# Interfacing to a Radiation Tolerant DAQ Transducer

## *Transducer Electrical Description*

The transducer outputs values for the six strain gauges that sense the transducer's loading and outputs a value for the temperature of the transducer. All output pairs are differentially driven analog voltages ranging from –10V to +10V. Individual signals in the pairs range from –5V to +5V. Table 1 details the electrical connections for -*OEM* and non -*OEM* transducers. The -*OEM* transducers do not have an external connector while the non -*OEM* transducers do have and external connector.

| Signal Name | Source | -*OEM* PCB Header Pin | Non -*OEM* Receptacle Pin | Description |
|---|---|---|---|---|
| -Vcc | User | 1, 2 | 11, 16 | -15V supply ±10% (100mA) |
| Gnd | User | 5, 6 | 10, 15 | 0V supply |
| +Vcc | User | 3, 4 | 2, 6 | +15V supply ±10% (100mA) |
| G0_out_pos | Transducer | 7 | 1 | Gauge 0 output signal (±5V) |
| G0_out_neg | Transducer | 8 | 3 | Gauge 0 inverted output signal (±5V) |
| G1_out_pos | Transducer | 9 | 7 | Gauge 1 output signal (±5V) |
| G1_out_neg | Transducer | 10 | 12 | Gauge 1 inverted output signal (±5V) |
| G2_out_pos | Transducer | 11 | 17 | Gauge 2 output signal (±5V) |
| G2_out_neg | Transducer | 12 | 20 | Gauge 2 inverted output signal (±5V) |
| G3_out_pos | Transducer | 13 | 8 | Gauge 3 output signal (±5V) |
| G3_out_neg | Transducer | 14 | 4 | Gauge 3 inverted output signal (±5V) |
| G4_out_pos | Transducer | 15 | 13 | Gauge 4 output signal (±5V) |
| G4_out_neg | Transducer | 16 | 18 | Gauge 4 inverted output signal (±5V) |
| G5_out_pos | Transducer | 17 | 9 | Gauge 5 output signal (±5V) |
| G5_out_neg | Transducer | 18 | 5 | Gauge 5 inverted output signal (±5V) |
| T_out_pos | Transducer | 19 | 14 | Temperature output signal (±5V) |
| T_out_neg | Transducer | 20 | 19 | Temperature inverted output signal (±5V) |

Table 1: Transducer Electrical Connections

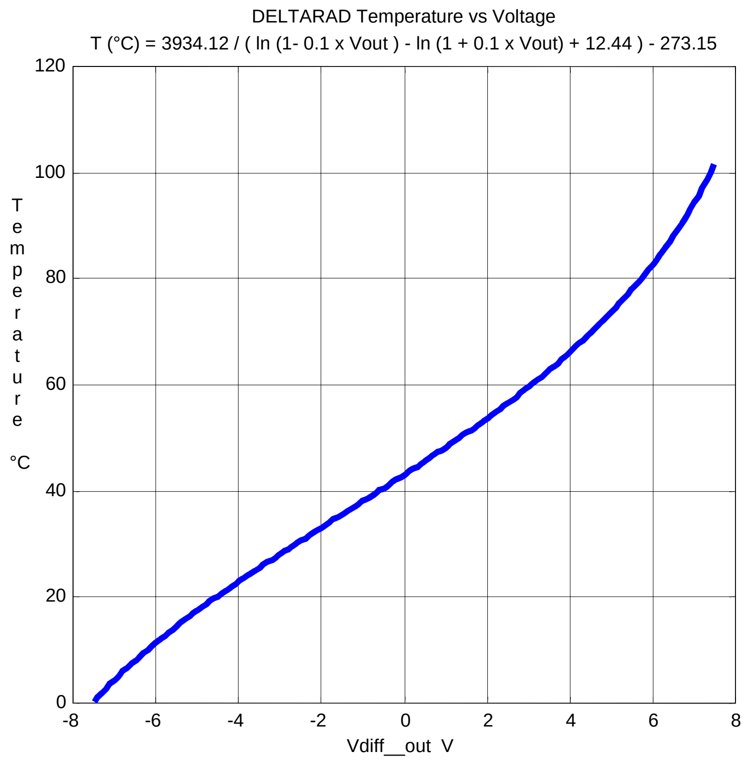
The -*OEM* transducer mates to a Harwin M22-254-1005 or similar 2×10 pinstrip of 0.50mm square pins spaced at 2mm apart. Harwin's web site can be found at http://www.harwin.com.
The non -*OEM* transducer mates to an Hirose HR25-9TP-20S connector. Hirose's web site can be found at http://www.hirose.com.

## *Obtaining Strain Gauge Values*

All gauge outputs are differentially driven by the electronic board of the sensor. The outputs are referenced to ground and must be measured by a differential amplifier. An instrumentation amplifier or equivalent should be used to convert the outputs to single ended. An instrumentation amplifier with a gain of 1 should be used if ±10V range is desired. Each output wire ranges from –5V to +5V. This allows the differential pair to range from –10V to +10V.

## *Temperature Gauge Reading.*

The temperature gauge voltage reading can be used to get the temperature measurement of the sensor. The transfer function is shown in Figure 1 below.




$$T_{^\circ C} = \frac{3934.12}{\ln(1 - 0.1 \cdot V_{out}) - \ln(1 + 0.1 \cdot V_{out}) + 12.44} - 273.15$$

where ln($x$) = natural logarithm of $x$

Figure 1: Temperature Reader Transfer Function

The temperature gauge raw measurements are also used for software post-acquisition temperature compensation. See next paragraph for an example of calculation, more details in the Microsoft Spreadsheet “DAQ FT Manual Calculations.xls” on the CDROM.

## *Software interface with customer application*

The supported way to interface customer application under Microsoft Windows is to use the ActiveX automation server ATIDAQFT.DLL, which must be installed prior to convert the read voltages into force and torque data. Please see the help file on the CDROM for more details. Application examples are supplied on the CDROM for Microsoft VisualBasic and with a Microsoft Excel spreadsheet using the ActiveX automation server.

Another way to interface customer application is to use the C library supplied on the CDROM, in the subdirectory “ATIDAQ C Library”. See “readme.txt” file for more details.

The basic process of calculating forces and torques from the measurements is described in the following section.

## Calculating Force/Torque Values

The transducer's strain gauge readings are representative of the load on the transducer. Each strain gauge reading is a composite of loads in a number of different Cartesian directions. The resolved loads Fx, Fy, Fz, Tx, Ty, and Tz can be extracted from the strain gauge readings with matrix multiplication. The calibration matrix is the result of an accurate calibration of the sensor at ATI.

Resolved output can be figured using the following matrix math:

$$R = V \times C^T$$

where:

- $R$ = 1×6 array of resolved output, Fx, Fy, Fz, Tx, Ty, Tz as true forces and torques
- $C$ = 6×6 calibration matrix array supplied by ATI
- $C^T$ = C transposed
- $V$ = 6×1 array of strain gauge readings expressed in voltage. This may be with or without the mathematical temperature compensation applied. The seventh temperature reading is used for temperature compensation and measurement.

Software temperature compensation can be applied on strain gauge readings V. In this case, compensated values VC are given by

$$VC_i = \frac{V_i + BS_i\left(V_T - V_{Tcal}\right)}{1 - GS_i\left(V_T - V_{Tcal}\right)} \quad \text{(for each gauge reading)}$$

where

- i : number of the considered gauge
- $VC_i$ : temperature compensated reading of gauge i (6 x 1 array in volts)
- $V_i$ : raw reading of gauge i (6 x 1 array in volts)
- $BS_i$ : Bias slope value of gauge i (6 x 1 array unitless, supplied by ATI)
- $GS_i$ : Gain Slope value of gauge i (6 x 1 array in $\text{Volts}^{-1}$ , supplied by ATI)
- $V_T$ : raw reading of current measurement temperature gauge, in volts
- $V_{TCal}$ : raw reading of temperature gauge during ATI's calibration, in volts (supplied by ATI)

Each transducer has an electronic calibration file that is unique to the transducer. The calibration file is named FT*xxxx*.CAL, where FT*xxxx* is the transducer serial number. This file is on the CDROM in the "Calibration" subdirectory. Calibration file FT*xxxx*.CAL can only be read using the ActiveX Automation Server ATIDAQFT.DLL or by the C routine *createCalibration*. To install this ActiveX component, launch setup.exe on the CDROM.

After the installation, the Microsoft Excel spreadsheet "DAQ FT Manual Calculations.xls" can be used to perform example calculations to obtain resolved forces and torques from raw gauges measurements.

Each transducer is also shipped with an ASCII printout of the working calibration matrix, which can be used to customize Voltage to Force/Torque Calculation for a specific application, as explained below.

Example of "How to calculate Force Torque measurements from raw gauge voltages" from FT4179.txt working calibration matrix file.

### 1. Use the most recent F/T Transducer Calibration Information printout whose serial number matches the transducer.

```
F/T Transducer Calibration Information

Serial: FT4179
Body style: Delta
Calibration: SI-660-60
Calibration Date: 09-Aug-01
# Channels: 7     # Axes: 6   Family: DAQ
Output Mode: True Differential
Output Range: 20   Output Polarity: Bipolar
Force Units: N    Torque Units: Nm
Temperature Compensation: Yes

Rated Loads
Fx: 660 N
Fy: 660 N
Fz: 1980 N
Tx: 60 Nm
Ty: 60 Nm
Tz: 60 Nm

Calibration Matrix
     G0           G1           G2           G3           G4           G5
Fx: -7.80631E-01  6.95154E-01 -4.21828E+00 -6.03031E+01 -1.00034E+00  6.07761E+01
Fy:  4.61675E+00  7.19552E+01 -2.34137E+00 -3.57835E+01  8.47541E-01 -3.52083E+01
Fz:  1.12204E+02  1.45867E+00  1.13147E+02 -9.44446E-01  1.12968E+02 -2.46144E-01
Tx:  6.32881E-02  8.74734E-01 -3.92967E+00 -3.71224E-01  3.85507E+00 -4.51821E-01
Ty:  4.46339E+00  3.37424E-02 -2.21578E+00  7.38694E-01 -2.24931E+00 -7.08845E-01
Tz: -1.49923E-01 -2.14664E+00 -1.46360E-01 -2.15315E+00  5.62663E-02 -2.16827E+00

Temperature Compensation Information
BS:  7.71569E-03  1.88744E-02 -6.46388E-03  9.61531E-03  2.33153E-02  1.82687E-02
GS:  1.04166E-03  4.46070E-03  4.96998E-04 -2.46547E-03  2.22370E-03  3.98426E-03
Therm: -3.324620864

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Apex, NC 27502, USA
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```

The Calibration Matrix C is

$$C = \begin{pmatrix} -7.80631E-01 & 6.95154E-01 & -4.21828E+00 & -6.03031E+01 & -1.00034E+00 & 6.07761E+01 \\ 4.61675E+00 & 7.19552E+01 & -2.34137E+00 & -3.57835E+01 & 8.47541E-01 & -3.52083E+01 \\ 1.12204E+02 & 1.45867E+00 & 1.13147E+02 & -9.44446E-01 & 1.12968E+02 & -2.46144E-01 \\ 6.32881E-02 & 8.74734E-01 & -3.92967E+00 & -3.71224E-01 & 3.85507E+00 & -4.51821E-01 \\ 4.46339E+00 & 3.37424E-02 & -2.21578E+00 & 7.38694E-01 & -2.24931E+00 & -7.08845E-01 \\ -1.49923E-01 & -2.14664E+00 & -1.46360E-01 & -2.15315E+00 & 5.62663E-02 & -2.16827E+00 \end{pmatrix}$$

The Bias Slope vector BS for temperature compensation is

$$BS = \begin{pmatrix} 7.71569E-03 & 1.88744E-02 & -6.46388E-03 & 9.61531E-03 & 2.33153E-02 & 1.82687E-02 \end{pmatrix}$$

The Gain Slope vector BS for temperature compensation is

$$GS = \begin{pmatrix} 1.04166E-03 & 4.46070E-03 & 4.96998E-04 & -2.46547E-03 & 2.22370E-03 & 3.98426E-03 \end{pmatrix}$$

The raw reading of temperature gauge during ATI's calibration $V_{TCal}$ is

$VTCal$ = -3.324620864

### 2. Taring the sensor

Prior to measurements, the sensor outputs should be "tared" for an initial load condition. The corresponding gauge voltage vector is called $V_0$ and temperature gauge$VT_0$. All following measurements are then made relatively to the tare value.

*Raw Tare gauge values* $V0 = ($-0.2102 0.0189 -0.2076 0.0058 -0.2098 -0.0133$)$ Volts

*Temperature gauge value at tare*$V_{T0}$=-2.8748 Volts

Measured outputs for the current load condition

*Current gauge values* $V = ($-0.3464 0.3158 -0.3019 -0.0697 -0.3522 0.0817$)$ Volts

*Current temperature gauge value* $V_T$=-2.968 Volts

### 3. Calculate force and torque values (no temperature compensation)

If you want to use temperature compensation, go directly to step 4.

Form the difference between V and V0

*Current Measurement-Tare Reading, no temperature compensation*

| G0 | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| -0.2102 | 0.0189 | -0.2076 | 0.0058 | -0.2098 | -0.0133 |

We can now apply the matrix calculation $R = (V - V0) \times C^T$ to resolve forces and torques relative to the tare value.

*Calibrated Output, No temperature compensation*

| Fx (N) | Fy (N) | Fz (N) | Tx (Nm) | Ty (Nm) | Tz (Nm) |
|---|---|---|---|---|---|
| 0.10 | 0.96 | -70.75 | 0.01 | 0.01 | 0.03 |

### 4. Calculate temperature compensated force and torque values

From the above equation $VC0_i = \dfrac{V0_i + BS_i\left(V_{T0} - V_{Tcal}\right)}{1 - GS_i\left(V_{T0} - V_{Tcal}\right)}$, calculate the compensated values for the tare: We obtain VC0:

*Tare Reading, Temperature Compensated*

| G0 | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| -0.1328 | 0.3060 | -0.0972 | -0.0711 | -0.1320 | 0.1034 |

From the same equation $VC_i = \dfrac{V_i + BS_i\left(V_T - V_{Tcal}\right)}{1 - GS_i\left(V_T - V_{Tcal}\right)}$ calculate the current compensated gauge values VC. We obtain VC

*Current Measurement, Temperature Compensated*

| G0 | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| -0.3438 | 0.3230 | -0.3043 | -0.0662 | -0.3442 | 0.0883 |

Now, form the difference between VC and VC0

*Current Measurement-Tare Reading, Temperature Compensated*

| G0 | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| -0.2110 | 0.0170 | -0.2070 | 0.0049 | -0.2121 | -0.0151 |

and apply the matrix calculation $R = (VC - VC0) \times C^T$ to resolve temperature compensated Forces and Torques relative to the tare value.

We obtain

| *Calibrated Output, Temperature Compensated* | | | | | |
|---|---|---|---|---|---|
| Fx (N) | Fy (N) | Fz (N) | Tx (Nm) | Ty (Nm) | Tz (Nm) |
| 0.05 | 0.91 | -71.04 | 0.00 | 0.01 | 0.04 |

## 5. Temperature measurement

The temperature gauge value of the current reading can be used to calculate the temperature of the sensor by using the transfer function $T_{\circ C} = \dfrac{3934.12}{\ln(1 - 0.1 \cdot V_{out}) - \ln(1 + 0.1 \cdot V_{out}) + 12.44} - 273.15$, where $\ln(x)$ = natural logarithm.

With $V_T$=`-2.968` Volts, we obtain T=28.3°C