Honeywell Integrated Pressure Transducer

IPT User’s Manual
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1 Introduction

1.1 Overview

The Honeywell IPT provides high accuracy pressure data in an industry standard SPI digital format. The core of the IPT is a proven Honeywell silicon piezo-resistive pressure sensor with both pressure and temperature sensitive elements. The IPT is both small and lightweight and can be easily integrated into a wide variety of applications that require high performance in a small package.

Applying coefficients stored in the on-board EEPROM to normalized IPT pressure and temperature output yields accurate pressure readings over a -40 to 85°C compensated temperature range.

2 Specifications

2.1 Block Diagram
## 2.2 Specifications/Performance

<table>
<thead>
<tr>
<th>Specifications/Performance</th>
<th>Details</th>
</tr>
</thead>
</table>
| **Total Error Band**<sup>(1)</sup> | ±0.04%FS absolute  
±0.10%FS gauge, differential  
±0.20%FS 1 psi gauge |
| **Supply Voltage** | 4 to 12 VDC |
| **Current Consumption** | 6 mA typical, 7.5 mA max |
| **Operating Temperature Range** | -40 to 85°C (-40 to 185°F) |
| **Storage Temperature Range** | -55 to 125°C (-67 to 257°F) |
| **Sample Rate** | See section 3.1.2 |
| **Long Term Stability** | 0.025%FS max per year typical |
| **Pressure Ranges/Type** | 20, 50 psia  
1, 2, 5, 10, 20 psig  
1, 2, 5, 10, 20 psid |
| **Pressure Units** | PSI<sup>(2)</sup> |
| **Media Compatibility** | Non-condensing, non-corrosive, non-combustible gases |
| **Weight**<sup>(3)</sup> | ~ 8.0 grams (absolute)  
~ 9.7 grams (gauge, differential) |
| **Size** | See section 2.3<sup>(3)</sup> |
| **Interface** | 3.3V SPI (mode 1,1)<sup>(4)</sup>  
SCLK ≤ 5 MHz |
| **Output** | 24-bit pressure value  
16-bit temperature value  
256 x 8 EEPROM configuration |
| **Overpressure** | 3X FS |
| **Burst Pressure** | 3X FS |
| **Humidity Sensitivity of Pressure Ports** | DO-160E, Section 6.0, category A<sup>(5)</sup> |
| **Electromagnetic Immunity/Emissions** | DO-160E Section 7.0, Category A, Figure 7.2, Operational Standard |
| **Mechanical Shock** | Storage Temperature Cycling per JESD22-104, Section 5.0: -55°C to +125°C, |
| **Vibration** | DO-160E Section 8, Category H, Aircraft Type 2, Aircraft Zones 1 & 2. |
| **ESD** | Class 3A, Table III, MIL-STD-883G, Method 3015.7, section 3.4 |
| **RoHS Compliant (2011/65/EU)** | Yes |

--- *(1)* Total Error is the sum of worst case linearity, repeatability, hysteresis, thermal effects, and calibration errors over the operating temperature range. Accuracy is only achieved after applying the correction coefficients and algorithm as shown in section 3.2. (FS = Full Scale) For total error calculations of differential units, “Full Scale” is the pressure difference between the minimum and maximum pressures. For example, full scale for a 1 psid PPT is 2 psi (-1 to +1 psi).  
*(2)* After applying the correction coefficients stored in EEPROM, the resultant pressure reading is expressed in PSI (pounds per square inch).  
*(3)* Not including any mounting hardware. Dimensions in section 2.3 do not include Humiseal 1A33 conformal coating which is typically applied to the PWB assembly at a thickness of 1-3 mils.  
*(4)* Operation with a digital interface > 3.3V can damage the IPT and cause shifts in the ADC output.  
*(5)* IPT electronics require protection from humidity.  
*(6)* IPT requires shielding from EMI.
2.3 Outline/Dimensions (inches)

Tolerances not noted: ± 0.005"
2.4 Electrical Connections

2.4.1 Connector

2mm, 2x4 Low Profile Bottom & Top-Entry Connector, Samtec P/N CLT-104-02-L-D-A-K-TR

Connector centered on circuit board and aligned with mounting holes.

Compatible Samtec mating connectors: TMM, MMT, TW, TMMH, MTMM
3 Operation

3.1 Commands and Format

3.1.1 Initialization

The IPT piezo-resistive pressure sensing die contains two bridge circuits; one for pressure, one for temperature. The IPT provides two serial (SPI-compatible) Analog-to-Digital Converters (ADCs), one for each of these data channels. The pressure channel uses a 24-bit ADC from Analog Devices, P/N AD7799. The temperature channel uses a 16-bit ADC from Analog Devices, P/N AD7790. After applying power to the IPT and before obtaining data, each data channel needs to be initialized.

As per the manufacturer’s data sheets, the SPI serial clock for each ADC should be \( \leq 5 \text{ MHz} \). During reads and writes to the ADC’s as detailed below, the appropriate chip-select line must be brought low (CS_P or CS_T).

3.1.1.1 Pressure Channel

The pressure channel ADC is controlled and configured via a number of on-chip registers. ALL communication to the pressure channel ADC starts with a write operation to the 8-bit write-only communication register. Initializing the pressure channel ADC requires writing data to a sequence of four registers; the Communication register, the Mode register, the Communication register, and the Configuration register.

3.1.1.1.1 Communication Register

Sending 0x10 to the Communication register tells the ADC the following write will be to the 16-bit Configuration register.

3.1.1.1.2 Configuration Register

Sending 0x1020 to the Configuration register sets the ADC’s gain and buffering.

3.1.1.1.3 Communication Register

Sending 0x08 to the Communication register tells the ADC the following write will be to the 16-bit Mode register.

3.1.1.1.4 Mode Register

Sending 0x3001 to the Mode register places the ADC into a single conversion mode and sets the update rate, \( f_{\text{ADC}} \) to 470 Hz.

From the AD7799 manufacturer’s datasheet:

“When single-conversion mode is selected, the ADC powers up and performs a single conversion. The oscillator requires 1 ms to power up and settle. The ADC then performs the conversion, which takes a time of \( 2/f_{\text{ADC}} \) [4.26 ms]. The conversion result is placed in the data register, \( \text{RDY} \) goes low, and the ADC returns to power-down mode. The conversion remains in the data register and \( \text{RDY} \) remains active (low) until the data is read or another conversion is performed.”
3.1.1.5 Reading

Note: after initialization is complete, reading the Configuration and Mode Registers is recommended to ensure they have been set as desired. See the AD7799 manufacturer’s datasheet for information regarding reads of the Configuration and Mode registers.

3.1.1.2 Temperature Channel

The temperature channel ADC is controlled and configured via a number of on-chip registers. ALL communication to the temperature channel ADC starts with a write operation to the 8-bit write-only Communication register.

Initializing the temperature channel ADC requires writing data to a sequence of four registers; the Communication register, the Mode register, the Communication register, and the Filter register.

3.1.1.2.1 Communication Register

Sending 0x20 to the communication register tells the ADC the following write will be to the 8-bit Filter register.

3.1.1.2.2 Filter Register

Sending 0x03 to the Filter register sets the ADC’s update rate \( f_{\text{ADC}} \) to 20 Hz.

3.1.1.2.3 Communication Register

Sending 0x10 to the Communication register tells the ADC the following write will be to the 8-bit Mode register.

3.1.1.2.4 Mode Register

Sending 0x80 to the Mode register places the ADC into a single conversion mode.

From the AD7790 manufacturer’s datasheet:

“When single conversion mode is selected, the ADC powers up and performs a single conversion, which occurs after a period \( 2/f_{\text{ADC}} \) [100 ms]. The conversion result is placed in the data register, \( \overline{RDY} \) goes low, and the ADC returns to power-down mode. The conversion remains in the data register and \( \overline{RDY} \) remains active (low) until the data is read or another conversion is performed.”

3.1.1.2.5 Reading

Note: after initialization is complete, reading the Filter and Mode registers is recommended to ensure they have been set as desired. See the AD7790 manufacturer’s datasheet for information regarding reads of the Filter and Mode registers.
3.1.2 Normal Operation (Polling)

3.1.2.1 Pressure Channel

After initializing the Mode register per section 3.1.1.2, a new 24-bit pressure value will be available in ~ 5.26 ms (1 ms settle time + 4.26 ms conversion).

The pressure conversion remains in the data register and DOUT/ RDY remains active (low) until the data is read or another conversion is performed.

The process of reading the conversion and reconfiguring the ADC for single conversion mode requires repeated cycling through the following steps:

1. Wait > 5.26 ms for the conversion to complete, and/or monitor the status of the DOUT/ RDY line.
2. Send 0x58 to the Communications register to indicate a subsequent read of the 24-bit Data register.
3. Send 24 clock cycles to read the 24-bit Data register.
4. Send 0x08 to the Communications register to indicate a subsequent write to the 16-bit Mode register.
5. Send 0x3001 to the Mode register to place the ADC into a single conversion mode and set the update rate to 470 Hz.
6. Repeat

3.1.2.1 Temperature Channel

After initializing the Mode register per section 3.1.1.1, a new 16-bit temperature value will be available in ~ 100 ms. (As temperature is generally a more slowly changing input than pressure, and has a modest impact on the pressure output, this conversion rate should be adequate for most applications.)

The temperature conversion remains in the data register and DOUT/ RDY remains active (low) until the data is read or another conversion is performed.

The process of reading the conversion and reconfiguring the ADC for single conversion mode requires repeated cycling through the following steps:

1. Wait 100 ms for the conversion to complete and/or monitor the status of the DOUT/ RDY line.
2. Send 0x38 to the Communications register to indicate a subsequent read of the 16-bit Data register.
3. Send 16 clock cycles to read the 16-bit Data register.
4. Send 0x10 to the Communications register to indicate a subsequent write to the 8-bit Mode register.
5. Send 0x80 to the Mode register to place the ADC into a single conversion mode.
6. Repeat
3.1.3 Other Modes

The Honeywell IPT has been tested using the “Initialization” and “Normal Polling” as described in sections 3.1.1 and 3.1.2. above.

Both pressure and temperature channel ADCs may also be configured to operate in Continuous Conversion and Continuous Reads modes. Performance should be substantially the same in these alternate modes. However, they have not been thoroughly tested.
3.2 Correction Algorithms

3.2.1 Pressure

One of 2 similar algorithms for converting IPT temperature and pressure channel ADC values into corrected pressure readings is identified for each IPT. (Section 3.3.2.7 describes how the applicable algorithm identity is documented in the IPT EEPROM contents.)

Coefficients (A, a1, a2, etc.) for the identified algorithm are stored in the IPT EEPROM. The algorithm result (Y) is a corrected pressure reading in pounds per square inch (PSI). ADC values from the temperature channel (normalized) are used to correct the readings for thermal effects.

3.2.1.1 Algorithm #1

\[ Y = A + (F_1 \times p) + (F_2 \times p^2) + (F_3 \times p^3) + (F_4 \times p^4) + (F_5 \times p^5) + (F_6 \times p^6) \]

Where:
\[ F_1 = a_1 + (b_1 \times t) + (c_1 \times t^2) + (d_1 \times t^3) + (e_1 \times t^4) + (f_{a1} \times t^5) \]
\[ F_2 = a_2 + (b_2 \times t) + (c_2 \times t^2) + (d_2 \times t^3) + (e_2 \times t^4) + (f_{a2} \times t^5) \]
\[ F_3 = a_3 + (b_3 \times t) + (c_3 \times t^2) + (d_3 \times t^3) + (e_3 \times t^4) + (f_{a3} \times t^5) \]
\[ F_4 = a_4 + (b_4 \times t) + (c_4 \times t^2) + (d_4 \times t^3) + (e_4 \times t^4) + (f_{a4} \times t^5) \]
\[ F_5 = a_5 + (b_5 \times t) + (c_5 \times t^2) + (d_5 \times t^3) + (e_5 \times t^4) + (f_{a5} \times t^5) \]
\[ F_6 = a_6 + (b_6 \times t) + (c_6 \times t^2) + (d_6 \times t^3) + (e_6 \times t^4) + (f_{a6} \times t^5) \]

Output: \( Y = \text{pressure value in PSI} \)

Inputs:
- \( p = 24\text{-bit pressure channel ADC value, normalized 0 – 1} \)
  Normalized pressure channel ADC value = pressure channel ADC value / 16,777,215
- \( t = 16\text{-bit temperature channel ADC value, normalized 0 - 1} \)
  Normalized temperature channel ADC value = temperature channel ADC value / 65,535

3.2.1.1 Horner’s Method, Algorithm #1

Horner’s method is a suggested microcontroller-friendly alternative for evaluating the above equations:

\[ Y = A + p(F_1 + p(F_2 + p(F_3 + p(F_4 + p(F_5 + p(F_6)))))) \]

(6 multiplies, 6 additions)

\[ F_1 = a_1 + t(b_1 + t(c_1 + t(d_1 + t(e_1 + t(f_{a1})))))) \]

(5 multiplies, 5 additions)

\[ F_2 = a_2 + t(b_2 + t(c_2 + t(d_2 + t(e_2 + t(f_{a2})))))) \]

(5 multiplies, 5 additions)

\[ F_3 = a_3 + t(b_3 + t(c_3 + t(d_3 + t(e_3 + t(f_{a3})))))) \]

(5 multiplies, 5 additions)

\[ F_4 = a_4 + t(b_4 + t(c_4 + t(d_4 + t(e_4 + t(f_{a4})))))) \]

(5 multiplies, 5 additions)

\[ F_5 = a_5 + t(b_5 + t(c_5 + t(d_5 + t(e_5 + t(f_{a5})))))) \]

(5 multiplies, 5 additions)

\[ F_6 = a_6 + t(b_6 + t(c_6 + t(d_6 + t(e_6 + t(f_{a6})))))) \]

(5 multiplies, 5 additions)

Total: 36 multiplies, 36 additions
3.2.1.2 Algorithm #2

Differences from Algorithm #1 are highlighted in blue

\[ Y = A + (F_1 \times p) + (F_2 \times p^2) + (F_3 \times p^3) + (F_4 \times p^4) + (F_5 \times p^5) + F_6 \]

Where:

\[ F_1 = a_1 + (b_1 \times t) + (c_1 \times t^2) + (d_1 \times t^3) + (e_1 \times t^4) + (fa_1 \times t^5) \]
\[ F_2 = a_2 + (b_2 \times t) + (c_2 \times t^2) + (d_2 \times t^3) + (e_2 \times t^4) + (fa_2 \times t^5) \]
\[ F_3 = a_3 + (b_3 \times t) + (c_3 \times t^2) + (d_3 \times t^3) + (e_3 \times t^4) + (fa_3 \times t^5) \]
\[ F_4 = a_4 + (b_4 \times t) + (c_4 \times t^2) + (d_4 \times t^3) + (e_4 \times t^4) + (fa_4 \times t^5) \]
\[ F_5 = a_5 + (b_5 \times t) + (c_5 \times t^2) + (d_5 \times t^3) + (e_5 \times t^4) + (fa_5 \times t^5) \]
\[ F_6 = a_6 + (b_6 \times t) + (c_6 \times t^2) + (d_6 \times t^3) + (e_6 \times t^4) + (fa_6 \times t^5) \]

Output: \( Y \) = pressure value in PSI

Inputs: \( p \) = 24-bit pressure channel ADC value, normalized 0 – 1
Normalized pressure channel ADC value = pressure channel ADC value / 16,777,215

\( t \) = 16-bit temperature channel ADC value, normalized 0 - 1
Normalized temperature channel ADC value = temperature channel ADC value / 65,535

3.2.1.2.1 Horner’s Method, Algorithm #2

Horner’s method is a suggested microcontroller-friendly alternative for evaluating the above equations:

\[ Y = A + p(F_1 + p(F_2 + p(F_3 + p(F_4 + p(F_5)))))) + F_6 \quad (5 \text{ multiplies, 6 additions}) \]

\[ F_1 = a_1 + t(b_1 + t(c_1 + t(d_1 + t(e_1 + t(fa_1)))))) \quad (5 \text{ multiplies, 5 additions}) \]
\[ F_2 = a_2 + t(b_2 + t(c_2 + t(d_2 + t(e_2 + t(fa_2)))))) \quad (5 \text{ multiplies, 5 additions}) \]
\[ F_3 = a_3 + t(b_3 + t(c_3 + t(d_3 + t(e_3 + t(fa_3)))))) \quad (5 \text{ multiplies, 5 additions}) \]
\[ F_4 = a_4 + t(b_4 + t(c_4 + t(d_4 + t(e_4 + t(fa_4)))))) \quad (5 \text{ multiplies, 5 additions}) \]
\[ F_5 = a_5 + t(b_5 + t(c_5 + t(d_5 + t(e_5 + t(fa_5)))))) \quad (5 \text{ multiplies, 5 additions}) \]
\[ F_6 = a_6 + t(b_6 + t(c_6 + t(d_6 + t(e_6 + t(fa_6)))))) \quad (5 \text{ multiplies, 5 additions}) \]

Total: 35 multiplies, 36 additions
3.2.2 Pressure Sensor Temperature

Starting in the May 2011 timeframe, coefficients for converting 16-bit Pressure Sensor Temperature values to °C have been appended to the EEPROM contents of new IPT transducers. This supplemental information allows users, if desired, to separately monitor the temperature of the pressure sensor. The algorithm is a simple 3rd order polynomial as described below:

3.2.2.1 Algorithm

\[ Y = g_1 + (g_2 \times t) + (g_3 \times t^2) + (g_4 \times t^3) \]

Output: \( Y \) = pressure sensor temperature in °C

Inputs: \( t \) = 16-bit temperature channel ADC value, normalized 0 – 1:

Normalized temperature channel ADC value = temperature channel ADC value / 65,535

Coefficients (\( g_1, g_2, g_3 \) and \( g_4 \)) for the identified algorithm are stored in the IPT EEPROM.

3.2.2.1.1 Horner’s Method

Horner’s method is a suggested microcontroller-friendly alternative for evaluating the above equation:

\[ Y = g_1 + t(g_2 + t(g_3 + t(g_4))) \]  (3 multiplies, 3 additions)
3.3 EEPROM Storage

3.3.1 EEPROM Format

The IPT transducer uses a 2 Kbit serial EEPROM from Microchip, P/N 25LC020AT-E/MC. The EEPROM is organized as 256 x 8. Reads/writes to the EEPROM should be per the manufacturer’s data sheet. Note: values are stored “big-endian”; most significant bit first.

3.3.2 Contents

3.3.2.1 Pressure Correction Coefficients

The 37 correction coefficients (A through fa6) are stored in 32-bit IEEE 754 format in locations 00 through 93.

Example: $-7.2467064 = \text{C0E7E504}$

3.3.2.2 Full Scale Pressure Range

The IPT full scale pressure range ($FS$) is stored in 32-bit IEEE 754 format in locations 94 through 97.

Example: $20 = \text{41A00000}$

3.3.2.3 Minimum/Maximum Operating/Storage Temperature Limits

IPT operating/storage temperature limits (Min/Max Op/Stor Temp) are stored as 8-bit signed integers in locations 98 through 9B.

Examples: Min Operating $-40 = \text{D8}$
Max Operating $85 = \text{55}$
Min Storage $-55 = \text{C9}$
Max Storage $125 = \text{7D}$

3.3.2.4 Minimum Pressure Output

The minimum pressure output value ($P_{min}$) is the minimum value observed from the pressure channel ADC over the IPT operating temperature/pressure range and is stored as a 24-bit unsigned integer. Location 9C is padded with 00 and $P_{min}$ is stored in locations 9D through 9F.

Example: $1213487 = \text{12842F}$

3.3.2.5 Maximum Pressure Output

The maximum pressure output value ($P_{max}$) is the maximum value observed from the pressure channel ADC over the IPT operating temperature/pressure range and is stored as a 24-bit unsigned integer. Location A0 is padded with 00 and $P_{max}$ is stored in locations A1 through A3.

Example: $11021407 = \text{A82C5F}$
Note: These values can be used to determine if the IPT is being used within its specified operating range. If samples from the pressure ADC are outside this range, the accuracy of the correction algorithm cannot be guaranteed.

3.3.2.6 Minimum/Maximum Temperature Output

The minimum and maximum temperature output values (Min/Max Tout) are the minimum and maximum values observed from the temperature channel ADC over the IPT operating temperature/pressure range and are stored as 16-bit unsigned integers. The minimum value is stored in locations A4 through A5 and the maximum value in A6 through A7.

Examples:
- Min 40175 = 9CEF
- Max 60503 = EC57

Note: These values can be used to determine if the IPT is being used within its specified operating range. If samples from the temperature ADC are outside this range, the accuracy of the correction algorithm cannot be guaranteed.

3.3.2.7 Algorithm/Type, Date

Four unsigned bytes are used to identify the correction Algorithm, IPT transducer Type and the manufacturing Date Code (Algorithm/Type/Date Code) at locations A8 through AB.

The most significant byte is used to identify both the correction Algorithm and IPT type with high nibble for Algorithm and low nibble for Type (shown here in binary).

Algorithm is:
- #1 = 0000b
- #2 = 0001b

Type is defined as:
- Absolute = 0001b
- Gauge = 0010b
- Differential = 0011b

Date is stored using the three remaining bytes in the format of mmddyy.

Example: 010C1B07 = Algorithm #1, Absolute, December 27, 2007
Example: 13060B0A = Algorithm #2, Differential, June 11, 2010

3.3.2.8 Serial Number

The IPT’s serial number (Serial No.) is stored as an unsigned 32-bit value in locations AC through AF.

Example: 1100009827 = 4190D163

3.3.2.9 Honeywell Part Number

The Honeywell part number (Hon. P/N) stored in EEPROM is encoded to form a P/N in the form of 22xxxxxx-0xx or 58xxxxxx-xxx with a special-order code of –Tyyy.

xxxxxxx is 24-bit unsigned value from 000000 to 16777215 and yyy is an 8-bit unsigned value from 00 to 255.
is stored in locations B0 through B2. yyy is stored in location B3.

Examples:

\[
\begin{align*}
2FDDE901 &= \text{Honeywell Part Number 22031370-001} \\
& \quad \text{Special-order code } \sim T001. \\
37107D07 &= \text{Honeywell Part Number 58036087-001} \\
& \quad \text{Special-order code } \sim T007.
\end{align*}
\]

3.3.2.10 Checksum Bytes

Two checksum bytes (Checksum Bytes) are stored in locations B4 and B5. The checksum bytes are stored such that an 8-bit Fletcher checksum calculation (Modulo 256) on the primary storage area (00 through B5) yields a zero for each of the calculated 8-bit Fletcher Checksum values.

In the case of the example Table 1 below, the checksum bytes are B4 and 64. See section 6 for a description of the Fletcher Checksum.

3.3.2.11 Supplemental Information: Pressure Sensor Temperature to °C Coefficients

The 4 correction coefficients (g1 through g4) are stored in 32-bit IEEE 754 format in locations B8 through C7.

Example: \(-1796.9403 = \text{C4E09E17}\)

3.3.2.12 Supplemental Information: “Seed” Values and Corresponding Corrected Pressure

To aid in development and debug of the Pressure Correction Algorithms found in section 3.2.1, a transducer-specific 24-bit Seed Pressure Count (spc), a 16-bit Seed Temperature Count (stc) and the corresponding 32-bit IEEE 754 Corrected Seed Pressure reading (csp) have been stored in the IPT EEPROM:

- The 24-bit spc value is stored in locations C8 through CB with leading zero’s.
- The 16-bit stc value is stored in locations CC through CF with leading zero’s.
- The 32-bit csp value is stored in locations DO through D3 in IEEE 754 format.

3.3.2.13 Supplemental Information: Checksum Bytes

Two checksum bytes (Checksum Bytes) are stored in locations D4 and D5. The checksum bytes are stored such that an 8-bit Fletcher checksum calculation (Modulo 256) on the supplemental storage area (B8 through D5) yields a zero for each of the calculated 8-bit Fletcher Checksum values.

In the case of the example Table 1 below, the supplemental checksum bytes are CB and 1A. See section 6 for a description of the Fletcher Checksum.

3.3.2.14 Unused Locations

Locations B6, B7 and D6 through FF are unused and available for storage of customer information.
### Table 1. EEPROM Map w/ Example Values

<table>
<thead>
<tr>
<th>Description</th>
<th>Inputs</th>
<th>ADDR</th>
<th>Stored Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-10.251645</td>
<td>00</td>
<td>C1 24 06 BD</td>
</tr>
<tr>
<td>a1</td>
<td>-1796.9403</td>
<td>04</td>
<td>C4 E0 9E 17</td>
</tr>
<tr>
<td>a2</td>
<td>-4162.3979</td>
<td>08</td>
<td>C5 82 13 2F</td>
</tr>
<tr>
<td>a3</td>
<td>6.8445935</td>
<td>0C</td>
<td>40 DB 06 E9</td>
</tr>
<tr>
<td>a4</td>
<td>-2651.1321</td>
<td>10</td>
<td>C5 25 B2 1D</td>
</tr>
<tr>
<td>a5</td>
<td>-5778.0547</td>
<td>14</td>
<td>C5 B4 90 70</td>
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<td>00 C9 1 A1</td>
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<td>A4</td>
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<th>01</th>
<th>07</th>
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<th>0A</th>
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<td>Checksum Bytes</td>
<td>byte1</td>
<td>byte2</td>
<td>B4</td>
<td>B4</td>
<td>64</td>
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| q1          | -2882.41  | BB | C5 | 34 | 26 | 8F   |
| q2          | 11581.7   | BC | 46 | 34 | F6 | CD   |
| g3          | -16459.2  | C0 | C6 | 80 | 96 | 66   |
| g4          | 8494.38   | C4 | 46 | 04 | B9 | 85   |
| spc         | 10086589  | C8 | 00 | 99 | E8 | BD   |
| stc         | 41487     | CC | 00 | 00 | A2 | 0F   |
| csp         | 13.9968   | DO | 41 | 5F | F2 | E5   |

| Checksum Bytes | byte1 | byte2 | D4 | CB | 1A |
4 Installation Recommendations

1. IPT media compatibility is non-condensing, non-corrosive, non-combustible gases. To ensure the best transducer performance it is strongly suggested that IPT transducers and associated plumbing be oriented to prevent accumulation of debris or condensation in the pressure ports.

2. Pressure ports P1 and P2 should be shielded from direct light due to a strong photoelectric effect on the sense element.

3. Although conformally coated, electronics should be protected from humidity exposure.

4. Transducer should be mounted to minimize mechanical stress between circuit board and on-board pressure sensor.

5. Although there is no official specification for the SPI interface (a defacto standard), it is intended for short distance on-board communications between a microcontroller or microprocessor (Master) and a peripheral (Slave). To help ensure signal integrity, minimize signal path distance between any Master and the IPT.

4.1 Installation Examples

The three examples below are for illustrative purposes only and do not represent all possible methods of installing the IPT.

4.1.1 Flexible Tubing and Double-wire Hose Clamps

Considerations:

1. Select tubing size/material for the application's temperature and pressure extremes.
2. Ensure hose clamps do no contact any IPT circuitry.
3. Shield port P2 from light due to strong photoelectric effect upon the sense element.
4. Minimize mechanical stress between the circuit board and the on-board pressure sensor.
4.1.2 Static Radial O-ring Seals

Considerations:

1. Select o-ring size/material for the application’s temperature and pressure extremes.
2. Minimize mechanical stress between the circuit board and the on-board pressure sensor.

4.1.3 Static Radial and Face O-ring Seals

Considerations:

1. Select o-ring size/material for the application’s temperature and pressure extremes.
2. Minimize mechanical stress between the circuit board and the on-board pressure sensor.

5 Marking

An adhesive label on the O.D. of the IPT sensor contains the unit's model code, serial number, and date code (MMDDYY).

Example: IPT0020A33R-T003 S/N 2376 081710
6 Fletcher Checksum

6.1 Calculation

The Fletcher checksum calculation results in two sums:

\[
\text{SUM1}[R-1] = D[0] + D[1] + \ldots + D[R-1] \\
\text{SUM2}[R-1] = \text{SUM1}[0] + \text{SUM1}[1] + \ldots + \text{SUM1}[R-1]
\]

where \( R \) = number of bytes in the EEPROM storage area from 00 through B5 (182d), including the check bytes, and where all additions are modulo 256.

If no errors are found, \( \text{SUM1}[R-1] = \text{SUM2}[R-1] = 0 \)

**Example: 4 bytes of data, 2 check bytes, no errors**

<table>
<thead>
<tr>
<th>Hex</th>
<th>Binary</th>
<th>Decimal</th>
<th>SUM1</th>
<th>SUM2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>C0</td>
<td>11000000</td>
<td>192</td>
<td>192</td>
</tr>
<tr>
<td>Data</td>
<td>E7</td>
<td>11100111</td>
<td>231</td>
<td>167</td>
</tr>
<tr>
<td>Data</td>
<td>E5</td>
<td>11100101</td>
<td>229</td>
<td>140</td>
</tr>
<tr>
<td>Data</td>
<td>04</td>
<td>00000100</td>
<td>4</td>
<td>144</td>
</tr>
<tr>
<td>Check Byte #1</td>
<td>ED</td>
<td>11101101</td>
<td>237</td>
<td>125</td>
</tr>
<tr>
<td>Check Byte #2</td>
<td>83</td>
<td>10000011</td>
<td>131</td>
<td>0</td>
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</table>

**Example with single-bit error**

<table>
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<th>Binary</th>
<th>Decimal</th>
<th>SUM1</th>
<th>SUM2</th>
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<td>Data</td>
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<td>00000100</td>
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<td>112</td>
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<td>0</td>
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</table>

**Example with two single-bit errors**

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<th>SUM2</th>
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<tr>
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<td>237</td>
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</table>

**Example with multiple errors**

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