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OPERATING GUIDE

MODEL SERIES 1050V

LIVM™ FORCE SENSORS

This manual includes:

1) Outline/Installation drawing 1050V
2) Paper, “Low Impedance Voltage Mode (LIVM) Theory and Operation”

* **NOTE: LIVM** is Dytran's trademark for its line of **L**ow **I**mpedance **V**oltage **M**ode sensors with built-in amplifiers operating from constant current sources over two wires. **LIVM** instruments are compatible with most other manufacturers’ comparable systems. **LIVM** systems are compatible with systems designated **IEPE**.

OPERATING INSTRUCTIONS MODEL SERIES 1050V
LIVM (LOW IMPEDANCE VOLTAGE MODE) DYNAMIC FORCE SENSORS

INTRODUCTION

The series 1050v force sensors are designed to measure dynamic forces over a wide dynamic range, e.g., from 10 Lbs full scale to 5000 Lbs full scale over a very wide frequency range, quasi static to 50 kHz.

These sensors are available in six full-scale compression ranges: 10, 50, 100, 500, 1000 and 5000 Lbs input for 5 Volts output. Refer to the chart of ranges and sensitivities in the specification sheet provided with this guide.

Thin x-cut quartz crystal held under very high preload, provide a voltage output analogous to dynamic force inputs when stressed by force. The output polarity is positive-going for compression and negative-going for tension.

An integral IC unity gain amplifier built within the instrument, converts the very high impedance voltage generated by the quartz crystals to a low impedance voltage output signal with excellent noise immunity. These instruments thus are able to drive long cables, unaffected by cable capacitance and by triboelectric noise generated by moving cables.

The integral IC amplifier is powered by simple current source power units. Connections from power unit to force sensor may be made using inexpensive two-wire cable in lieu of coaxial cable if desired.

Model series 1050V features an axial, integral mounting stud (threaded boss) which protrudes from the bottom of the unit. The amplifier is housed within this stud and the electrical connector is at the end of the stud.

DESCRIPTION

Refer to figure 1 below for a representative cross section of Model Series 1050V force sensors.

Series 1050V features an integral threaded (5/16-24 thread) mounting stud, protruding from the bottom surface of the sensor, for convenient mounting where radial space is limited. As previously stated, the internal amplifier is mounted within this hollow stud and the electrical connector is located at the bottom end of the stud.

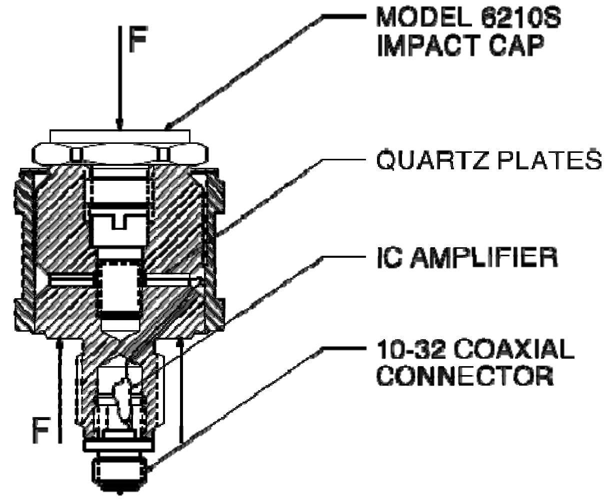

Figure 1
CROSS SECTION, SERIES 1050V

Model series 1050V is recommended, especially, for use where radial space is limited such as in some drop shock testers, in impact hammers or when instrumenting shafts or pushrods where there is no space around the machine for the electrical connector to exit radially.

Referring to Figure 1, the upper female - threaded member (called the platen) distributes the force evenly across the quartz crystals while sealing the instrument against moisture and other contaminants. The very thin quartz crystals comprise a relatively small portion of the length of the sensor which results in a very high stiffness, (high rigidity) thus, high natural frequency. The overall stiffness of this instrument is almost comparable to a solid piece of steel of similar dimension.

Refer to the Outline/Installation drawing, 127-1050V, supplied with this manual, for a dimensioned outline of Model series 1050V.

THEORY OF OPERATION

Refer to Figure 2, below.

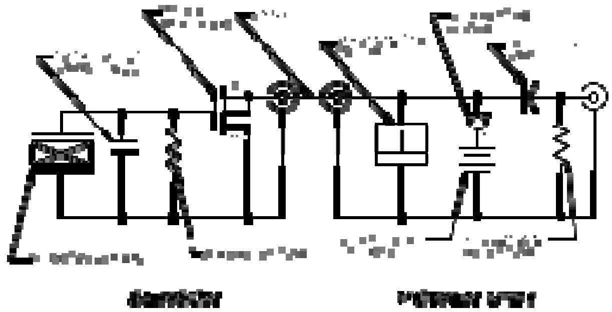

FIGURE 2
SYSTEM SCHEMATIC DIAGRAM

Figure 2 schematically illustrates a typical Sensor/ Cable/Power Unit measurement system. The readout instrument is connected directly to the power unit output signal jack at the right hand side of Figure 2.

The input force stresses (squeezes) the crystals producing an analogous electrostatic charge, Q. The total shunt capacitance (see figure 2) converts this charge to a voltage V. This process is governed by the electrostatic equation:

$$V = \frac{Q}{C} \qquad \text{Eq. 1}$$

where: Q = total electrostatic charge,
C = total shunt capacitance across crystals,
V = resultant voltage across crystals

This voltage V, from the crystals, is connected across the gate of the unity gain MOSFET input IC amplifier where its impedance level is decreased approx. 10 orders of magnitude, i.e., from 1 Terraohm to 100 Ohms.

During normal operation, the source terminal of the IC amplifier in series 1050V is supplied with constant current (in the range of 2 to 20 mA) from the LIVM power unit using a single 2-wire cable (coax, twisted pair, etc.) to connect sensor to power unit. The dynamic force signal from the sensor appears superimposed upon the DC bias level of the internal amplifier. This bias voltage (about +10 Volts DC) is blocked by the circuitry in the power unit and the dynamic voltage signal is passed along to the readout instrument via the Output jack.

Power inputs for the many types of power units available are 115VAC power mains, batteries and +28 VDC aircraft power, among others.

SIGNAL POLARITY

Compressive forces on these sensors (see Figure 1) produce positive-going output signal voltages while tension produces negative-going output signals.

SENSITIVITY

The voltage sensitivity of each sensor is fixed at time of manufacture and cannot be changed. The exact sensitivity of the specific force sensor is given on a calibration certificate supplied with each sensor. Consult the chart for available nominal sensitivities and ranges for each model, in the specification sheet supplied with this guide.

INSTALLATION

Refer to outline/installation drawing 127-1050V, supplied with this guide.

To mount model 1050V, it is necessary to prepare a flat smooth mounting surface of 5/8" (.626") minimum diameter. The surface should be flat to .0005 TIR for best results.

To mount the sensor, drill and tap a thru hole to accept the 5/16-24 thread on the mounting stud to secure the 1050V to its mounting surface. The mounting port must provide for room to connect the cable to the 10-32 connector at the end of the threaded integral mounting stud.

Before mounting the 1050V, thread the sensor into the mounting port and examine the fit of the mounting surfaces. The surfaces must meet parallel, i.e., a wedge must not be formed between these surfaces. Also, at this time, inspect the mating surfaces for foreign particles, which may become lodged between these surfaces and clean if necessary. It is important that the mating surfaces meet squarely and intimately with no particles of foreign matter of any kind included between them.

Foreign particles included between mating surfaces could damage the sensor and/or modify the sensitivity of the sensor.

When you are satisfied that the surfaces are square and clean, place a thin layer of silicone grease on one of the surfaces and thread the force sensor into the tapped mounting port, torquing it in place with 25 to 30 Lb-inches of torque to secure.

For most impact applications, the Model 6210S (steel) impact cap will be utilized. This cap is designed to be threaded into the platen (top surface of the force sensor). Thread this cap securely into the tapped hole in the platen, again inspecting for foreign particles between mating surfaces and clean if necessary. For more permanent installations, thread-locking compounds may be used to secure the installation. Use these compounds sparingly.

For a slightly higher resonant frequency, the aluminum cap, Model 6210A, may be a better choice in some applications.

Connect the sensor to the power unit using Series 6010AXX cable (10-32 to 10-32) or Series 6011AXX (10-32 to BNC plug), depending on the connector called for by the power unit. Tighten the cable lock ring snugly by hand. Do not use a pliers or vise grips on these cable lock rings.

OPERATION

After connecting the cable from the sensor to the power unit, wait several seconds for the internal coupling capacitors to fully charge and for the sensor bias voltage to stabilize. In the higher range units, (1050V4 to V6) the extra-long discharge time constant (2000 Sec.) will require a longer wait to completely stabilize the output voltage level. The instrument may be used before complete stabilization of the sensor bias voltage since the DC bias is blocked within the power unit.

BIAS MONITOR METER

Most Dytran power units feature self-test bias monitoring voltmeters on the front panel to check for normal system operation. This meter will indicate in the mid-scale area (Normal) when the sensor and cable are functioning normally. If the cable is open or disconnected, the meter will read full scale (Open) and if the cable or sensor is shorted, the meter will indicate to the left of the scale limit (Short).

This feature presents the user with a very handy trouble-shooting tool when looking for system problems. Consult the paper, “Low Impedance Voltage Mode (LIVM) Theory and Operation” included with this manual, for a more in-depth description of this feature.

LOADING CONSIDERATIONS, IMPACT

When applying loads to the force sensor, it is important to note that the load must be distributed evenly across the force sensitive face of the force sensor.

For impact measurements, the impact cap accomplishes this adequately in most cases. During impact testing, try to control the impact point so the contact occurs close to the center of the sensor. For more massive objects impacting the sensor, a special thicker cap may need to be employed. Consult the factory for special applications such as this.

Remember also, that the impact caps may be supplied in a variety of materials to suit the exact needs of the measurement. Call the factory to ask about the many different materials available, on special order, to meet your needs.

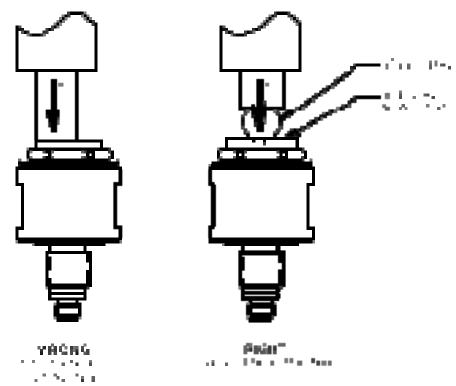

FIGURE 3
ILLUSTRATING OFF-CENTER LOADING

Figure 3 is intended to illustrate the proper way to apply loads to the 1050V. Obviously we cannot address the many different applications but merely want to illustrate, in the most basic sense, the proper and improper ways to apply loads to these instruments for the purpose of heading off measurement problems which may be incurred by improper use.

In the illustration chosen in Figure 3, the force sensor is being loaded dynamically by a hydraulic or pneumatic ram. It is important that the force be evenly distributed, centrally, to the force sensor and the right way would be to use a steel ball to evenly load the sensor through a special adaptor which has been designed to center the ball over the force sensor.

Dytran offers such adaptors as a special order accessory. Our engineering department and our state of the art machine shop are at your disposal for the design and fabrication of such adaptors. Call the factory for assistance with your particular measurement problem.

TENSILE LOADING

Figure 4 illustrates one proper way to load the 1050V in tension. Again, the forces must travel through the center of the sensor.

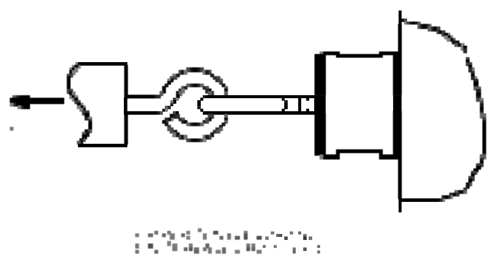

FIGURE 4
PROPER TENSILE LOADING

The arrangement shown in Figure 4 ensures that the load is applied centrally to the sensor without bending moments and transverse loading.

One important point to keep in mind when making tensile measurements is that, due to limits in the design of the internal preload structure of these sensors, the **maximum tensile force is limited** to **1000 Lbs**. in this series. If this level is exceeded, the sensor may be destroyed and the load will be suddenly released. This could engender dangerous situations for personnel and equipment if this eventuality is not fully understood.

Remember that the maximum force is the combination of both static and dynamic tensile forces. For example, if the sensor is supporting a static load of 500 Lbs., the maximum dynamic range possible is ±500 Lbs.

QUASI-STATIC CONSIDERATIONS

The discharge time constant of the Model series 1050V, especially for the higher ranges, is long enough to allow near static measurements to be performed. However, it is important to consider other coupling time constants in the measurement system that could effect quasi-static measurements, such as the value of the coupling capacitor in the power unit.

As previously stated, the integral IC amplifier in the LIVM sensor is powered by a single coaxial cable. This cable supplies anywhere from 2 to 20 mA of current from the power unit. (Refer to Figure 5 below.)

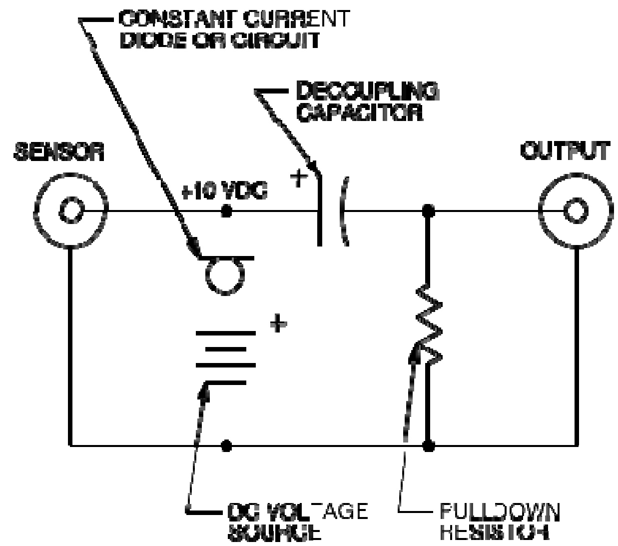

FIGURE 5
POWER UNIT DECOUPLING CONSIDERATIONS

The voltage produced by dynamic force acting upon the crystals is superimposed upon the fixed bias voltage of the internal IC.

Most power units are AC coupled, i.e., the bias voltage is “blocked” by a capacitor (usually 10 uF) within the power unit as shown in Figure 5. This effectively returns the signal level to zero volts.

A potential problem with this is that the readout instrument puts a resistive load at the output terminal of this coupling capacitor which forms a high pass filter. This filter limits the low frequency response of the power unit making the system unsuitable for quasi-static measurements.

In most Dytran AC coupled power units, a “pulldown:” resistor (usually 1 Megohm) is placed across the output jack of the power unit (Refer to Fig. 5) to reduce the amount of DC offset which would result from leakage from the 10 uF tanalytic capacitor used in the output decoupling circuit. This further exacerbates the problem raising the low frequency cutoff frequency still higher.

As an example, lets assume your readout instrument has a 1 Megohm input resistance. This appears in parallel with the 1 Megohm pulldown resistor to place a 500 kΩ load across the 10uF capacitor. The coupling time constant (TC) is:

TC = RC = 500,000 x 10uF = 5 Seconds

The low frequency cutoff is:

$$f_l = \frac{1}{2\pi RC} = \frac{.16}{5} = .032 \text{ Hz}$$

The first 10% of the RC discharge curve is relatively linear so we may say that in order to make a measurement with 1% accuracy, the total elapsed time of the measurement of a static event must be less that 1% of the discharge TC

With a discharge TC of 5 seconds, we may calculate the time to take a 1% reading.

T = 1% x 5 = 0.50 Seconds.

This result states that we have a maximum of 0.5 seconds to take the reading after the application of the static force. This of course, is very difficult to do without the use of a digital storage oscilloscope. A better solution is to use a power unit, which does not use a de-coupling capacitor, but rather a DC coupled voltage level shifting circuit.

The Dytran Model 4115B is such a power unit. (Refer to simplified schematic, Figure 6) In the Model 4115B, the input signal from the sensor is applied to a DC coupled summing amplifier. A variable negative DC voltage is applied to the negative terminal of the summing amplifier. By adjusting this negative voltage to exactly the amplitude of the positive DC bias voltage from the sensor, the output of the 4115B may be set precisely to zero volts, and with the discharge time constant limited only by the TC of the sensor itself. Model 4115B is virtually unaffected by readout load.

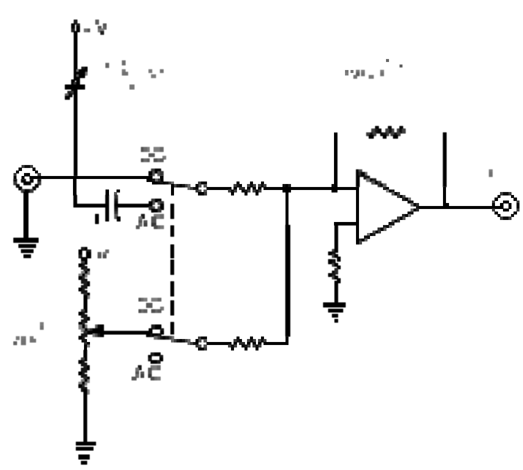

FIGURE 6
SIMPLIFIED SCHEMATIC, 4115B

CALIBRATION

Since the Model 1050V sensors are dynamic sensors, i.e., sensors designed to measure dynamic (rapidly changing) forces, it makes sense to calibrate them dynamically.

These sensors are calibrated at the factory by placing a traceable force on them, then rapidly removing it and capturing the resultant negative-going step function on a digital storage oscilloscope. This is a very accurate and repeatable method for calibration of these sensors.

It is recommended that these sensors be returned to the factory for periodic recalibration with frequency of calibration determined by the usage factor.

MAINTENANCE AND REPAIR

The sealed construction of Series 1050V precludes field maintenance. Should you experience a problem with your sensor, contact the factory to discuss the problem with one of our sales engineers. If the instrument must be returned to the factory, you will be issued a Returned Materials Authorization (**RMA**) number so we may better follow the instrument through the evaluation process. Please do not return an instrument without first obtaining the RMA number. There is no charge for the evaluation and you will be notified of any charges before we proceed with a repair.