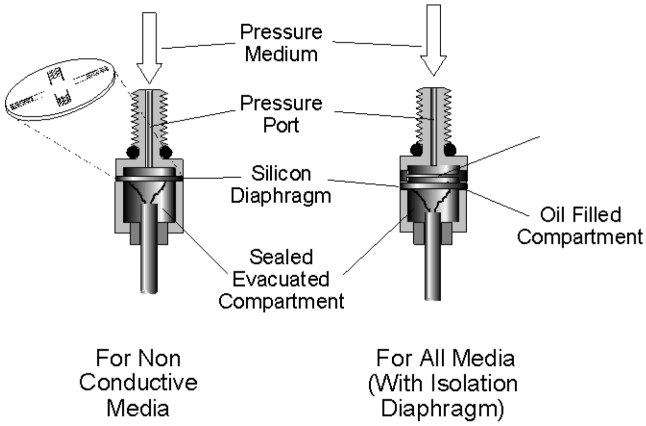
Pressure Sensors

McLaren Electronic Systems offers pressure sensors which incorporate strain gauges on a silicon diaphragm.

Principle of Operation

The pressure sensing element is formed by diffusing semi-conductor strain gauges directly into the silicon diaphragm. Strain gauges are elements which change their resistance when they are deformed. The strain gauges are connected together to form a Wheatstone Bridge circuit. When pressure is applied to the diaphragm, it deforms and stretches or compresses the strain gauges, which causes an imbalance in the bridge circuit, and a change in the output voltage.

The sensors are “absolute” gauges which means that the back of the diaphragm is evacuated and sealed.



Pressure Media

The simplest pressure sensors in the McLaren Electronic Systems range use a sensor element in which the silicon diaphragm is directly exposed to the medium being measured. This construction allows high sensitivity and good dynamic response, at a reasonable cost. However, this construction cannot be used with electrically conductive media.

Most automotive oils and fuels are not electrically conductive and sensors with unprotected diaphragms can be used. Water is not acceptable with this type of sensor unless it is very pure. Trace quantities of water can be tolerated, but the sensor should not be used to measure water pressure.

Unprotected sensors may be used for measuring intake (manifold) air pressure, but care should be taken to prevent condensed water accumulating inside the sensor. If you are in any doubt about the fluids you are using, contact our technical consultancy department, or use a sensor specified for “all media”.

Sensors for use with all media are constructed with a metal isolation diaphragm to separate the silicon diaphragm from the medium being measured. Pressure is transmitted to the silicon diaphragm by oil sealed in the compartment between it and the isolation diaphragm.

Body Material

McLaren Electronic Systems pressure sensors are constructed in either 316 stainless steel or Titanium. Where an isolation diaphragm is used, it is the same material as the body. 316 stainless steel is non magnetic and is resistant to chemical attack by the fluids generally found in the automotive and motorsport industries. Titanium is lighter but it is susceptible to attack by certain cleaning solvents and by methanol.

Pressure Rating

The Product Summaries quote three pressure ratings for each sensor. These are defined as follows:

Rated Pressure is the pressure which gives full scale output. The sensor will operate above this pressure without any permanent damage, provided the maximum pressure is not exceeded, but is not guaranteed to meet its specified characteristics.

Maximum Pressure is the maximum pressure that the sensor can withstand before it permanently deviates from its specification.

Burst Pressure is the highest pressure at which the sensor diaphragm and isolation header can be guaranteed to remain intact. Above this pressure the medium may burst through past the sensor backshell.

If there are shock waves or rapid fluctuations in the fluid (for example near an oil pump), a “snubber” is recommended. This is a restriction, between the sensing element and the pressure source. The snubber damps out the pressure shocks which reduces the risk of damage to the sensor diaphragm and reduces the possibility of false readings due to transients. Some of our sensors incorporate an internal snubber as standard. All other models can be supplied with a snubber as an option.

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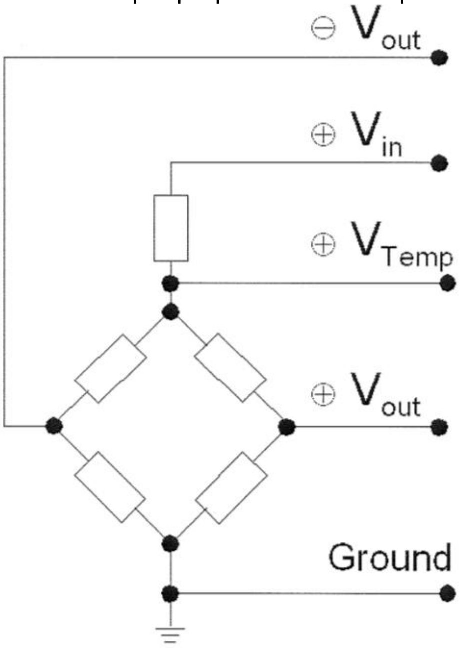
Pressure Sensors

5 Wire Sensors

In a 5-wire sensor, connections are made directly to the sensing element, there are no active components. The strain gauges are arranged in a Wheatstone bridge circuit which has four wires. A fifth wire is brought out of the sensor with an output proportional to temperature.



The output of 5-wire sensors is in the mV range and varies with fluctuations in the supply voltage. This means that the control unit, to which the sensor is connected, needs to provide a very stable and accurate supply voltage and must include an accurate, stable, differential instrument amplifier with a high input impedance. Some of our control units, and the SN-6 sensor nodes of the DATA*Lab* system, incorporate these features, so they can be connected directly to 5 wire sensors.

Temperature Compensation

Pressure sensors made from silicon have a very linear response, but the output is affected by changes in temperature, so thermal compensation is necessary. McLaren Electronic Systems pressure sensors include internal temperature compensation components which are individually trimmed to minimise thermal sensitivity. The unwanted thermal sensitivity can be reduced still further by measuring the temperature of the sensor, using the output from the fifth wire and using this additional information to correct the sensor output externally.

This active temperature compensation is done by converting the pressure and temperature outputs of the sensor to digital values and using the values to look up the corrected value of pressure.

Active compensation eliminates practically all thermal influences. As a bonus, the temperature at the sensor is available as a measured variable of limited accuracy.

The conversion and calculation require sophisticated circuitry and it is not current practical to incorporate this within the sensor body. However, McLaren Electronic Systems have pioneered the application of active compensation by providing the necessary circuitry within our control units. This is a very cost effective solution, which results in outstanding pressure sensor accuracy. The sensor prices are kept to a minimum without increasing the cost of our control unit.

Amplified Sensors

McLaren Electronic Systems can supply an amplified version of each type of pressure sensor. These provide a more robust signal which is required where there are high levels of electro-magnetic interference or to connect to a device which does not have the appropriate input conditioning circuitry.

The amplifier converts the mV output of the sensor into a single-ended, amplified signal in the 0 to 5 Volt range. The amplifier circuit also stabilises the excitation supply for the sensor. This means that amplified pressure sensors can be connected directly to most ECUs, or even a simple voltmeter, as the amplification and signal processing is built into the sensor/amplifier package.

In the sensor for non-conductive fluids, the amplifier is packaged as a sealed unit in the sensor cable. It is not integrated into the sensor body because the amplifier electronics cannot tolerate as high a temperature as the sensor itself. This should be considered when selecting the length of cable between the amplifier and the sensor, and when locating the amplifier in the vehicle.

In the sensors suitable for all media, the amplifier is integrated into the sensor body without compromising the operating temperature range of the sensor. The high temperature variant of this sensor can operate at up to 175°C.

To avoid ground loops, and to minimise the effects of electromagnetic interference, it is best to run a ground wire from the sensor amplifier to the ECU rather than relying on the vehicle frame to complete the circuit. The temperature of the sensor is brought out as a signal on a dedicated wire and may be used for active compensation.

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Pressure Sensors

Testing and Calibration

Each sensor is calibrated at a range of 7 pressures and 6 temperatures across its operating range. The results are printed out in graphical and tabular form and supplied with the sensor. This data is also available in a computer readable form which can be loaded directly into McLaren Electronic Systems' control units or data logging systems. The amplified sensors are also supplied with gain and offset values calculated to fit the response at the temperature specified in the Product Summary. Gain and offset values at other temperatures can be supplied on request.

Selecting a Sensor

The easiest way to select a sensor is to choose the ones that will meet your technical requirements at the lowest cost. We suggest you make your decisions in the following order:

- Pressure measurement range
- Media to be measured – the amplified pressure sensors are suitable for all media, whereas the modules are only suitable for use with non-corrosive gas
- Material – Titanium is lighter than stainless steel but is susceptible to attack by some cleaning solvents and by methanol.
- Operating Temperature – Make sure the operating temperature is appropriate for your installation.
- Connector – Certain models are available with integral connectors. Other types have a flying lead.
- Mounting – Flanged versions of certain models are available.

Tyre Pressure Systems

The Tyre Pressure Systems are used as a safety device for puncture detection and also as a tyre development tool.

The sensor transmission is activated with pressure, so if installed to tyres in the garage in a static environment will transmit at the lowest rate to conserve battery life. During use, the transmission rate increases if the rate of change of pressure increased (dt/dp).

The standard receiver sends data to the car control via CAN. An analogue version is also available. For racing car applications in which data logging and pit telemetry are not used, the Tyre Pressure Dash/Display displays information received from the tyre pressure receivers on an LCD screen so that the driver can monitor tyre pressures from the cockpit.

The NASCAR Tire Pressure system has a higher pressure range due to higher operating pressures.

Pressure Sensor Modules

Pressure modules consist of a cost-effective sensor element and signal conditioning electronics packaged into a rugged aluminium housing.

McLaren Electronic Systems offer the following types of module:

- Barometric pressure modules
- Manifold pressure/temperature
- Differential pressure

Because modules use exposed silicon components, they are only suitable for measuring non-aggressive, non-conductive fluids.

The Barometric pressure modules use absolute pressure elements housed within anodised aluminium bodies, with a variety of pressure port connections and sizes being available. Single or multi-channel arrangements can be manufactured and are typically used for air box pressure and aerodynamic pressure tappings.

They have a measuring range of 600mBar with the gain and offset being programmable at our factory depending on the customer requirements.

The Manifold pressure module houses an absolute pressure sensor. As an option, a precision temperature sensor can be included in the package. The module can be sealed to the mounting surface with O-rings.

The Differential pressure module houses a differential pressure sensor which is typically used with a pitot tube to measure air speed for aero-dynamic development. The module has pressure port connections to both sides of the diaphragm and measures the difference between two ports, it is insensitive to absolute pressure. Various pressure ranges are available. The Differential pressure module is available in a single, three channel or 16 channel configuration. The three channel and 16 channel parts are available with 0-5V output or CAN output.

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Pressure Sensors

16-channel Differential Pressure module CAN matrix

CAN COMMUNICATION

The CAN bus will run at 1Mbps and will be configured for 11bit message identifiers.

Between three and six message objects will be implemented; one global configuration message object, one production configuration message (for production test programming of the serial number etc) and up to four data message objects. The number of data message objects will depend upon the mode of operation. In non-multiplexed message mode 4 objects will be required, in full multiplexed mode one message object will be used. Split multiplexed mode will use 2 objects for the data transmission.

The CAN message ID for each of the message objects is defined as an offset from a base CAN message ID except for the production configuration message which will have a fixed ID.

At power up the unit configures the global configuration message object using a base CAN message ID (wDefaultCANBaseID) provided from the EEPROM stored configuration data (nominally 0x300).

The Pin-16 will not transmit any data unless either sent a global configuration message or set to run autonomously.

In order to set up the PIN-16 units they must each be sent a global configuration message to define (amongst other things) a CAN base ID (wGlobalCANBaseID) for the data message. This step may be bypassed by setting the autonomous boot bit in the configuration offcar.

Multiple PIN-16s running on the same CAN bus can then transmit data independently.

Each PIN-16 on the CAN bus checks any incoming global configuration message against its own unique unit serial number and will only act on the message if the serial number contained within the configuration message matches its own.

Once configured each unit will begin transmitting the output data message at the requested rate.

Where multiple PIN-16s communicate over a common CAN link the host sends configuration messages to each PIN-16 in turn. PIN-16's that receive a configuration that does not contain their serial number will ignore the message.

Message Object		Message Object Number	Dir	CAN Message Identification	Message Length (in bytes)
CAN_OBJECT_0	Production Configuration Message (Required for production test only)	0	RX	-	8
CAN_OBJECT_1	Global configuration message	1	RX	wDefaultCANBaseID	8
CAN_OBJECT_2 CAN_OBJECT_3 CAN_OBJECT_4 CAN_OBJECT_5	Output Sampled Data	2 3 4 5	TX	Offsets from GlobalCfgCANBaseID Dependent upon if muxed messaging is in use	8

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Pressure Sensors

Object 0: Production Configuration message object
Used only at the build stage

Object 1: Global configuration message object

<table>
<tr><th colspan="2">RX, CAN Msg ID#</th><th colspan="2">wDefaultCANBaseID</th></tr>
<tr><th colspan="4">Description: Global Configuration Message</th></tr>
<tr><th>Byte</th><th>Generic</th><th colspan="2"></th></tr>
<tr><td>0</td><td rowspan="4">PIN-16 Serial Number (32 Bit)</td><td rowspan="2">Serial number Low</td><td>LSB</td></tr>
<tr><td>1</td><td>MSB</td></tr>
<tr><td>2</td><td rowspan="2">Serial number High</td><td>LSB</td></tr>
<tr><td>3</td><td>MSB</td></tr>
<tr><td>4</td><td>Message Configuration byte</td><td colspan="2">Bit 0 = Autonomous Boot (1=Enable)
Bit 1 = Muxed Messaging (bMuxed)
Bit 2 = Split Muxed Messaging (bSplit)
Bit 3..5 = Transmission Rate (See Table below)
Bits 6..7 = Spare</td></tr>
<tr><td>5</td><td rowspan="2">Can Base Address Identifier (wGlobalCfgCANBaseID) (11 bits)</td><td colspan="2">CAN Base ID (LSByte)</td></tr>
<tr><td>6</td><td colspan="2">Bits 0..2 = CAN Base ID (MS 3 bits)
Bits 3..7 = Spare</td></tr>
<tr><td>7</td><td>Spare</td><td colspan="2"></td></tr>
</table>

Autonomous Boot
If the bAutonomous boot bit is set the unit will store the configuration into the EEPROM and use it, during the next power cycle, instead of waiting for a configuration message before starting to transmit the data. To return to non-autonomous use the unit must be sent another global configuration message without the bAutonomous bit set. This allows the unit to be configured off car in systems where a configuration message is not possible or not required.

Muxed Messaging
If the bMuxed Messaging bit is set the unit will output the CAN messages using the same CAN message identifier. The message data format will be indicated by the first 3 bits of byte 0.

Split Muxed Messaging
If the bMuxed messaging bit and the bSplit Muxed messaging bits are set the unit will split the CAN data across 2 messages so that a higher data rate can be achieved.

Transmission Rate
The transmission rate determines the frequency of the sample data output message.
The Unit will cycle through the Message Numbers in turn at the rate requested, using the message objects available. It will be set via the transmission rate code:

Rate Code	Transmission rate	
0	Off (unit dormant)	
1	1 kHz	Non-muxed Only
2	500 Hz	Non-Muxed / Split Muxed Only
3	200 Hz	
4	100 Hz	
5	50 Hz	
6	20 Hz	
7	1 Hz	

In Non-muxed mode (bMuxed=0) the transmission rate is equal to the message frequency.
In split muxed mode it is twice the message frequency, and in full muxed mode it is four times the message frequency.
If the transmission rate requested is too fast with the mode requested the unit will select the fastest speed available.
If the unit is requested to operate with a transmission rate of 1 kHz and non-multiplexed messaging it will not be compatible with configurable CAN which requires a minimum time between CAN messages of greater than or equal to 2ms.

Serial Number Interrogation
A unit with a programmed serial number will not respond to any messages that do not contain the correct serial number. A unit may return from the field with an unrecorded serial number.
If the unit has been configured in autonomous mode the unit will output the sampled data from power up and this data can be examined to determine the programmed serial number.
However, If the unit is not autonomous the forgotten serial number can still be recovered by sending the unit a global configuration message with a zero serial number. If the unit has not received a valid configuration message since reset it will respond to the message containing a zero serial number as if the correct serial number had been supplied. The output data message (mux value 3) containing the serial number can then be examined to determine the correct serial number.

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Pressure Sensors

Object 2: Output Sampled Data message object
The data message object is transmitted at the rate set by the transmission rate code

Data Coherency Bit
Each Data message contains a coherence bit. This bit is toggled after each message set has been transmitted. The host can use this bit to ensure that all the data was measured during the same sequential scan of the Pitot inputs.

TX, CAN Msg ID#				**wGlobalCfgCANBaseID**				
Description: Output Sampled Data Message (Muxed) (bMuxed = 1, bSplit=0)								
Can Id			Msg Num	Parameter	Data size	Start bit	End bit	Scaling
bMuxed = 0 bSplit = 0	bMuxed = 1 bSplit = 0	bMuxed = 1 bSplit = 1						
BaseCanId + 0	BaseCanId + 0	BaseCanId + 0	0	Mux Value	2	0	1	Mux Value=0
				Pitot 0	11	2	12	11 bit 0-5v
				Pitot 1	11	13	23	11 bit 0-5v
				Pitot 2	11	24	34	11 bit 0-5v
				Pitot 3	11	35	45	11 bit 0-5v
				Pitot 4	11	46	56	11 bit 0-5v
				Config	6	57	61	
				Coherency bit	1	63	63	
BaseCanId +1	BaseCanId + 0	BaseCanId + 1	1	Mux Value	2	0	1	Mux Value=1
				Pitot 5	11	2	12	11 bit 0-5v
				Pitot 6	11	13	23	11 bit 0-5v
				Pitot 7	11	24	34	11 bit 0-5v
				Pitot 8	11	35	45	11 bit 0-5v
				Pitot 9	11	46	56	11 bit 0-5v
				Unit Supply	6	57	62	312.7 mv/bit
				Coherency bit	1	63	63	
BaseCanId +2	BaseCanId + 0	BaseCanId + 0	2	Mux Value	2	0	1	Mux Value=2
				Pitot 10	11	2	12	11 bit 0-5v
				Pitot 11	11	13	23	11 bit 0-5v
				Pitot 12	11	24	34	11 bit 0-5v
				Pitot 13	11	35	45	11 bit 0-5v
				Pitot 14	11	46	56	11 bit 0-5v
				Unit Temperature	6	57	62	2.25 °C/bit
				Coherency bit	1	63	63	
BaseCanId +3	BaseCanId + 0	BaseCanId + 1	3	Mux Value	2	0	1	Mux Value=3
				Pitot 15	11	2	12	11 bit 0-5v
				Serial Number	32	13	44	
				Code Version	16	45	60	
				Spare	2	61	62	
				Coherency bit	1	63	63	

3-CHANNEL DIFFERENTIAL PRESSURE MODULE CAN MATRIX

CAN COMMUNICATION

The PIN-3 will communicate to a host unit via CAN. The CAN bus will run at 1Mbps and will be configured for 11bit message identifiers. Four message objects are implemented; one configuration message object, two data message objects and one configuration message (for production test programming of the serial number).

Where multiple PIN-3s communicate over a common CAN link the PIN-3s are supplied from the same switched supply and start up together. The host unit must be configured with the PIN-3 serial numbers (via configurable data).

The host then sends configuration messages to each PIN-3 in turn. PIN-3's that receive a configuration that does not contain their serial number will ignore the message

The CAN message ID for each of the message objects is defined as an offset from a base CAN message ID except for the configuration message which will have a fixed ID. At power up the unit configures the configuration message object using a base CAN message ID (wDefaultCANBaseID) provided from the configuration data (nominally 0x130).

In order to set up the PIN-3 units they must each be sent a configuration message to define (amongst other things) a CAN base ID (wGlobalCANBaseID) for the data message.

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Multiple PIN-3s running on the same CAN bus can then transmit data independently.

Each PIN-3 on the CAN bus checks any incoming global configuration message against its own unique unit serial number and will only act on the message if the serial number contained within the configuration message matches its own. Once configured each unit will begin transmitting the output data message and the diagnostic data message, if enabled, at the requested rate.

In order to provide a reference to the PIN-3 for input sampling and message transmission, the Sampled Data output message can be transmitted as a remote frame (If selected in the global configuration message). Its transmission time is therefore dictated by the host unit. The transmit interrupt from the CAN controller is then used as the reference point for input processing which is timed to be complete by the next remote frame request. In the absence of a remote request (expected every 1ms (nominal)) a default timer will initiate the sampling and message transmission at 1.2ms (nominal) intervals. The response time for the remote frame request will be approx 300 ms.

Message Object		Message Object Number	Dir	CAN Message Identification	Message Length (in bytes)
CAN_OBJECT_0	Global configuration message	0	RX	wDefaultCANBaseID	8
CAN_OBJECT_1	Production Configuration Message (Required for production test only)	1	RX		8
CAN_OBJECT_2	Output Sampled Data	2	TX	wGlobalCfgCANBaseID	8
CAN_OBJECT_3	Diagnostic Data (if enabled in CAN_OBJECT_0)	3	TX	wGlobalCfgCANBaseID + 1	8

Object 0: Global configuration message object

RX, CAN Msg ID#		wDefaultCANBaseID	
Description: Global Configuration Message			
Byte	Generic		
0	PIN-3 Serial Number (32 Bit)	Serial Number Low	LSB
1			MSB
2		Serial Number High	LSB
3			MSB
4	Message Configuration byte	Bit 0 = Diagnostic data enable/disable (1 = Enable) Bit 1 = Remote Frame enable/disable (1 = Enable) Bits 2..4 = Transmission Rate (See Table below) Bits5..7 = Spare	
5	Can Base Address Identifier (wGlobalCfgCANBaseID) (11 bits)	CAN Base ID (LSByte)	
6		Bits 0..2 = CAN Base ID (MS 3 bits) Bits 3..7 = Spare	
7	Spare		

Pressure Sensors

Diagnostic Data
If the Diagnostic Data bit is set to 0 then no diagnostic data transmission will occur. If set to 1 the PIN33 will transmit the Diagnostic message at the requested transmission rate (1000ms nominal)

Serial number recovery
Should the serial number identification label becomes removed or dislodged from the PIN-3, the unit can be sent a serial number of zero in the Global Configuration message. The unit will treat the message as if the correct serial number is supplied, the diagnostic data can be enabled and the electronic copy of the serial number can then be recovered from the unit.

Transmission Rate
The transmission rate determines the frequency of the sample data output message and the diagnostic data message (if enabled).

If the Remote frame option is configured then the transmission rate time is increased by 20% and used to define the time between automatic transmissions of the message in the absence of a remote frame request receipt.

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