Calculation of Temperature Compensated Pressure from Digiquartz® Frequency Output Transducers

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"The standard by which other standards are measured"

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Paroscientific, Inc. designs and manufactures high performance pressure sensors and instruments which are intrinsically digital. The basic building block common to all Paroscientific pressure instruments is our Digiquartz® resonant quartz pressure transducer. Please note that Digiquartz® pressure transducers can be combined with “intelligent” electronics to provide a bi-directional serial (RS-232/485) signal and/or digital display. The following discussion concerns Digiquartz® transducers only; however, should your application require a serial and/or digital display, please see our “intelligent” instruments documentation, or contact us for a detailed description of our “intelligent” products.

Digiquartz® transducers measure pressure by utilizing a force sensitive quartz crystal whose output frequency changes with applied pressure or load. The quartz is excited by a very low power oscillator circuit. Any change in the applied pressure or load will result in a change to the output frequency (or period). Since pressure measurements are compensated for the temperature of Digiquartz® transducers, in addition to measuring pressure frequency output from a transducer, there is a second resonant quartz element which provides a temperature frequency output used to compensate the pressure readings.

For a given temperature, an applied pressure will generate a specific crystal period. Therefore, provided the relationship between crystal period and pressure is known, a measure of the crystal period will indicate the applied pressure. This relationship is usually expressed as the “C, D, Tau” equation. C, D, and Tau are coefficients that are unique to Digiquartz® transducers, and are different for each transducer. In addition, these coefficients are characterized for thermal effects. For each temperature, they are expressed as polynomial expansions with coefficients C1, C2, C3, D1, D2, T1, etc. Typically, it requires between 7 and 10 coefficients to fully describe the relationship (also called the "CD thermal model") between crystal output, temperature, and pressure.

The determination of all coefficients is done at the Paroscientific Calibration Laboratory and is called "calibration". Digiquartz® transducers are calibrated over the full temperature and pressure range, such that the indicated pressure as calculated by the CD thermal model will agree with the true applied pressure with a typical absolute accuracy of ± 0.01 percent of transducer full scale at all temperatures and pressures.

To read pressure from Digiquartz® transducers, you will need a signal processing system capable of reading frequency. Typically pressure frequency varies from 30 kHz to 42 kHz and temperature frequency varies from 168 kHz to 172 kHz. Once the pressure and the temperature frequencies are measured, begin by calculating the temperature according to the following equation:

$$T=Y_1*U + Y_2*U^2 + Y_3*U^3$$

Where
T= Temperature (deg C)
U_0= Temperature period (µsec) at 0 deg C
U= Temperature period (reading in µsec) – U_0 (µsec)

Temperature coefficients (provided): U_0 Y_1 Y_2 Y_3

The results from the above formula will provide the temperature reading from the internal temperature sensor.

Pressure is calculated as follows:

$$P= C^* (1- T_0^2/Tau^2)[1-D^*(1- T_0^2/ Tau^2)]$$

Where
P = Pressure (in psi)
Tau = Pressure Period (µsec)
U = Temperature period (reading in µsec) – U_0 (µsec)
$C = C_1 + C_2*U + C_3*U_2$
$D = D_1 + D_2*U$
$T_0 = T_1 + T_2*U + T_3*U^2 + T_4*U^3 + T_5*U^4$

Pressure coefficients: C_1 C_2 C_3 D_1 D_2 T_1 T_2 T_3 T_4 T_5

Having calculated pressure from frequency and coefficient data, the final pressure output is calculated as below.

$$P_{Output} = PM [(units\ multiplier) \times P + PA]$$

Where
P_{Output} = Final output in pressure units
P = Raw pressure value from equations above (in psi)
PM = Value from transducer datasheet (pressure multiplier)
PA = Value from transducer datasheet (pressure adder)
Units multiplier = Value used to convert psi to another pressure unit.

For reference, the following chart shows the typical wires which are brought out from a Digiquartz® transducer.

Wire Color	Signal
Red	Power
Blue/Black twisted	Pressure signal/ground
White/Black twisted	Temperature signal/ground

Beginning in 2003, some Digiquartz® transducer models are now being shipped with Digiquartz® data storage feature (DDS). DDS is an onboard serial EEPROM that contains calibration and transducer information. This information can be accessed electronically to provide plug and play transducer interchangeability.

If a transducer has the DDS feature, additional wires are bundled separately with a transducer. DDS wires can be distinguished as below.

Wire Color	Signal
White/Brown	SCL (Clock line)
White/Violet	SDA (Data line)
Black	Ground

DDS lines are not required to calculate pressure and temperature values unless you are using the coefficients stored in the instrument.

As mentioned in the introductory paragraph, Paroscientific can provide “intelligent” interface cards or our Model 735 Intelligent Display to convert the output from a Digiquartz® transducer to provide an RS-232/485 instrument which performs the aforementioned calculations real-time.