Inertial Tech Note:

Jewell Instruments Inclinometer Output to Angle Scaling

The Jewell Instruments LSO, LSR, LCF, and LCI series' inclinometers are precision inertial instruments. They utilize closed-loop sensor technology to produce a highly accurate output at a relatively low price for the specified performance. Jewell's inclinometer products are gravity referenced transducers. The sensor output is an analog voltage or current proportional to the sine of the input angle. Please note that gravity-referenced transducers will respond to both earth's gravity (tilt) and acceleration.

The sensing element in a Jewell force balance inertial instrument is the torquer, a meter mechanism designed specifically for sensor use. A torquer used to sense tilt is intentionally unbalanced in its plane of allowable angular motion. When tilt (or acceleration) is present, a torque proportional to the mechanism unbalance and the physical input is developed. The torque results in an angular motion sensed by a position detector. The position detector output is compared to a reference voltage, and the difference is an error signal that is the input to a servo amplifier. The servo amplifier output current is applied to the torquer in opposition to the tilt (acceleration) torque. At a constant inertial input, the torquer mechanism angular position is minutely different from the zero position. The servo amplifier output current is directly proportional to the applied inertial input. Therefore, the servo amplifier output current is proportional to the sine of the input angle or proportional to the input acceleration. Measuring the servo current with a load resistor produces an analog voltage.

Note that an accelerometer and an inclinometer are the same device. The distinction is one of application, not operation. Accelerometer users typically sense changes in velocity and characterize outputs and errors in g. Inclinometer users typically sense changes in angular position and think of outputs and errors in units of angular measurement. Again, inertial instruments respond to both earth's gravity and acceleration.

When using a gravity-referenced transducer to measure tilt, it is important to remember that the sensor is responding to earth's gravity. The relationship between earth's gravity and tilt measured in degrees is trigonometric. Therefore, the following equations must be utilized to determine the angle of inclination from the output of the inclinometer. The equation EQ1 demonstrates the scaling for sensors with a voltage output and equation EQ2 demonstrates the scaling for sensors with a 4-20mA current output.

(EQ1) $\text{Angle}(^\circ) = \sin^{-1}[(V_o - K_o) / K_1]$

(EQ2) $\text{Angle}(^\circ) = \sin^{-1}[(I_o - K_{Io}) / K_{I1}]$

Where:
V_o = Voltage output of the sensor
I_o = Current (4-20mA) output of the sensor
K_o = Bias of sensor in volts
K_{Io} = Bias of sensor in current
K_1 = Scale Factor in V/g
K_{I1} = Scale Factor in mA/g

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The scale factor (V/g) or scale factor (mA/g) has a nominal value listed for each range on the product literature of the sensor. However, the scale factor can be accurately calculated based on the individual data of the particular sensor. In order to calculate the scale factor, the full-scale output must be known. Depending on the model of the sensor, the individual data sheet provided with the sensor indicates either the full-range output or the full-scale output. In the case where the full-range output is provided, the full-scale output can be determined by dividing the full-range output in two. This is demonstrated in EQ3 below. The range of the sensor in “g” is the sine of the range in degrees. Please see EQ4 below. Once the Full-Scale Output and the range of the sensor in g is known, the scale factor can be calculated as demonstrated in EQ5 below.

(EQ3) (FSO) = (FRO) / 2

(EQ4) Sensor range (g) = sin (range of sensor in degrees)

(EQ5) SF (V/g) or SF (mA/g) = (FSO) / range of sensor in g

Where:

FSO = Full Scale Output
FRO = Full Range Output

More information can be found at How Do I Select A Sensor?

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