K Range: 15 m (50')

SUBMERSIBLE CABLE

LENGTH	LENGTH cont'd
0.6 m (2')	15.2 m (50')
1.5 m (5')	18.3 m (60')
3.0 m (10')	19.8 m (65')
4.5 m (15')	22.8 m (75')
6.0 m (20')	30.4 m (100')
7.6 m (25')	45.7 m (150')
9.1 m (30')	60.9 m (200')
12.2 m (40')	91.4 m (300')

Custom cable length available.

POPULAR OPTIONS

DESCRIPTION	SUFFIX
± 5 Vdc Output (calibrated 0 to 5 Vdc in tension)	**"-5T" (Ranges 75k)**
Overload Stops	**Consult factory**
Dual Bridge	**Available**

To Order

CAPACITY					
lb	kg	MODEL NO.	COMPATIBLE METERS	LOAD BUTTON	ROD END
5	2.3	**LSHD-5**	DP41-S, DP25B-S, DPi8-S	**LBC-14**	**REC-014M**
10	4.5	**LSHD-10**	DP41-S, DP25B-S, DPi8-S	**LBC-14**	**REC-014M**
25	11	**LSHD-25**	DP41-S, DP25B-S, DPi8-S	**LBC-14**	**REC-014M**
50	23	**LSHD-50**	DP41-S, DP25B-S, DPi8-S	**LBC-38**	**REC-038M**
100	45	**LSHD-100**	DP41-S, DP25B-S, DPi8-S	**LBC-38**	**REC-038M**
250	114	**LSHD-250**	DP41-S, DP25B-S, DPi8-S	**LBC-38**	**REC-038M**
500	227	**LSHD-500**	DP41-S, DP25B-S, DPi8-S	**LBC-38**	**REC-038M**
1000	455	**LSHD-1K**	DP41-S, DP25B-S, DPi8-S	**LBC-38**	**REC-038M**
2000	909	**LSHD-2K**	DP41-S, DP25B-S, DPi8-S	**LBC-012**	**REC-012M**
3000	1.3T	**LSHD-3K**	DP41-S, DP25B-S, DPi8-S	**LBC-012**	**REC-012M**
4000	1.8T	**LSHD-4K**	DP41-S, DP25B-S, DPi8-S	**LBC-012**	**REC-012M**
5000	2.2T	**LSHD-5K**	DP41-S, DP25B-S, DPi8-S	**LCB-012**	**REC-100M**
7500	3.4T	**LSHD-7.5K**	DP41-S, DP25B-S, DPi8-S	**LBC-100**	**REC-100M**
10,000	4.5T	**LSHD-10K**	DP41-S, DP25B-S, DPi8-S	**LBC-100**	**REC-100M**
15,000	6.8T	**LSHD-15K**	DP41-S, DP25B-S, DPi8-S	**LBC-100**	**REC-100M**
20,000	9.1T	**LSHD-20K**	DP41-S, DP63900-S	**LBC-112**	**REC-112M**
30,000	13T	**LSHD-30K**	DP41-S, DP63900-S	**LBC-112**	**REC-112M**
50,000	22T	**LSHD-50K**	DP41-S, DP63900-S	**LBC-112**	**REC-112M**
75,000	34T	**LSHD-75K**	DP41-S, DP63900-S	—	—
100,000	45T	**LSHD-100K**	DP41-S, DP63900-S	—	—
150,000	68T	**LSHD-150K**	DP41-S, DP63900-S	—	—
200,000	90T	**LSHD-200K**	DP41-S, DP63900-S	—	—
300,000	135T	**LSHD-300K**	DP41-S, DP63900-S	—	—
400,000	180T	**LSHD-400K**	DP41-S, DP63900-S	—	—
500,000	225T	**LSHD-500K**	DP41-S, DP63900-S	—	—

Comes complete with 5-point NIST traceable calibration certificate, 59K shunt data, and 3 m (10') cable.
Note: *Ranges over 300,000 lb are calibrated at 300,000 lb.*
Ordering Examples: LSHD-500 *is a 500 lb range waterproof load cell.*
LSHD-20K*, 20,000 lb range waterproof load cell.*

Pressure Sensors

160PC Series

Low Pressure Differential, Gage, Vacuum Gage/Amplified

FEATURES

- Low pressure measurement
- PCB terminals on opposite side from the ports
- Fully signal conditioned

160PC SERIES PERFORMANCE CHARACTERISTICS at 8.0 ±0.01 VDC Excitation, 25°C (Exception 163PC at 10 ±0.01 VDC Excitation, 25°C)

	Min.	Typ.	Max.	Units
Excitation	6.00	8.00	16	VDC
Supply Current	---	8.00	20	mA
Current Sourcing Output	---	---	10	mA
Null Offset (161/162/164PC)*	0.95	1.00	1.05	V
Null Offset (163PC)**	3.45	3.50	3.55	V
Output at Full Pressure (161/162/164PC)	5.90	6.00	6.10	V
Output at Full Vacuum (163PC)	0.80	1.00	1.20	V
Span (161/162/164PC)	4.85	5.00	5.15	V
Span (163PC)**	---	5.00	---	V
Ratiometricity Error				
7 to 8 V or 8 to 9 V	---	±0.50	---	%Span
9 to 12 V	---	±2.00	---	
Stability over One Year	---	±0.50	---	%Span
Response Time	---	---	1.00	msec
Weight	---	28	---	grams
Short Circuit Protection	Output may be shorted indefinitely to ground			
Output Ripple	None, DC device			
Ground Reference	Supply and output are common			

*Positive (or negative) pressure measurement.
**Positive AND negative pressure measurement.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	–40° to +85°C (–40° to +185°F)	
Storage Temperature	–55° to +125°C (–67° to +257°F)	
Compensated Temperature	–18° to +63°C (0° to +145°F)	
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)	
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)	
Media	P2 port	Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass,and silicon-to-glass bond*
	P1 port	Dry gases only

*Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

Low Pressure Differential, Gage, Vacuum Gage/Amplified

160PC SERIES ORDER GUIDE, VACUUM GAGE AND GAGE TYPE

Catalog Listing	Pressure Range ″H_2O	Combined Null & Sensitivity Shift (%Span)			Sensitivity V/″H_2O	Overpressure psi Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C	25 to –18° 25 to +63°C	25 to –40° 25 to 85°C			P2 > P1	P2 < P1	
							%Span		
		Max.	Max.	Max.			Max.	Max.	
161PC01D	0-27.68	---	±1.00	±2.00	0.18	5	---	±1.00	±0.15 Vacuum Gage
162PC01G	0-27.68	---	±1.00	±2.00	0.18	5	---	±1.00	±0.15 Gage

160PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE

Catalog Listing	Pressure Range ″H_2O	Combined Null & Sensitivity Shift (%Span)			Sensitivity V/″H_2O	Overpressure psi Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C	25 to –18° 25 to +63°C	25 to –40° 25 to 85°C			P2 > P1	P2 < P1	
							%Span		
		Max.	Max.	Max.			Max.	Max.	
162PC01D	0-27.68	---	±1.00	±2.00	0.18	5	±2.00	---	±0.15
163PC01D36	±5	±1.00	---	---	0.50	5	±2.00	±1.00	±0.25
164PC01D37	0-10	±1.00	---	---	0.50	5	±2.00	---	±0.25
163PC01D75	±2.5	±1.25	---	---	1.00	5	±2.00	±1.00	±0.25
164PC01D76	0-5	±1.25	---	---	1.00	5	±2.00	---	±0.25

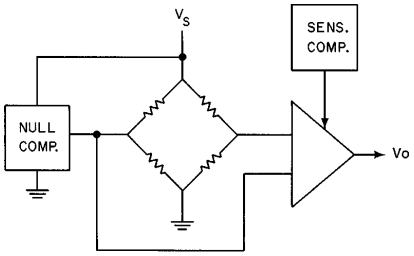
160PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE @ 10 VDC ±0.01 EXCITATION, 25°C

Catalog Listing	Pressure Range cmH_2O	Combined Null & Sensitivity Shift (%Span)			Sensitivity V/cmH_2O	Overpressure cmH_2O Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C	25 to –18° 25 to +63°C	25 to –40° 25 to 85°C			P2 > P1	P2 < P1	
							%Span		
		Max.	Max.	Max.			Max.	Max.	
163PC01D48	–20 to +120	±0.75*	---	---	0.36	350	±1.5	---	±0.15

*Null shift. Span shift is ±1.00/Span

Low Pressure Differential, Gage, Vacuum Gage/Amplified

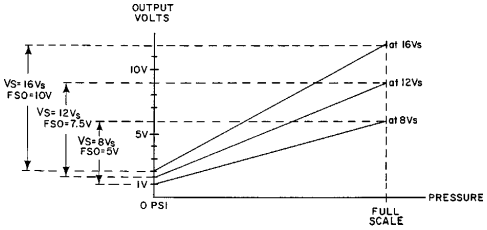
INTERNAL CIRCUITRY



NOTES

1. Terminals are labeled on the sensor.
2. Input and output share a common ground.
3. R_L must be greater than or equal to 3000 ohms.

RATIOMETRICITY



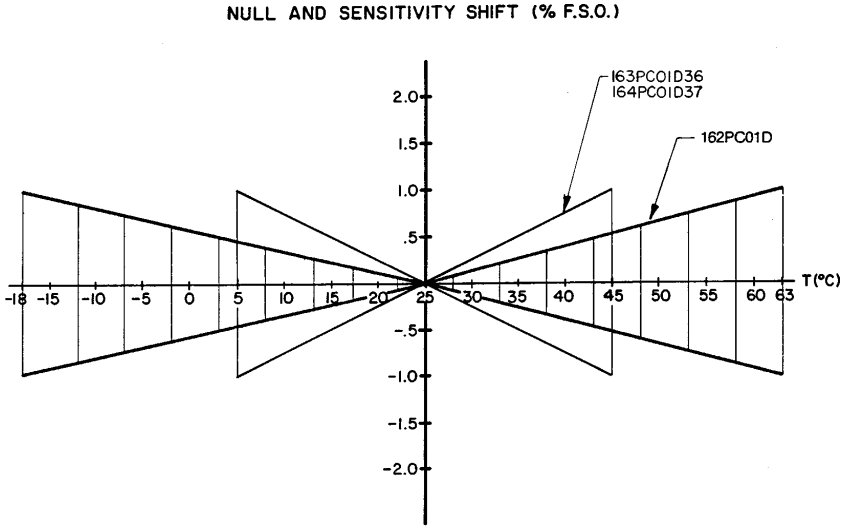
Ratiometricity refers to the output voltage being directly proportional to supply voltage. 160PC sensors in this catalog are calibrated at 8 VDC supply voltage (except 163PC) to provide a 1-6 volt (5 V Span) output swing. For example, if supply increases by 50% to 12 VDC, the output voltage increased by 50% to 1.5-9 volts (7.5 V Span).

NOTE
The output is not perfectly ratiometric. See Accuracy specifications for the degree of error.

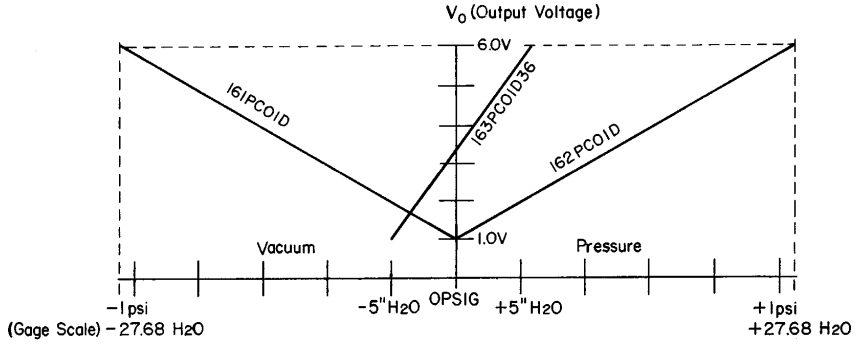
NULL AND SENSITIVITY TEMPERATURE SHIFT

Amplified pressure sensor are 100% tested to insure that the maximum null and sensitivity temperature shift does not exceed the specification. The diagram below illustrates how null and sensitivity shift relates to temperature. Note that the maximum shift occurs at temperature extremes. Therefore, if a sensor is not exposed to the entire temperature range, the maximum null and sensitivity shift will actually be less than the value specified.

This diagram indicates the temperature shift pertaining to a few listings. Maximum null and sensitivity shift varies from listing to listing.



SCALING OF 160PC SERIES SENSORS WITH 8V EXCITATIONS

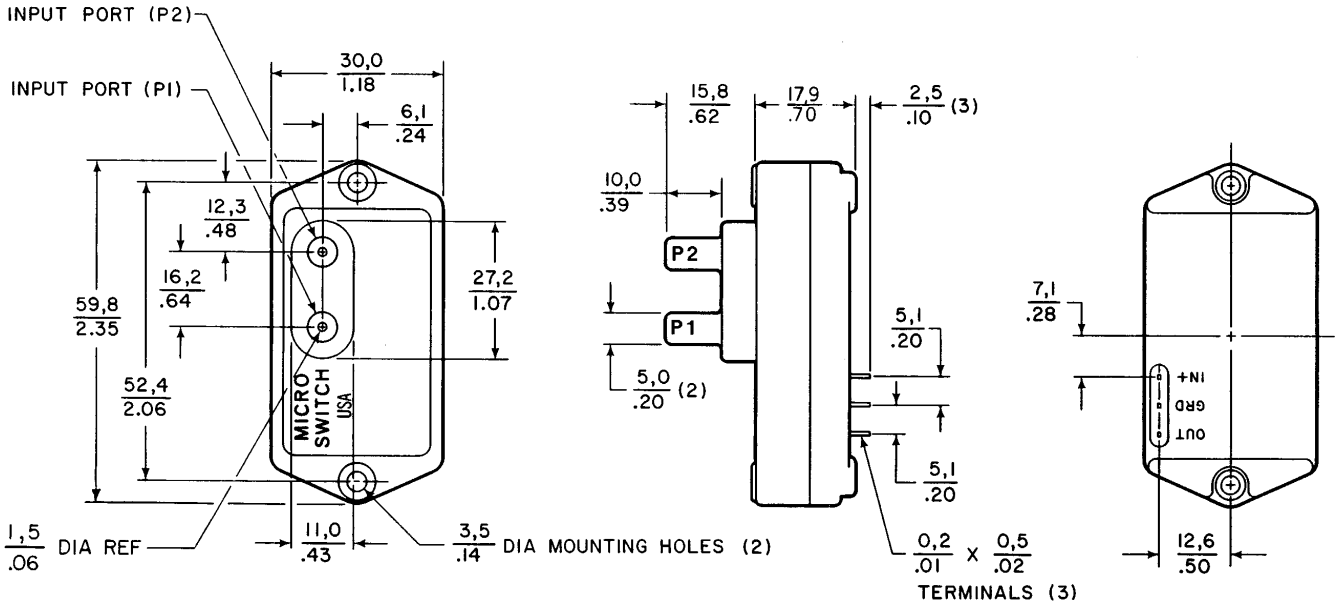


161PC01D	Vacuum Gage	V_O = 1 V at 0 psig & 6 V at –1 psig
162PC01D	Differential	V_O = 1 V at 0 psig & 6 V at 1 psig
163PC01D36	Differential	V_O = 1 V at –5″ H_2O & 6 V at –5″ H_2O

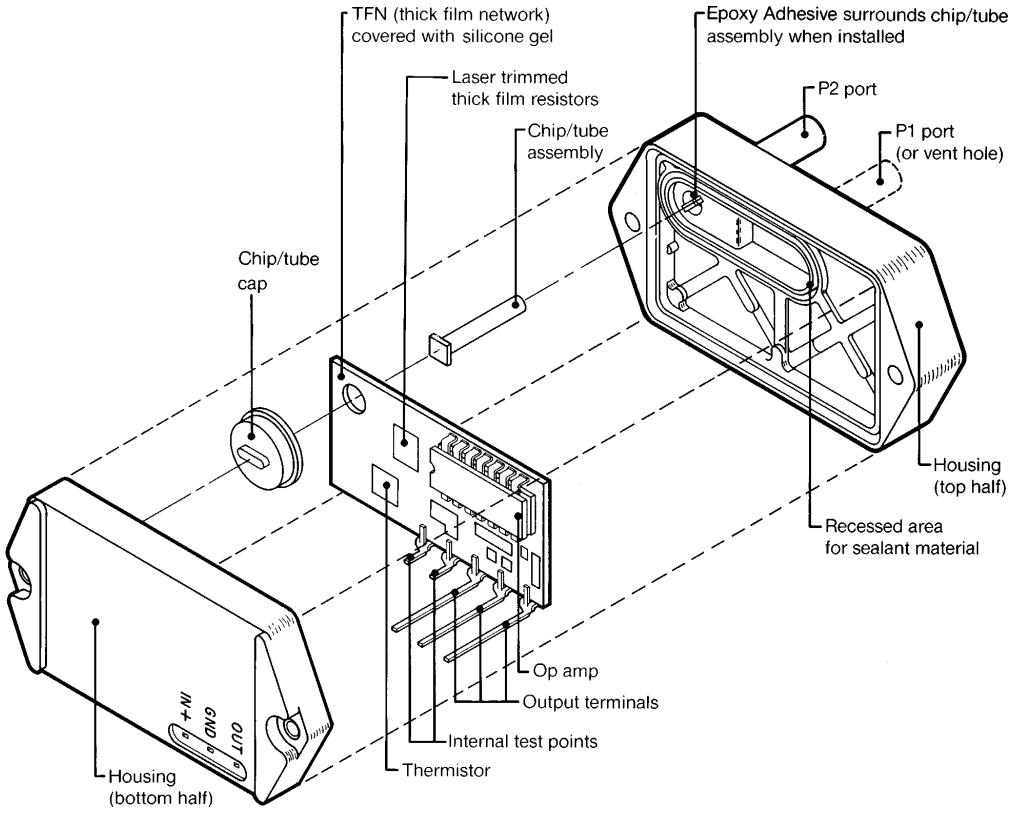
NOTE: 161PC sensors are scaled for greater pressure on the P1 side of the chip. 162PC sensors are scaled for greater pressure on the P2 side of the chip. Other scalings available upon request.

Low Pressure Differential, Gage, Vacuum Gage/Amplified

MOUNTING DIMENSIONS (For reference only)

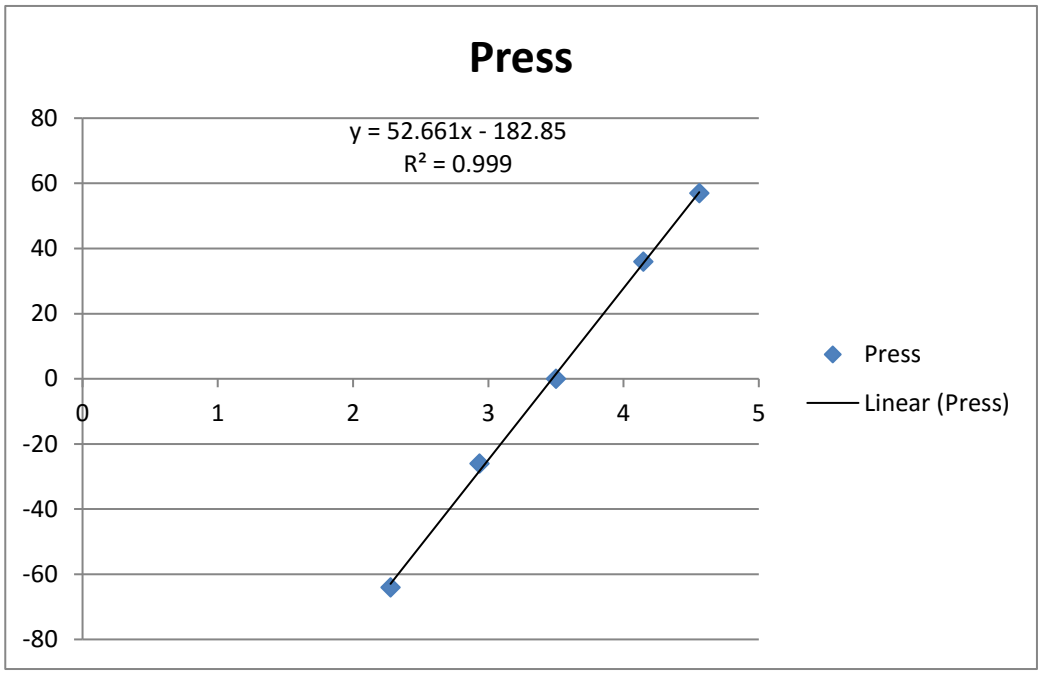


160PC CONSTRUCTION

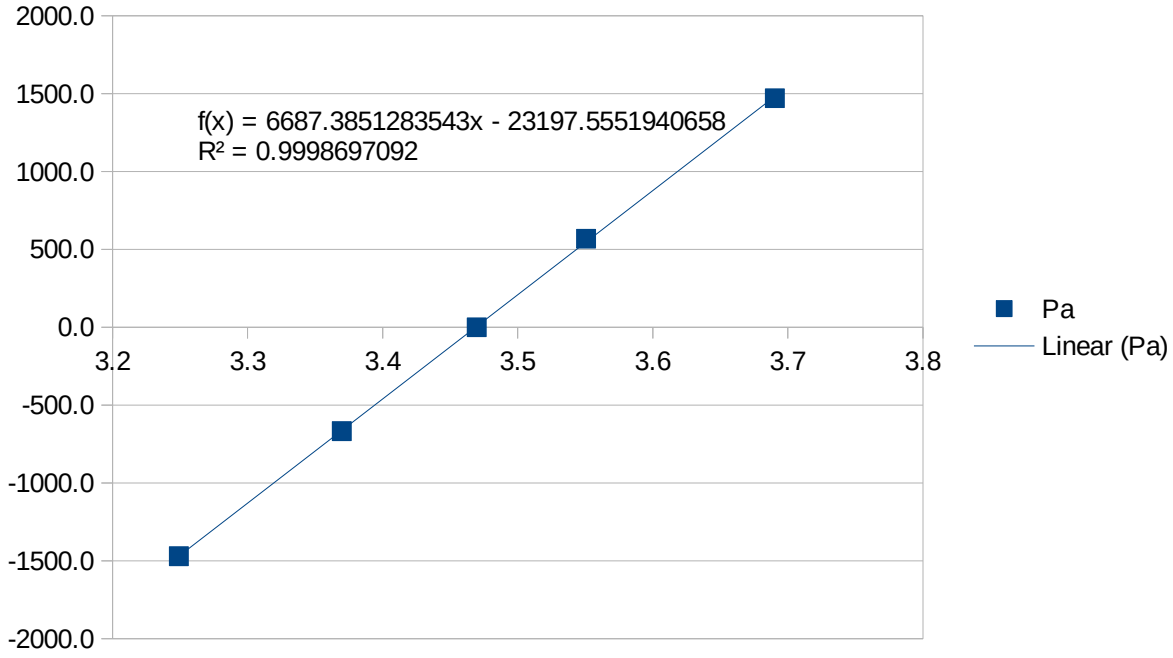


Amplified

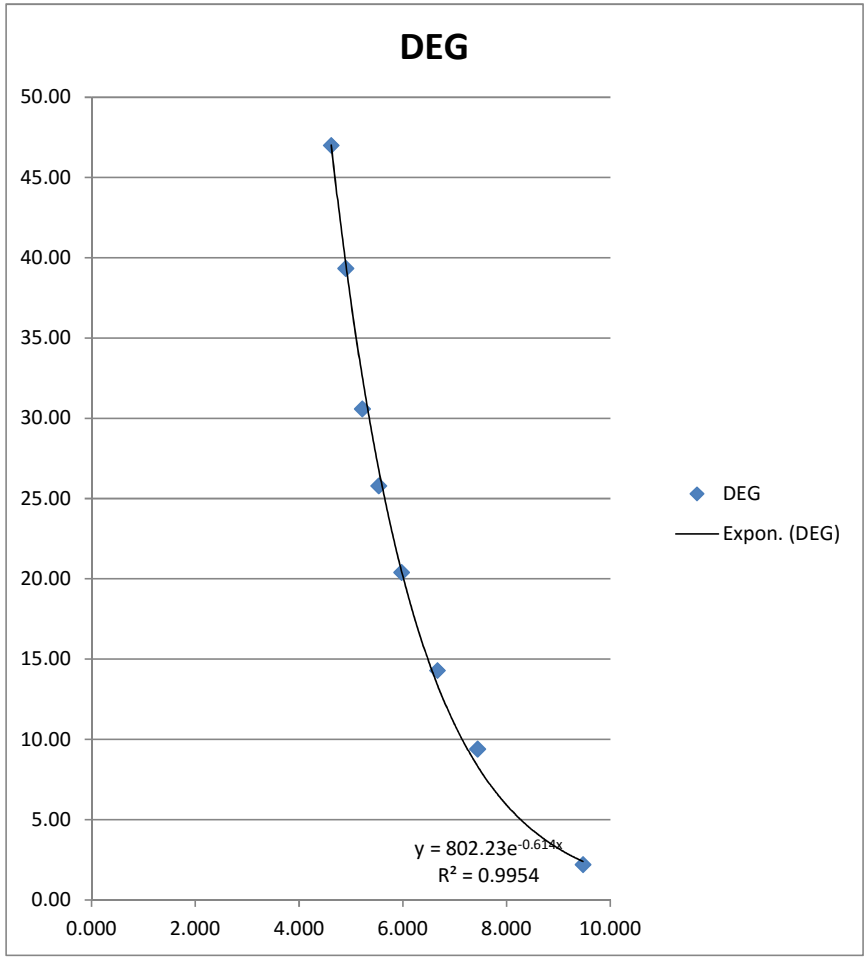
Volts	Press
3.501	0
4.146	36
4.56	57
2.934	-26
2.277	-64

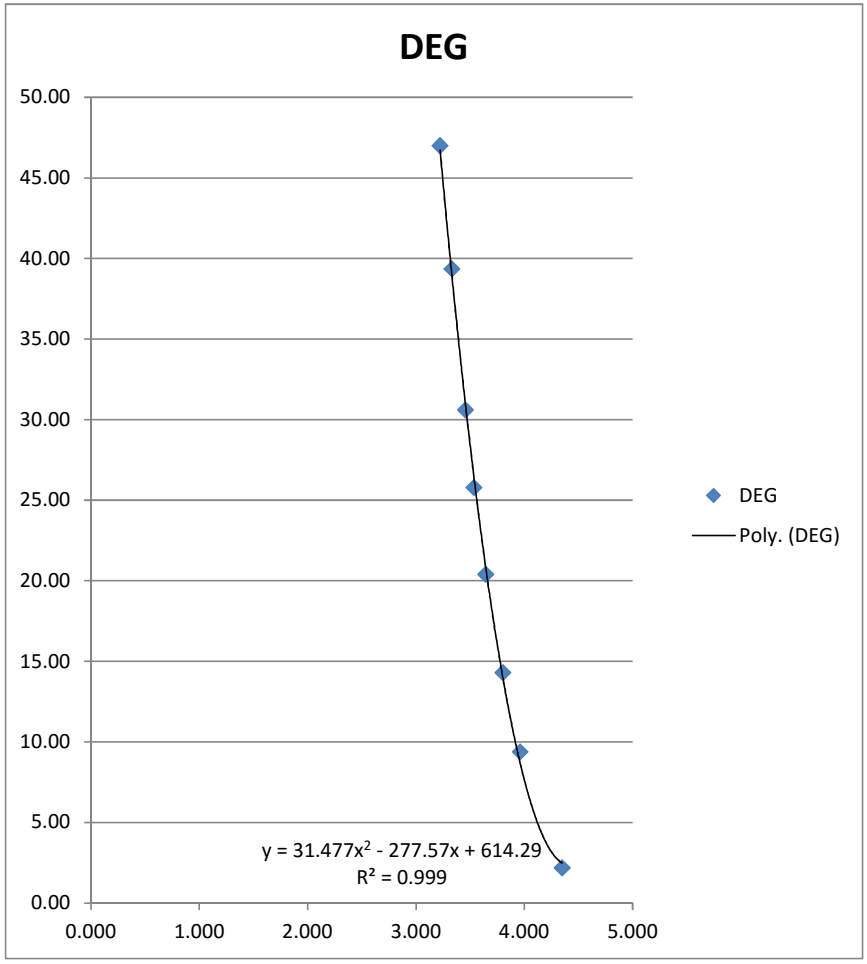


VDC	P mm	Pa
3.4697	0	0.0
3.5506	58	568.8
3.6905	150	1471.0
3.3697	-68	-666.9
3.2491	-150	-1471.0

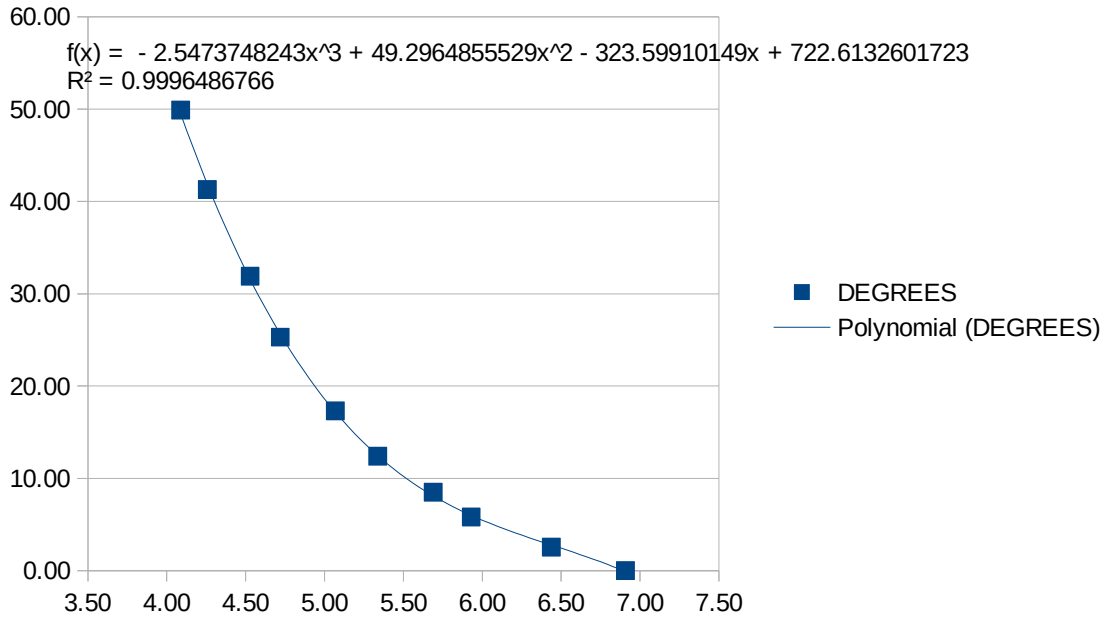


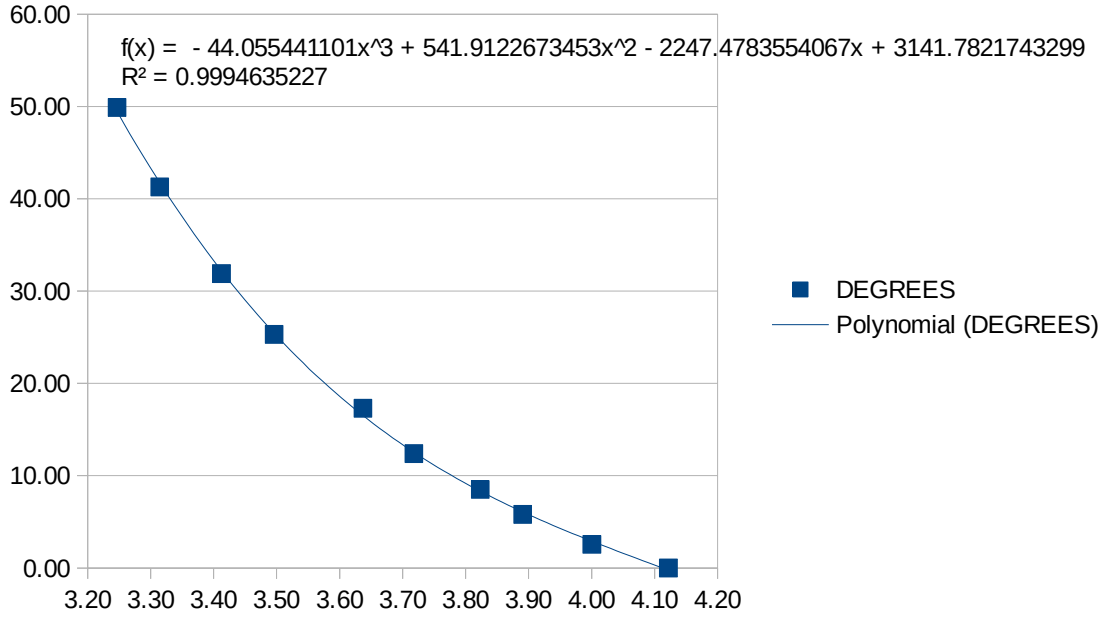
V STBD	V PORT	DEG
9.472	4.350	2.20
7.442	3.962	9.40
6.670	3.803	14.30
5.979	3.643	20.40
5.538	3.535	25.80
5.221	3.457	30.60
4.903	3.330	39.35
4.621	3.222	47.00





2 V PORT		DEGREES
5.93	3.89	5.80
5.69	3.82	8.50
5.34	3.72	12.40
5.07	3.64	17.30
4.72	3.50	25.30
4.53	3.41	31.90
4.26	3.31	41.30
4.09	3.25	49.90
6.44	4.00	2.55
6.91	4.12	0.00





Instruction Leaflet
Bedienungsanleitung
Hojas de instrucciones
Foglio d'instruzioni

Ultra Low Differential Pressure Sensors (GB)

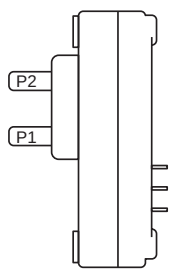
Differenzsensoren mit ultraniedrigem Druck (D)

Sensores de Diferencia de Presión Ultrabaja (E)

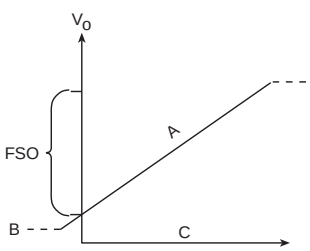
Sensori di bassissima pressione differenziale (I)

Figures / Abbildung / Figures / Figura

①



②



GB Gauge differential
A. *Best linearity
B. Null
C. P (differential, gauge)
*Reversing the pressure relationship will cause the output to saturate below null.

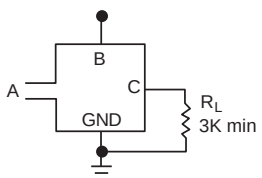
D Überdruckdifferenz
A. *Beste Linearität
B. Null
C. P (Differenzdruck, Überdruck)
*Durch die Umkehrung des Druckverhältnisses wird der Ausgang auf unter Null gesättigt.

E Manométrica diferencial
A. Linealidad
B. Nullóptima*
C. P (Diferencial, manométrica)
*La inversión de la relación de presiones hara que la salida se sature por debajo de cero. Conexiones eléctricas y de presión

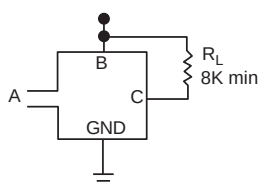
I Differenziale del misuratore
A. *Linearità migliore
B. Null
C. P (differenziale, misuratore)
*Invertendo il rapporto di pressione si causa la saturazione dell'uscita al di sotto di 'Null"

③

1



2



GB Electrical and pressure connections
1. Current source
A. Pressure input
B. Supply
C. Out

2. Current sink
A. Pressure input
B. Supply
C. Out

D Elektrische Anschlüsse und Druckanschlüsse
1. Stromquelle
A. Druckeingang
B. Versorgung
C. Ausgang

2. Stromsenke
A. Druckeingang
B. Versorgung
C. Ausgang

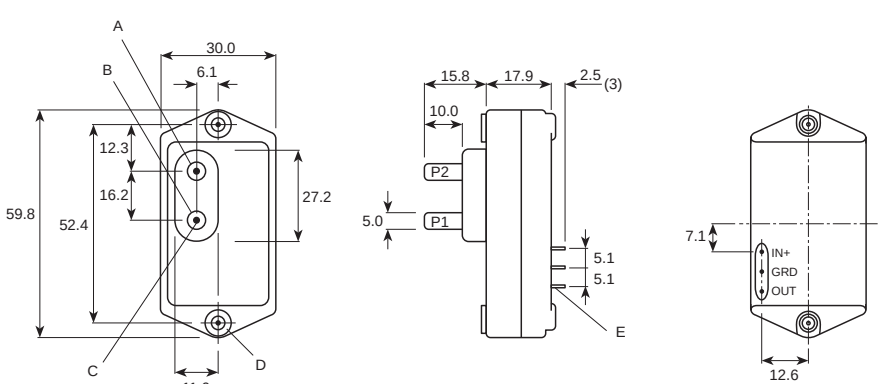
E Conexiones eléctricas y de presión
1. Fuente de corriente
A. Entrada de presión
B. Alimentación
C. Salida

2. Sumidero de corriente
A. Entrada de presión
B. Alimentación
C. Salida

I Collegamenti elettrici e di pressione
1. Sorgente di corrente
A. Ingresso di pressione
B. Alimentazione
C. Uscita

2. Dissipazione di corrente
A. Ingresso di pressione
B. Alimentazione
C. Uscita

④



GB Dimensions in mm
A. Input port (P2)
B. Input port (P1)
C. 1.5 dia. ref
D. 3.5 dia. mounting holes (2)
E. 0.2 x 0.5 terminals (3)

D Abmessungen in mm
A. Eingangsanschluß (P1)
B. Eingangsanschluß (P2)
C. Ref. Ø 1,5
D. Befestigungslöcher Ø 3,5 (2)
E. 0,2 x 0,5 Klemmen (3)

E Dimensiones en mm
A. Puerto de entrada (P1)
B. Puerto de entrada (P2)
C. Ref. Ø 1,5
D. Orificios de montaje diam. 3,5 (2)
E. Terminales 0,2 x 0,5 (3)

I Dimensioni in mm
A. Porta d'ingresso (P2)
B. Porta d'ingresso (P1)
C. Rif. Ø 1,5
D. Fori di montaggio Ø 3,5 (2)
E. Terminali 0,2 x 0,5 (3)

GB

RS Stock No.

395-229, 395-235, 395-241, 395-257, 395-263

General

These ultra low pressure differential sensors provide an output voltage proportional to applied pressure. They operate from a single positive supply voltage ranging from 6 to 16V ⎓. Signal conditioning results in directly useable outputs and temperature compensation results inpredictable performance over the specified temperature range.

Soldering

Limit soldering to 315°C (600°F) maximum, with 10 seconds maximum duration.

Cleaning

Proper cleaning fluids should be selected, based on type of contaminant to be removed. Alcohols or fluorinated solvents should be suitable for general purpose use, subject to customer evaluation.

Measurand compatibility

P2 Materials in contact with media are polyester, epoxy adhesive and silicon bonded to borosilicate glass with an electrostatic bond (passive side of IC).

P1 Dry gases only (active side of IC).

Measurement type		Measurand applied to port
Differential	D	P1 and P2
Gauge	G	P2 only

Pressure reference

Differential pressure transducers apply P1 to the active (connection) side of the chip, and P2 to the passive side.

Gauge pressure is measured with respect to atmospheric (room) pressure reference.

WARNING: Damage may result from reversal of supply and ground connections.

Technical specification

Parameter	Min.	Typ.	Max.	Units
FSO (Full Scale Output)*	4.85	5.00	5.15	Volts
Null offset	0.95	1.00	1.05	Volts
Null offset 395-257, 395-263	3.45	3.5	3.55	Volts
Excitation	6.0	8.00	16.0	Vd.c
Output current				
Source	10.0			mA
Sink	5.0			
Supply current (10kΩ load)		8.0	20.0	mA
Overpressure			5	p.s.i.
Operating temperature		-40°C to +85°C		
Storage temperature		-55°C to +125°C		

*FSO is the algebriac difference between end points (null and full pressure outputs). Output voltage at full pressure equals 6.0 ±0.20V at 8.0V ⎓.

Selection table

RS stock no.	Range
395-229	0-28" H2O
395-235	0-5" H2O
395-241	0-10" H2O
395-257	0 ± 2.5" H2O
395-263	0 ± 5" H2O

D

RS Best-Nr.

395-229, 395-235, 395-241, 395-257, 395-263

Allgemeines

Diese Differenzsensoren mit ultraniedrigem Druck liefern eine Ausgangsspannung proportional zum angelegten Druck. Sie arbeiten mit einer einzelnen mitlaufenden Versorgungsspannung, die von 6 bis 16V reicht. Die Signalaufbereitung führt zu direkt benutzbaren Ausgängen, und der Temperaturausgleich resultiert in einer nicht vorhersagbaren Leistung über dem angegebenen Temperaturbereich.

Löten

Die Temperaturgrenze beim Löten liegt bei 315°C. Die Dauer sollte 10 Sekunden nicht überschreiten.

Reinigen

Saubere Reinigungsflüssigkeiten benutzen, die für die Art des zu entfernenden Schmutzes geeignet sind. Der Kunde kann für allgemeine Zwecke Alkohol oder fluorierte Lösungsmittel verwenden.

Kompatibilität der Meflgröfle

P2: Zu den Materialien, die mit dem Medium in Berührung kommen, gehören Polyester sowie Epoxid und Silikon, die in einem elektrostatischen Prozefl auf Borosilikatglas geklebt wurden (passive Seite der Leiterplatte).

P1: Nur Trockengase (aktive Seite der Leiterplatte).

Meßart		An den Anschluß angelegte Meßgröße
Differenzdruck	D	P1 und P2
‹berdruck	G	nur P2

Druckreferenz

Differenzdruck- Meflumformer legen P1 an die aktive (Anschlufl) Seite der Leiterplatte an und P2 an die passive Seite.

Überdruck wird bezogen auf die Referenz für atmosphärischen (Raum) Druck gemessen.

WARNHINWEIS: Beschädigungen können durch Umkehrung der Versorgung und der Erdanschlüsse entstehen.

Technische Daten

Parameter	Min.	Typ.	Max.	Einheiten
FSO (Vollbereichssignal)*	4.85	5.00	5.15	Volts
Nulloffset	0.95	1.00	1.05	Volts
Nulloffset 395-257, 395-263	3.45	3.5	3.55	Volts
Erregung	6.0	8.00	16.0	Vd.c
Ausgangsstrom				
Stromquelle	10.0			mA
Stromsenke	5.0			
Versorgungsstrom(10kΩ Last)		8.0	20.0	mA
‹berdruck			5	p.s.i.
Betriebstemperatur		40°C to +85°C		
Lagertemperatur		55°C to +125°C		

*FSO ist die algebraische Differenz zwischen Endpunkten (Null - und Volldruckausgängen). Die Ausgangsspannung bei Volldruck ist gleich 6,0±0,20V bei 8,0V ⎓.

Auswahltabelle

RS Best.-Nr	Bereich
395-229	0-28" H2O
395-235	0-5" H2O
395-241	0-10" H2O
395-257	0 ± 2.5" H2O
395-263	0 ± 5" H2O

E

Código RS.

395-229, 395-235, 395-241, 395-257, 395-263

General

Estos sensores de diferencia de presión ultrabaja proporcionan una salida de tensión proporcional a la presión aplicada. Operan a partir de una inica tensión de alimentación positiva, que varìa entre 6 y 16V ⎓. El acondicionamiento de la señal da como resultado salidas directamente utilizables y la compensación de temperatura conduce a un rendimiento imprevisible sobre el rango especificado de temperaturas.

Soldadura

Límite de soldadura 315°C (600°F) maximo, con una duración maxima de 10 segundos.

Limpieza

Se deben utilizar líquidos apropiados de limpieza, en función del tipo de contaminante a eliminar. Alcoholes o disolventes fluorados suelen ser adecuados para aplicaciones de uso general, sujeto a la evaluación del cliente.

Compatibilidad de mediciones

P2 Materiales en contacto con los medios, como son poliéster, adhesivo epoxi y silicio aglomerado con vidrio de borosilicato mediante proceso de unión electrostatica (lado pasivo del circuito integrado).

P1 Gases secos inicamente (lado activo del circuito integrado).

Tipo de Medida		Medición aplicada a los puertos
Diferencial	D	P1 y P2
Manométrica	G	P2 inicamente

Referencia de presiones

Los transductores de presión diferencial aplican P1 al lado activo (conexión) del chip y P2 al lado pasivo.
La presión manométrica se mide con respecto a la presión atmosférica (ambiental).

Aviso: Se pueden producir daóos si se invierten las conexiones de alimentación y tierra.

Especificaciones técnicas

Parametro	Mín.	Típ.	Max.	Unidades
FSO (Salida a Fin de Escala)*	4.85	5.00	5.15	Volts
Desplazamiento del cero	0.95	1.00	1.05	Volts
Excitación 395-257, 395-263	3.45	3.5	3.55	Volts
Excitation	6.0	8.00	16.0	Vd.c
Corriente de salida				
Fuente	10.0			mA
Sumidero	5.0			
Corriente de alimentación (carga 10kΩ)		8.0	20.0	mA
Sobrepresión			5	p.s.i.
Temperatura de operación		-40°C to +85°C		
Temperatura de almacenaje		-55°C to +125°C		

*FSO es la diferencia algebraica entre puntos extremos (salidas de presión nula y maxima). La salida de tensión a la maxima presión es igua a 6,0 ±0,20V a 8,0V ⎓.

Tabla de selección

No de stock RS	Rango
395-229	0-28" H2O
395-235	0-5" H2O
395-241	0-10" H2O
395-257	0 ± 2.5" H2O
395-263	0 ± 5" H2O

I

RS Codici.

395-229, 395-235, 395-241, 395-257, 395-263

Descrizione generale

Questi sensori di pressione offrono una tensione di uscita proporzionale alla pressione applicata. Le unità sono azionate da una tensione di alimentazione positiva singola che varia da 6 a 16 V. Il condizionamento del segnale permette di ottenere uscite che possono essere utilizzate in modo diretto, mentre la termocompensazione gestisce i rendimenti imprevedibili sul campo di temperatura specificato.

Saldatura

Le operazioni di saldatura vanno limitate a 315°C, con durate massime di 10 secondi.

Pulizia

Selezionare detergenti adatti secondo ie tipo di contaminante da eliminare. I solventi a base di alcool e fluoro sono adatti per impieghi generici (dietro valutazione dell'operatore).

Compatibilità con materiali

P2 I materiali a contatto con gli elementi sono poliestere, adesivo epossidico e silicio applicato a vetro al borosilicato con un legame elettrostatico (lato positivo del c.i.).

P1 Solo gas secchi (lato attivo del c.i.).

Tipo di misurazione		Materiale applicato alla porta
Differenziale	D	P1 e P2
Misuratore	G	solo P2

Riferimento di pressione

Differenziale I trasduttori di pressione applicano P1 al lato attivo (collegamento) del processore e P2 al lato passivo.

Misuratore La pressione viene misurata in relazione al riferimento di pressione atmosferica (ambiente).

ATTENZIONE: Invertendo i collegamenti di alimentazione e massa si possono provocare danni.

Specifiche tecniche

Parametror	Min.	Tip.	Max.	Unità
FSO *	4.85	5.00	5.15	Volts
Offset nullo	0.95	1.00	1.05	Volts
Offset nullo 395-257, 395-263	3.45	3.5	3.55	Volts
Eccitazione	6.0	8.00	16.0	Vd.c
Corrente di uscita				
Sorgente	10.0			mA
Dissipazione	5.0			
Corrente di alimentazione (carico 10 kΩ)		8.0	20.0	mA
Sovrapressione			5	p.s.i.
Temperatura di esercizio	-40°C to +85°C			
Temperatura di stoccaggio	-55°C to +125°C			

*FSO rappresenta la differenza algebrica fra i punti finali (uscite nulla e di pressione totale). La tensione di uscita a pressione totale equivale a 6 ±0,20 V a 8 V ⎓ .

Tabella di selezione

Codice **RS**	Gamma
395-229	0-28" H2O
395-235	0-5" H2O
395-241	0-10" H2O
395-257	0 ± 2.5" H2O
395-263	0 ± 5" H2O