



MINIATURE ELECTRONIC PRESSURE SCANNERS

ESP-32HD/64HD

ESP Pressure Scanners are miniature electronic differential pressure measurement units consisting of an array of silicon piezoresistive pressure sensors, one for each pressure port. The sensors are mounted on a common hybrid ceramic substrate using a proprietary technique which maximizes long term stability. The outputs of the sensors are electronically multiplexed through a single onboard instrumentation amplifier at rates up to 70,000 Hz using binary addressing. The multiplexed amplified analog output is capable of driving long lengths of cable to a remote A/D converter.

The ESP scanners also incorporate a two-position calibration manifold actuated by momentary pulses of control pressures. When placed in the calibrate position, all sensors are connected to a common calibration pressure port. A series of accurately measured pressures can be applied through this port to characterize the sensors, in place, at the condition to which they are being subjected. Proper and periodic on-line calibration maintains static errors within +/-0.03% or better of the full scale (FS) pressure range. The calibration manifold automatically switches between two common reference pressures to ensure a stable reference is applied during calibration. The calibration manifold incorporates a visual position indicator and utilizes a dynamic o-ring seal design for high reliability and easy servicing in the field.

Options include purge capability, isolated from the pressure sensors, to clear measurement lines of moisture and contamination as well as to prevent closure of model pressure taps during application of pressure sensitive paint. Other options include a nickel foil RTD output to monitor internal scanner temperature and Digital Temperature Compensation technology now incorporating PSI's Gen-2 amplifier technology.

The Digital Temperature Compensation (DTC) option incorporates the latest PSI innovations in ESP technology including temperature signal outputs from each silicon pressure sensor, embedded EEPROM retaining factory calibration information including temperature characteristics, programmable dual gain amplifier with optional dual range calibration, calibration manifold position sensing, and internal sensor excitation regulation with sense output. DTC Series ESP scanners are supported by PSI's Optimus System Processor, DTC Initium System and the FDS Initium to dramatically reduce calibration requirements. The ESP scanners are also supported by a variety of third-party compatible systems.

Features

- Unparalleled Long-Term Stability
- Digital Temperature Compensation (DTC)
- Individual Offset and Thermal Zero Compensation
- Automatically Switched Reference Pressures
- Optional Isolated Purge Capability
- Optional Temperature Sense Output

Applications

- In-Model Windtunnel Testing
- Aircraft Flight Testing
- Automotive Track Testing

MINIATURE ELECTRONIC PRESSURE SCANNERS

ESP-32HD/64HD

Specifications

* After 1 hour warmup @ 25°C with atmospheric reference pressure unless otherwise stated. (Specifications subject to change without notice)

PARAMETER	DTC		CONVENTIONAL		UNITS	COMMENTS
	32HD	64HD	32HD	64HD		
PNEUMATICS						
Number of Pressure Inputs	32	64	32	64	ports	
Pressure Ranges ¹					in WC (kPa) psid (kPa) psid (kPa)	
		±4 (1.0) to ±20 (5.0) ±1 (7) to +150 (1034)				
Proof Pressure ²		400 150			% FS % FS	ranges ≤ 30 psid ranges > 30 psid
Max Reference Pressure (Line Pressure)		50 (345) 15 (103)			psid (kPa) psid (kPa)	ranges ≥ 2.5 psid ranges < 2.5 psid
Manifold Control Pressure		100 (689) 125 (862)			psig (kPa) psig (kPa)	min max
Optional Purge Pressure		greater than max input pressure 150 (1050)			psig (kPa) psig (kPa)	min max
Media:						
Measurement Ports	non-corrosive gases up to 100% non-condensing humidity dry, non-corrosive gases					
Reference Ports						
Pneumatic Connection	0.040 or 0.063	0.040	0.040 or 0.063	0.040	inches OD	SS bulged tubulation
PERFORMANCE						
Static Accuracy ³ @100% range ⁴	±0.03 ±0.06 ±0.15			N/A N/A N/A	% FS % FS % FS	range ≥ 10 psid range ≥ 10 in WC to < 10 psid range < 10 in WC
@33% range ⁷	±0.05			N/A	% FS	range ≥ 10 psid
2 nd order correction ⁵	N/A N/A			±0.15 ±0.20	% FS % FS	range > 2.5 psid range ≤ 2.5 psid
4 th order correction ⁶	N/A N/A			±0.05 ±0.10	% FS % FS	range > 2.5 psid range ≤ 2.5 psid
Thermal Zero Error	N/A			±0.06 ±0.20	% FS/°C % FS/°C	range > 2.5 psid range ≤ 2.5 psid
Thermal Span Error	N/A			±0.02 ±0.03	% FS/°C % FS/°C	range > 2.5 psid range ≤ 2.5 psid
Total Thermal Stability @100% range	±0.002 ±0.004 ±0.01			N/A N/A N/A	% FS/°C % FS/°C % FS/°C	range ≥ 5 psid range ≥ 10 in WC to < 5 psid range < 10 in WC
@33% range ⁷	±0.003			N/A	% FS/°C	range ≥ 5 psid

NOTES:

1. Consult factory for pressure ranges not listed.
2. Maximum applied pressure without reducing sensor performance.
3. Static accuracy includes combined errors due to non-linearity, hysteresis, and non-repeatability.
4. Achievable accuracy after span calibration. Consult applicable datasheets for DTC Series ESP specifications when used with legacy PSI System 8400 SDI configuration, DTC Initium or Optimus Systems.
5. Typical performance using 2nd order equation of the form $P_x = C_0 + C_1(V_x) + C_2(V_x^2)$.
6. Typical performance using 4th order equation of the form $P_x = C_0 + C_1(V_x) + C_2(V_x^2) + C_3(V_x^3) + C_4(V_x^4)$.
7. Accuracy is expressed as a percent of the deranged full scale when dual range calibration is specified.

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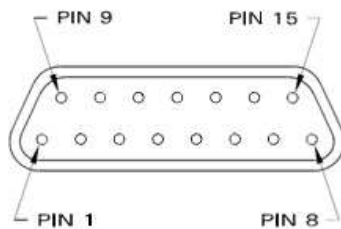
Specifications

* After 1 hour warmup @ 25°C with atmospheric reference pressure unless otherwise stated. (Specifications subject to change without notice)

PARAMETER	DTC		CONVENTIONAL		UNITS	COMMENTS
	32HD	64HD	32HD	64HD		
ELECTRICAL						
Power Supply						
+5 VDC	0	0	55	75	mA	Max
+12 VDC	75	110	5	5	mA	Max
-12 VDC	25	25	3	3	mA	max
Full Scale Output	±3.5 – 4.5				VDC	optional output available
Port Selection	5	6	5	6	bit	0-12 VDC, CMOS Logic
Scan Rate	70,000		20,000		chs/sec	
Electrical Connection	15 pin subminiature D-shell ⁸					ITT Cannon (PN: MDM 15SSB)
ENVIRONMENTAL/PHYSICAL						
Comp Temp Range	0 to 80				°C	optional 100 °C available
Operating Temp Range	-25 to 80				°C	optional 100 °C available
Storage Temp	-25 to 100				°C	
Weight	3.9 (112)	5.1 (143)	3.7 (106)	4.9 (140)	oz. (g)	
HEATER CHAMBERS						
Setpoint Adjustability	±3				°C	
Thermal Compensation	N/A ⁹		10:1			reduction in the effects of temperature to the scanner
Ambient Temperature	-55				°C	min
Power Requirements	28 VDC @ 1.5A					max
Electrical Connection	Two leads unterminated					Red: +28 VDC Black: GND
Temperature Overload	90				°C	with Auto Reset
Weight	6.8 (192)	6.8 (192)	6.8 (192)	6.8 (192)	oz. (g)	

NOTES:

⁸ Heater chambers for DTC Series scanners are only required to maintain minimum operating temperature.



PIN	FUNCTION
1	Digital Address A0
2	Digital Address A1
3	Digital Address A2
4	Digital Address A3
5	Digital Address A4
6	+12 VDC
7	-12 VDC
8	+VS, Sensor Supply Voltage (+5)

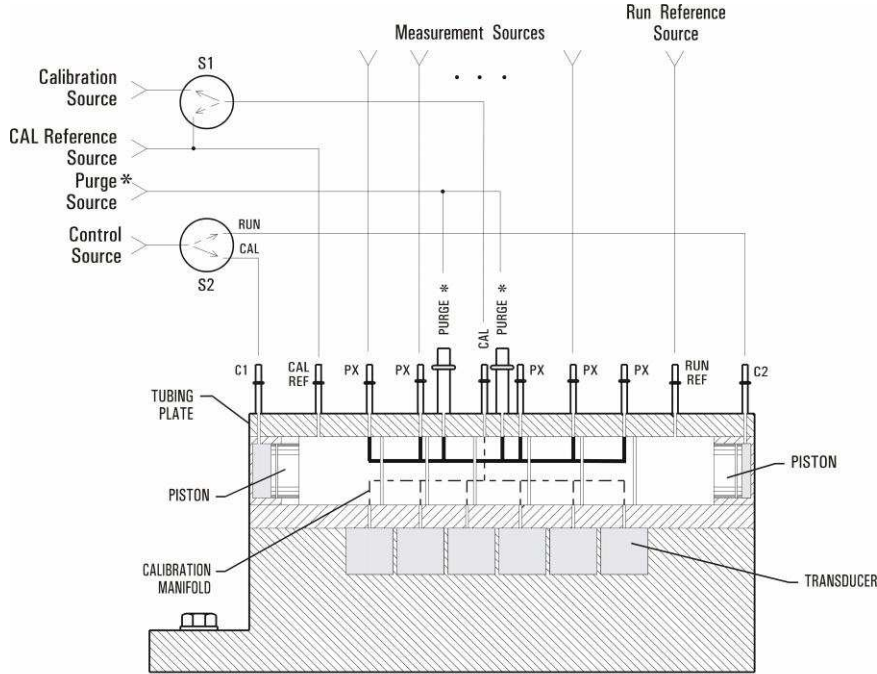
PIN	FUNCTION
9	-VS, Sensor Supply Voltage Return
10	GND
11	Voltage Output V ₀
12	Digital Address A5
13	GND Sense
14	+VS Sense (opt.)
15	V _t , Temperature Sense Output (opt.)

MINIATURE ELECTRONIC PRESSURE SCANNERS

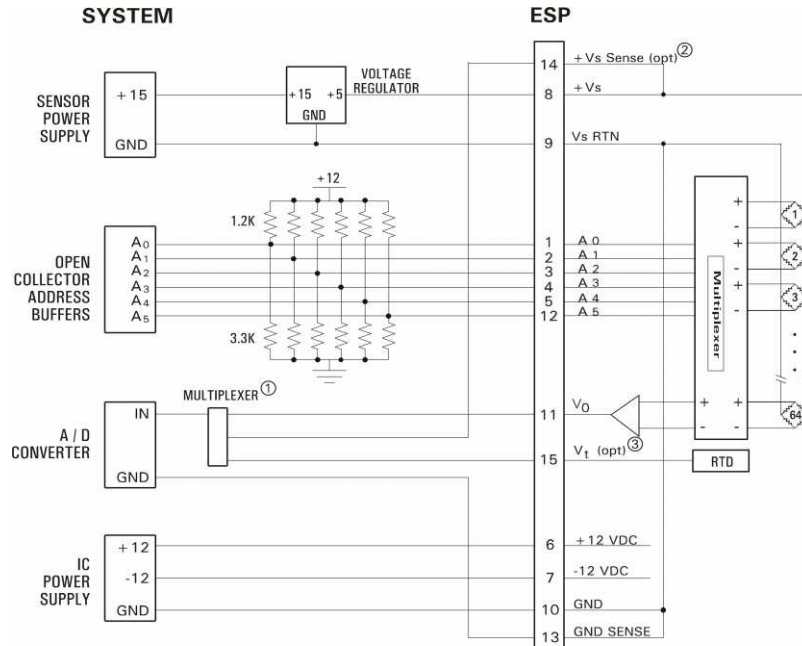
ESP-32HD/64HD

Pneumatic/Electrical Interface

Interfacing to the ESP-HD Series scanners consist of both electrical and pneumatic considerations. The PSI's Optimus System Processor, DTC Initium System and the FDS Initium provide turnkey pre-engineered solutions to these interfacing requirements. Custom data acquisition systems will require these interfaces to be developed.



- ① S1 - FOR REZERO ONLY.
- ② S2 - TO SHUTTLE MANIFOLD.
- ③ * ONLY REQUIRED FOR SCANNERS ORDERED WITH PURGE OPTION.

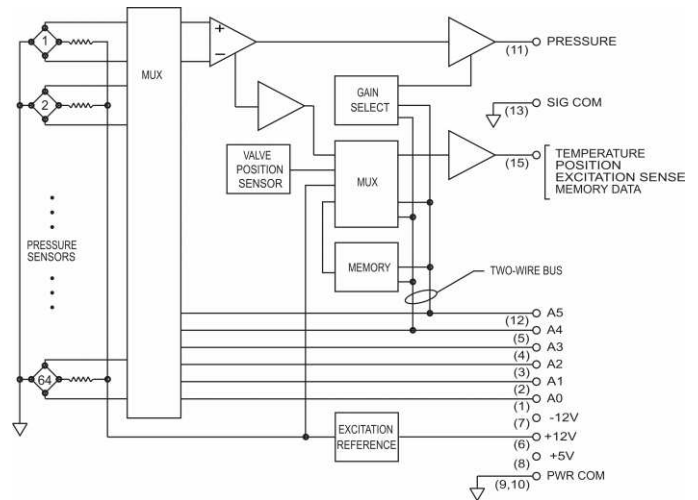


- ① ONLY REQUIRED FOR USE WITH TEMPERATURE SENSE OPTION.
- ② FOR RATIOMETRIC CORRECTION OF SPAN.
- ③ FOR TEMPERATURE CORRECTION OF ZERO AND SPAN.

Options

Digital Temperature Compensation (DTC)

The DTC option of the ESP pressure scanners incorporates many advanced features including the Gen-2 amplifier technology to increase the utility of the scanners while providing digital temperature compensation of the silicon sensors. An onboard EEPROM stores the thermal calibration data for each channel. Also stored in the EEPROM is information identifying the range of the scanner, the number of channels, the model number, the serial number, the date of manufacturer, the date of calibration, and the model and serial number of the calibration unit used to calibrate the scanner. This data is serially transmitted to a data acquisition system such as the Optimus System Processor, DTC Initium System and the FDS Initium using the ESP address lines and then transferred to the Optimus System Processor via fiber optic cable. Using a proprietary PSI-developed method, the temperature of each sensor within the scanner is measured and transmitted along with the raw pressure measurements to the data acquisition system. Utilizing the calibration data within the EEPROM, the data acquisition system compensates for temperature changes to the sensors in real time. This reduces thermal errors by a factor of 20 thereby reducing on-line calibration requirements by up to 90%. The ESP scanners also incorporate a hall effect sensor which is used to indicate the position of the calibration manifold. This position information can be transferred to the system upon command. Another advanced feature is the ability to derange the ESP scanner upon command. This alters the gain on the amplifier to derange the scanner by a factor of three, enabling additional windtunnel tests to be conducted without instrumenting the model with lower range ESP scanners. To optimize the accuracy of the DTC scanner at the highest gain, the optional dual range calibration is recommended.



Temperature Sense Output Option for Conventional ESP Scanners

The temperature sense output option involves embedding a nickel foil RTD within the scanner to indicate internal scanner temperature. The analog signal from the RTD is output on one of the pins of the electrical connector. Silicon sensors are repeatable with temperature and, once characterized, can be compensated for thermal errors using algorithmic techniques. Scanners with this option are factory calibrated at temperature intervals throughout the operational temperature span of the scanner and a curve fit established for each sensor. A fourth order polynomial equation is generated for each sensor at standard temperature points of -25, 0, 25, 50 and 75°C. These equations as well as the corresponding RTD voltages are provided to customers in a calibration report along with the scanner. The temperature sense option can be ordered with the scanner or existing scanners can be retrofitted by returning the scanner to the factory for upgrade. (See page 12 for order information.)

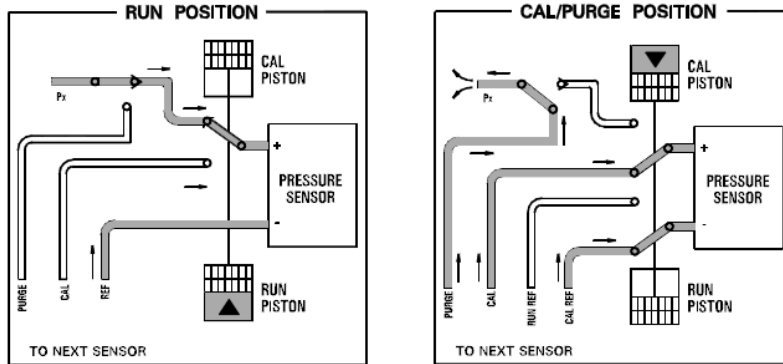
Pneumatic Connections

Pneumatic connections to the ESP scanners are made via user-specified 0.040" or 0.063" OD bulged stainless steel tubulations installed on the scanner tubing plate. Tubulations of 0.040" OD can optionally be installed at a 60° angle to minimize the overall height of the scanner. Scanners specified with Purge option must be installed at the standard 90° angle unless the Quick-Disconnect option is also specified. Flexible tubing is installed over the bulged tubulation and secured using retaining springs. Nylon tubing, retaining springs and tubing pliers to facilitate the installation of the tubing and springs are offered. (See page 12 for ordering information).

Options

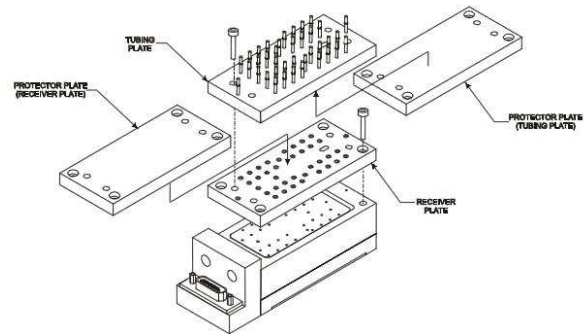
Purge Option

The purge option involves a modification to the scanner's calibration valve to manifold purge pressure inputs to the measurement ports during calibration. Anytime the valve is placed in the calibrate position, purge pressure applied to the purge ports will purge the measurement lines of any contamination such as moisture. This option enables simultaneous purging and calibration (or rezero) which is especially useful in-flight test applications. The purge option is also useful for preventing model surface pressure taps from becoming clogged during the application of pressure sensitive paint. During use, purge pressure must be present whenever the valve is shifted to the calibrate position to prevent "reverse" purge from occurring.



Heater Chambers

Heater chambers are available to insulate the ESP miniature pressure scanners from temperature changes and reduce the thermal effects by a factor of ten. The heater chambers are constructed of Delrin, a lightweight material with good insulation qualities. The scanners are housed within an embedded copper liner to evenly distribute the heat generated by the foil heating element. The heater circuitry includes proportional temperature control, adjustable temperature set point, and thermal overload protection. The +28 VDC power supply is input via two unterminated leads. The ESP scanners are mounted to the heater chamber top plate which includes an opening to route measurement lines to the scanner. A rubber grommet is provided to allow the scanner electrical cable to enter the heater chamber while thermally sealing the opening. The heater chambers also incorporate mounting provisions. (See page 3 for heater chamber specifications, page 8-11 for dimensions and page 12 for order information.)



Quick Disconnect ESP Tubing Plates

Quick-Disconnect ESP tubing plates enable users to disconnect the tubing plate from ESP-32HD or ESP-64HD scanners without exposing the internal calibration manifold to potential contaminants. Separating the tubing plate from the scanner helps reduce setup times by allowing tubing connections to be completed while simultaneously conducting electrical checkout of the scanner. The Quick-Disconnect option enables angled tubulation to be specified in conjunction with the Purge option.

Quick-Disconnect tubing plates can be ordered as an option on new ESP scanners. Spare tubing plates are available at time of original order or for later purchase as a spare part. Retrofit of older scanners is not recommended due to minor manufacturing mechanical tolerance changes.

Accessories and Spec Diagrams

Maintenance Kits and Spare Tubing Plates

To supplement the on-site ability to replace the transducer carriers and the amplifier assembly, maintenance kits are offered to service the calibration valve and tubing plate. These kits are available for each of the scanner models. The maintenance kits consist of spare bulged tubulations, a drill bit to clean the tubulation bore in the tubing plate, and the sealant to secure the tubulation to the plate. Also included are spare "O" rings for the calibration manifold and the pistons along with a generous supply of lubricant. Additional "O" rings can be purchased separately. Spare tubing plate screws are also provided.

Spare tubing plates can be used to replace damaged tubing plates or to alter the pneumatic connections of the scanner. When ordering spare tubing plates, the manifold configuration (standard or purge) as well as the ESP model must be indicated along with the pneumatic connection. Instructions for servicing the ESP scanners using these maintenance kits are provided in the ESP Miniature Scanners User's Manual. (See page 12 of this datasheet for order information.)

Cables

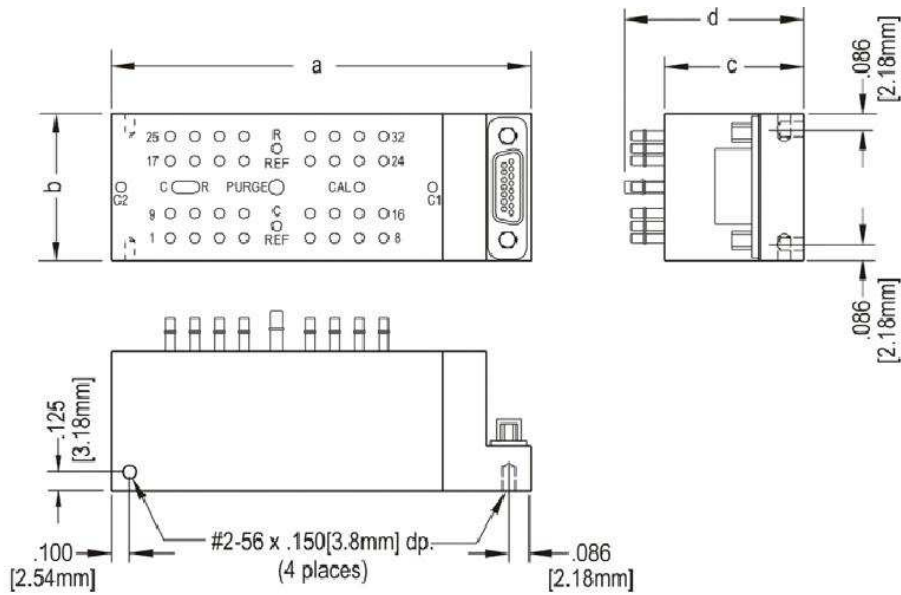
Pressure Systems offers a variety of cables including a mating connector with wiring harness to facilitate electrical connection to the system. These cables are custom designed to maximize noise immunity and flexibility. These cables can be used to interface the ESP miniature scanners to the Optimus System Processor, DTC Initium System and the FDS Initium Scanner Interfaces or to custom data acquisition systems. Both PVC and PTFE jacketed cables are available

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ESP-32HD/64HD

Spec Diagrams

ESP-32HD



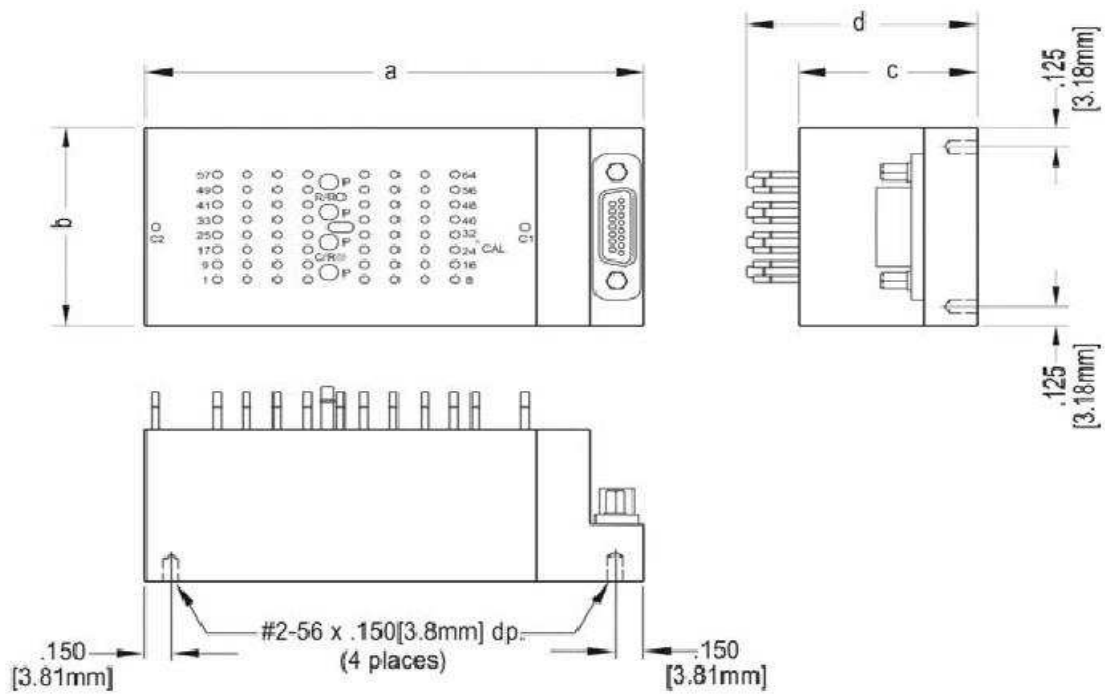
	ESP-32HD	a (length)		b (width)		c (height w/o tubes)		d (height incl. tubes)		c1/c2 tube dia.		purge tube dia.	
		in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
Conventional	0.040" OD, straight	2.80	71.1	1.00	25.4	0.93	23.7	1.17	29.8	0.040	1.0	-	-
	0.040" OD, angled	2.80	71.1	1.00	25.4	0.93	23.7	1.16	29.6	0.040	1.0	-	-
	0.063" OD, straight	2.80	71.1	1.00	25.4	0.93	23.7	1.18	30.0	0.063	1.6	-	-
	0.040" OD, straight, purge	2.80	71.1	1.00	25.4	0.93	23.7	1.36	34.5	0.040	1.0	0.125	3.2
	0.063" OD, straight, purge	2.80	71.1	1.00	25.4	0.93	23.7	1.36	34.5	0.063	1.6	0.125	3.2
	0.040" OD, straight, QDC	2.80	71.1	1.00	25.4	1.12	28.4	1.36	34.6	0.040	1.0	-	-
	0.040" OD, angled, QDC	2.80	71.1	1.00	25.4	1.12	28.4	1.35	34.3	0.040	1.0	-	-
	0.063" OD, straight, QDC	2.80	71.1	1.00	25.4	1.12	28.4	1.37	34.7	0.063	1.6	-	-
	0.040" OD, straight, QDC, purge	2.80	71.1	1.00	25.4	1.12	28.4	1.54	39.2	0.040	1.0	0.125	3.2
	0.040" OD, angled, QDC, purge	2.80	71.1	1.00	25.4	1.12	28.4	1.53	39.0	0.040	1.0	0.125	3.2
0.063" OD, straight, QDC, purge	2.80	71.1	1.00	25.4	1.12	28.4	1.54	39.2	0.063	1.6	0.125	3.2	
DTC Series	0.040" OD, straight	3.10	78.7	1.00	25.4	0.93	23.7	1.17	29.8	0.040	1.0	-	-
	0.040" OD, angled	3.10	78.7	1.00	25.4	0.93	23.7	1.16	29.6	0.040	1.0	-	-
	0.063" OD, straight	3.10	78.7	1.00	25.4	0.93	23.7	1.18	30.0	0.063	1.6	-	-
	0.040" OD, straight, purge	3.10	78.7	1.00	25.4	0.93	23.7	1.36	34.5	0.040	1.0	0.125	3.2
	0.063" OD, straight, purge	3.10	78.7	1.00	25.4	0.93	23.7	1.36	34.5	0.063	1.6	0.125	3.2
	0.040" OD, straight, QDC	3.10	78.7	1.00	25.4	0.93	28.4	1.36	34.6	0.040	1.0	-	-
	0.040" OD, angled, QDC	3.10	78.7	1.00	25.4	0.93	28.4	1.35	34.3	0.040	1.0	-	-
	0.063" OD, straight, QDC	3.10	78.7	1.00	25.4	0.93	28.4	1.37	34.7	0.063	1.6	-	-
	0.040" OD, straight, QDC, purge	3.10	78.7	1.00	25.4	0.93	28.4	1.54	39.2	0.040	1.0	0.125	3.2
	0.040" OD, angled, QDC, purge	3.10	78.7	1.00	25.4	0.93	28.4	1.53	39.0	0.040	1.0	0.125	3.2
0.063" OD, straight, QDC, purge	3.10	78.7	1.00	25.4	0.93	28.4	1.54	39.2	0.063	1.6	0.125	3.2	

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ESP-32HD/64HD

Spec Diagrams

ESP-64HD



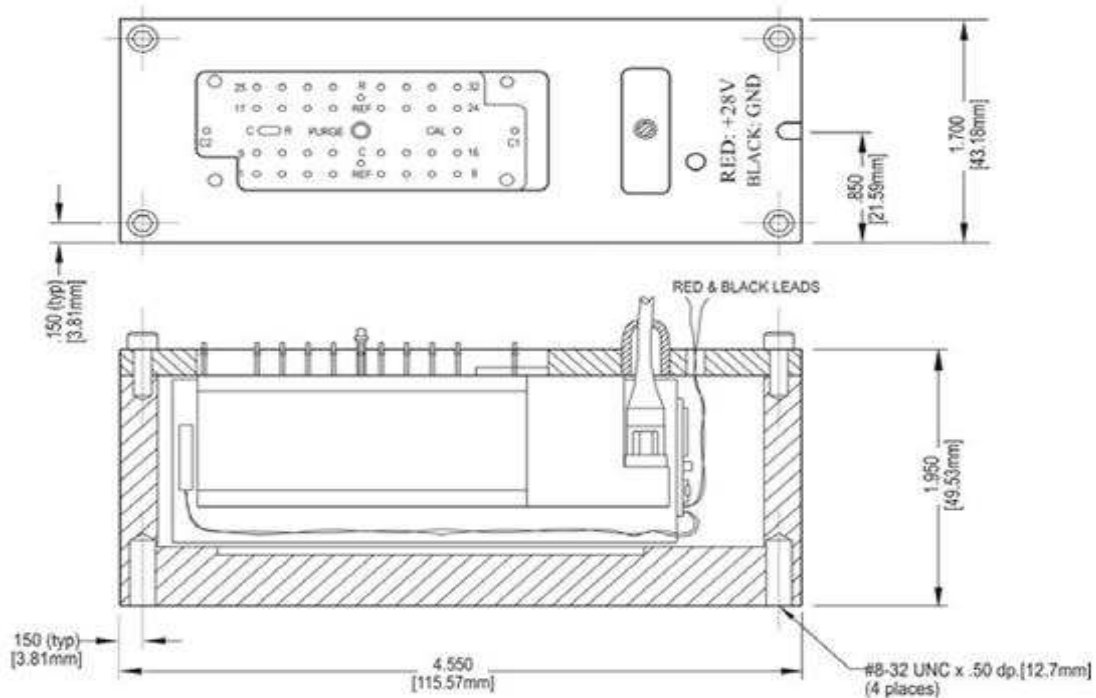
	ESP-64HD	a (length)		b (width)		c (height w/o tubes)		d (height incl. tubes)		c1/c2 tube dia.		purge tube dia.	
		in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
Conventional	0.040" OD, straight	2.80	71.1	1.30	33.0	1.00	25.4	1.23	31.3	0.040	1.0	-	-
	0.040" OD, angled	2.80	71.1	1.30	33.0	1.00	25.4	1.19	30.1	0.040	1.0	-	-
	0.040" OD, straight, purge	2.80	71.1	1.30	33.0	1.13	28.6	1.55	39.4	0.040	1.0	0.090	2.3
	0.040" OD, straight, QDC	2.80	71.1	1.30	33.0	1.31	33.3	1.54	39.2	0.040	1.0	-	-
	0.040" OD, angled, QDC	2.80	71.1	1.30	33.0	1.31	33.3	1.50	38.1	0.040	1.0	-	-
	0.040" OD, straight, QDC, purge	2.80	71.1	1.30	33.0	1.31	33.3	1.74	44.1	0.040	1.0	0.090	2.3
	0.040" OD, angled, QDC, purge	2.80	71.1	1.30	33.0	1.31	33.3	1.55	39.5	0.040	1.0	0.063	1.6
DTC Series	0.040" OD, straight	3.15	80.0	1.30	33.0	1.00	25.4	1.23	31.3	0.040	1.0	-	-
	0.040" OD, angled	3.15	80.0	1.30	33.0	1.00	25.4	1.19	30.1	0.040	1.0	-	-
	0.040" OD, straight, purge	3.15	80.0	1.30	33.0	1.13	28.6	1.55	39.4	0.040	1.0	0.090	2.3
	0.040" OD, straight, QDC	3.15	80.0	1.30	33.0	1.31	33.3	1.54	39.2	0.040	1.0	-	-
	0.040" OD, angled, QDC	3.15	80.0	1.30	33.0	1.31	33.3	1.50	38.1	0.040	1.0	-	-
	0.040" OD, straight, QDC, purge	3.15	80.0	1.30	33.0	1.31	33.3	1.74	44.1	0.040	1.0	0.090	2.3
	0.040" OD, angled, QDC, purge	3.15	80.0	1.30	33.0	1.31	33.3	1.55	39.5	0.040	1.0	0.063	1.6

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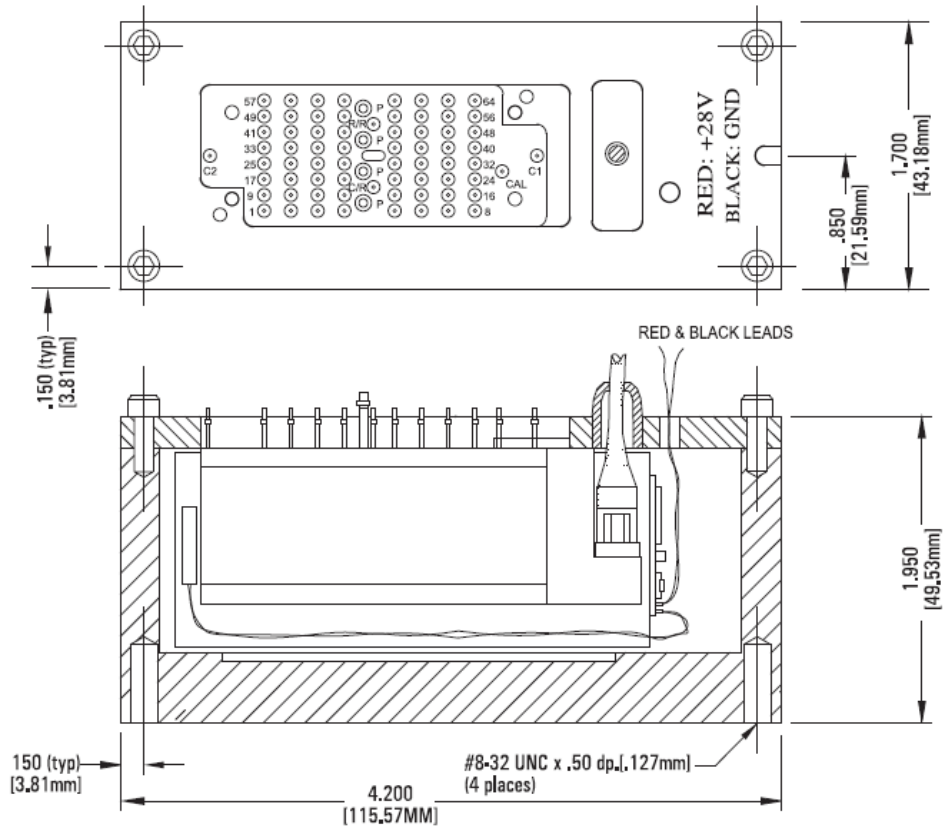
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Conventional Heater Chambers

ESP-32HD



ESP-64HD

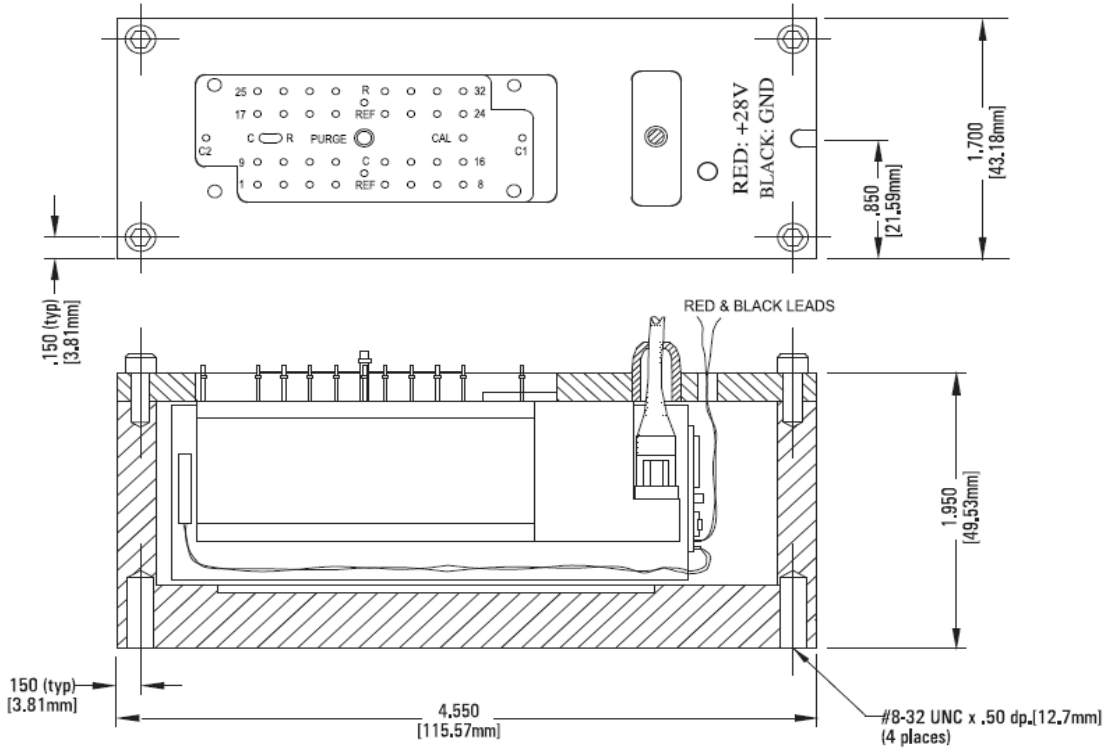


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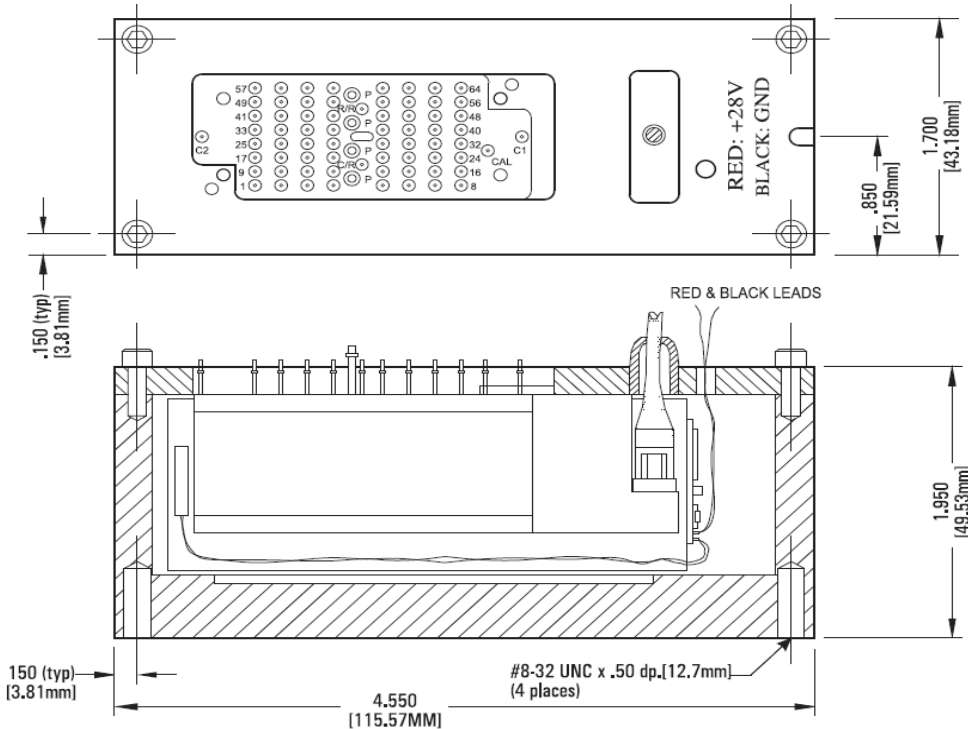
ESP-32HD/64HD

DTC Series Heater Chambers

ESP-32HD



ESP-64HD



MINIATURE ELECTRONIC PRESSURE SCANNERS

ESP-32HD/64HD

Ordering Information

Pressure Scanner:

PN: 32HD-AABBCCDDEE ESP-32HD Scanner, 32 channels

PN: 64HD-AABBCCDDEE ESP-64HD Scanner, 64 channels

AA = Pressure Ranges

01, ± 10 "WC	06, ± 10 psid	11, ± 7.5 psid	16, ± 3 psid	21, ± 12 psid
02, ± 20 "WC	07, -12 to +15 psid	12, -12 to +50 psid	17, ± 25 psid	
03, ± 1 psid	08, -12 to +30 psid	13, ± 1.5 psid	18, ± 20 psid	23, -12 to +100 psid
04, ± 2.5 psid	09, -12 to +45 psid	14, 0 to +75 psid	19, ± 4 "WC	
05, ± 5 psid	10, 0 to +100 psid	15, ± 2 psid	20, ± 4 psid	

BB = Pneumatic Connection (OD, angle)

01,	0.040", 90°
02,	0.040", 60° (not available with Purge option)
03,	0.063", 90° (16HD/32HD only)
21,	0.040", 90°, quick disconnect (32HD/64HD only)
22,	0.040", 60°, quick disconnect (32HD/64HD only)
23,	0.063", 90°, quick disconnect (32HD only)

CC = Manifold Options

00,	Standard
02,	Purge option

DD = Temperature Sense

00,	Standard
02,	Temp Sense Without Temperature Calibration
03,	Temp Sense with Temperature Calibration
11,	Digital Temperature Compensation (DTC) Single range calibration
28,	Chell DAQ System Compatible, (DTC) Single range calibration
29,	Chell DAQ System Compatible, (DTC) Dual range calibration

EE = Intermediate Cable Length (16HD only)

01,	1 foot
02,	2 feet <i>For requirements in excess</i>
03,	3 feet <i>of 6 feet, use ESCB scanner</i>
04,	4 feet <i>extension cable.</i>
05,	5 feet
06,	6 feet

EE = Amplifier Section (32HD & 64HD only)

00,	Conventional
20,	Gen-2 DTC (DD must = 11 or 12)
21,	Motor Drive Attachment
22,	Motor Drive & 100°C Operation (32HD Only)
23,	20 to 100°C Operation (32HD Only)

Order Example: 32HD-0103021120 ESP-32HD Scanner, ± 10 "WC, .063", 90°, purge, Digital Temperature Compensation with single range calibration

MINIATURE ELECTRONIC PRESSURE SCANNERS

ESP-32HD/64HD

Spare Quick-Disconnect:

32QD-AABBCC0000

Quick-Disconnect ESP Tubing Plate Kit, 32 ports

64QD-AABBCC0000

Quick-Disconnect ESP Tubing Plate Kit, 64 ports

AA = Kit Configuration
02, Tubing plate only
03, Protective plate only

CC = Manifold Options
00, Standard
02, Purge

BB = Pneumatic Configuration (OD, angle)
00, N/A
21, 0.040", 90° (32HD/64HD only)
22, 0.040", 60° (32HD/64HD only)
23, 0.063", 90° (32QD only)

Notes:

*32QD with purge option uses 0.125" OD purge tubes on all pneumatic configurations
64QD with purge option uses 0.090" OD purge tubes on 90° pneumatic configurations
and 0.063" OD purge tubes on 60° pneumatic configurations. Not available with heater chamber option*

Heater Chamber:

PN: 32HC-AA00000000

ESP-32HD Heater Chamber

PN: 64HC-AA00000000

ESP-64HD Heater Chamber

AA = Type of Scanner
01, Conventional
02, DTC

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