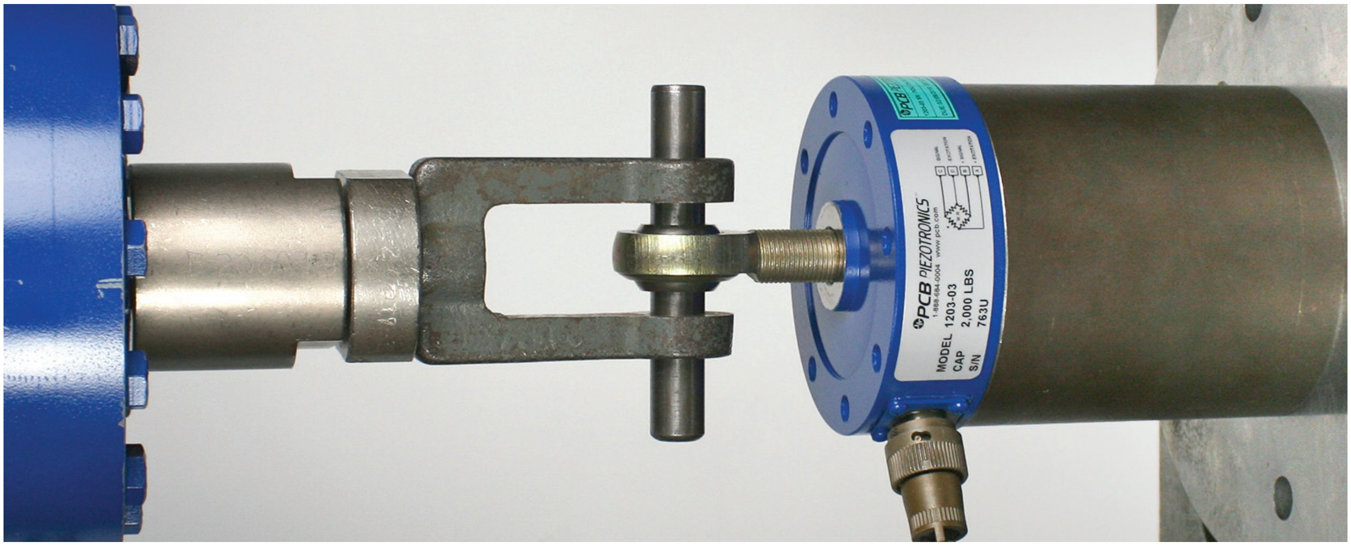
PCB PIEZOTRONICS
MTS SYSTEMS CORPORATION



LOAD CELLS

AN OVERVIEW OF THEIR DESIGN AND APPLICATION

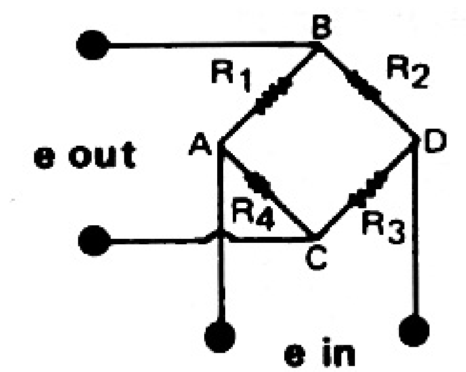
Written By
Kenneth Watkins

Load Cells
An Overview of their Design and Application

Principle of Operation

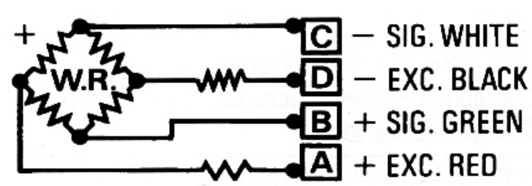
PCB Load & Torque, Inc. load cells consist of specially designed structures which perform in a predictable and repeatable manner when a force is applied. The force applied is translated into a voltage by the resistance change in strain gages which are intimately bonded to the transducer structure. The amount of change in resistance indicates the magnitude of deformation in the transducer structure and hence the load the applied.

The strain gages are connected in a four arm Wheatstone Bridge configuration, which acts as an adding and subtracting electrical network and allows for compensation for temperature effects as well as cancellation of signals caused by extraneous forces.



A regulated 5 to 20 volt DC or AC rms excitation is required and is applied between A and D of the bridge. When a force is applied to the transducer structure the Wheatstone Bridge is unbalanced causing an output voltage between B and C which is proportional to the applied load.

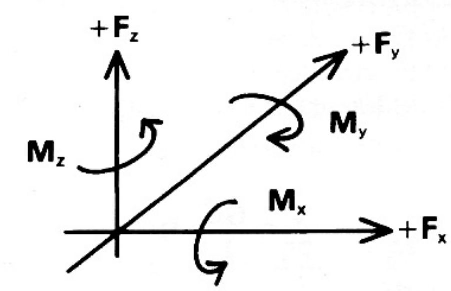
Most all load cells manufactured by PCB Load & Torque, Inc. follow a wiring code established by the Western Regional Strain Gage committee as revised in May 1960. The code is as follows:



Axis Definition

PCB Load & Torque, Inc. products comply with the Axis and Sense Definitions of NAS-938 (National Aerospace Standard-Machine Axis and Motion) nomenclature and recommendations of the Western Regional Strain Gage committee.

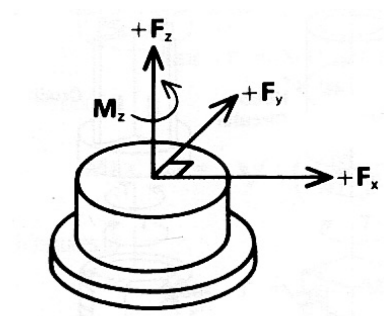
These axes are defined in terms of a “Right Handed” orthogonal coordinate system as show below:



A “+” sign indicates force in a direction which produces a “+” signal voltage and generally defines a tensile force.

The principal axis of a transducer is normally the Z axis. The Z axis will also normally be an axis of radial symmetry or axis of rotation. In the event there is no clearly defined axis, the following preference system will be used Z, X, Y.

The illustration below shows the axis and sense nomenclature for load cells supplied by PCB Load & Torque, Inc.:



Load Cell Structure Design

The most critical mechanical component in any strain gage based load cell is the “Spring Element”. In general terms, the spring element serves as the reaction to the applied load and focuses that load into a uniform, calculated strain path for precise measurement by the bonded strain gage. PCB Load & Torque, Inc. utilizes three basic load cell structure designs: Bending beam, column, and shear.

Bending Beam:

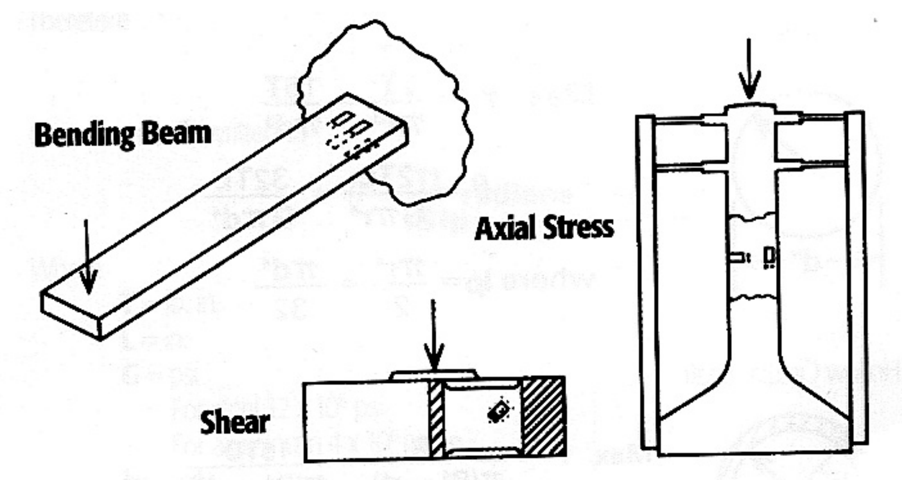
Load Cell spring elements that employ the bending beam structure design are the most common. This is because the bending beam is typically a high-strain, low force structural member that offers two equal and opposite surfaces for strain gage placement. At PCB Load & Torque, Inc. the bending beam design is typically used lower capacity load cells (≤ 5,000 lbs).

Column:

The column type load cell is the earliest type of strain gage transducer. Although simple in its design, the column spring element requires a number design and application considerations. The column should be long enough with respect to its cross section so that a uniform strain path will be applied to the strain gage. In application the end user must beware of second order effects as the column load cell is susceptible to the effects of off-axis loading.

Shear-Web:

The principal of Shear-Web load cell typically takes the form of a cantilever beam which has been designed with a cross section larger than normal with respect to the rated load to be carried in order to minimize structure deflection. Under this condition, the surface strain along the top of the beam would be too low to produce an adequate electrical output from the strain gage. However, if the strain gages are placed on the sides of the beam at the neutral axis, where the bending stress is zero, the state of stress on the beam side in one of pure shear, acting in the vertical and horizontal direction.



Load Cell Classification

PCB Load & Torque, Inc. manufactures load cells under two classifications – General Purpose and Fatigue Rated.

General Purpose:

General purpose load cells are designed for a multitude of applications across the automotive, aerospace, and industrial markets. The general purpose load cell, as the name implies, is designed to be utilitarian in nature. Within the general purpose load cell market there are several distinct categories: precision, universal, weigh scale, and special application. PCB Load & Torque, Inc. primarily supplies general purpose load cells into the universal and special application categories. Universal load cells are the most common in industry.

Special application load cells are load cells that have been designed for a specific unique force measurement task. Special application load cells can be single axis or multiple axis. PCB Load & Torque, Inc. offers a wide range of special application load cells especially for the automotive market, such as:

- Pedal Effort
- Crash Barrier
- Bumper Impact
- Tire Test
- Hand Brake
- Skid Trailer
- Steering Column
- Road Simulator

Fatigue Rated:

Fatigue rated load cells are specially designed and manufactured to withstand millions of cycles. PCB Load & Torque, Inc. utilizes premium fatigue resistant steel and special processing to insure mechanical and electrical integrity as well as accuracy. Fatigue rated load cells manufactured by PCB Load & Torque, Inc. are guaranteed to last 100 million fully reversed cycles (full tension through zero to full compression). An added benefit of fatigue rated load cells is that they are extremely resistant to extraneous bending and side loading forces.

Error Analysis

PCB Load & Torque, Inc. typically supplies accuracy information on its products in the form individual errors. They are: Non-Linearity, Hysteresis, Non-Repeatability, Effect of Temperature on Zero Unbalance, and Effect of Temperature on Output.

The customer can combine these individual errors to establish the maximum possible error for the measurement or just examine the applicable individual error. If the temperature is stable during the test, the temperature related errors can be ignored. If the sensor is used for increasing load measurement only, then the Hysteresis error can be ignored. If the load measurement is near the full capacity, the linearity error can be ignored. If the capability exists to correct the data through linearization-fit or a look-up-table, the error in the measurement can be minimized. A sophisticated user can get rid of all the errors except for the non-repeatability error in his measurement.

Often overlooked is the error due to the presence of non-measured forces and bending moments. Even though the Single Axis of Measurement sensors are designed and built to withstand these non-measured forces and bending moments (extraneous loads), the errors due to them are present. The Measurement Engineer can design the set-up to eliminate or minimize these extraneous loads. However, if these extraneous loads are present, the errors due to them should be considered.

Due to cost restraints, PCB Load & Torque, Inc., as with its competition, does not typically measure or compensate for errors due to extraneous loads. If the presence of these extraneous loads is known, the user should request the transducer manufacturer to run a special test at extra cost to define and quantify the extraneous load errors. These errors are defined as cross-talk errors.

Typical Application Examples

- Hydraulic Actuators
- Material Fatigue Testing
- Life Cycle Testing
- Torque Arm
- Quality Control
- Tank Weigh

Application Questions

1. **Determine the capacity required:**
   A. What is the maximum expected load?
   B. What is the minimum expected load?
   C. What is the typical expected load ?
   D. What are the dynamics of the system, i.e. frequency response?
   E. What are the maximum extraneous loads that the load cell will be subjected to?

2. **How will the load cell be integrated into the system:**
   A. What are the physical constraints, i.e. height, diameter, thread?
   B. Will the load cell be in the primary load path or will the load cell see forces indirectly?

3. What type of environment will the load cell be operating in?

A. Maximum temperature?

B. Minimum temperature?

C. Humidity?

D. Contaminants, i.e. water, oil, dirt, dust,?

4. What accuracy is required?

A. Non-Linearity?

B. Hysteresis?

C. Repeatability?

D. Cross-talk?

MTS SYSTEMS CORPORATION

3425 Walden Avenue, Depew, NY 14043-2495 USA
Toll-Free in the USA: **800 828 8840**
Phone: **1 716 684 0001** | Email: **info@pcb.com**

PCB Piezotronics, Inc. is a designer and manufacturer of microphones, vibration, pressure, force, torque, load, and strain sensors, as well as the pioneer of ICP® technology used by design engineers and predictive maintenance professionals worldwide for test, measurement, monitoring, and control requirements in automotive, aerospace, industrial, R&D, military, educational, commercial, OEM applications, and more. With a worldwide customer support team, 24-hour SensorLine℠, and a global distribution network, PCB® is committed to Total Customer Satisfaction. Visit www.pcb.com for more information. PCB Piezotronics, Inc. is a wholly owned subsidiary of MTS Systems Corporation. Additional information on MTS can be found at www.mts.com.

WPL_24_0319

MTS Sensors, a division of MTS Systems Corporation (NASDAQ: MTSC), vastly expanded its range of products and solutions after MTS acquired PCB Piezotronics, Inc. in July, 2016. PCB Piezotronics, Inc. is a wholly owned subsidiary of MTS Systems Corp.; IMI Sensors and Larson Davis are divisions of PCB Piezotronics, Inc.; Accumetrics, Inc. and The Modal Shop, Inc. are subsidiaries of PCB Piezotronics, Inc.