MTS FSE MODULAR TRAINING

Transducers

January 14, 2019 Rev B

be certain.

Transducer Definition

» Transducer = A device that converts variations in a physical quantity such as force, displacement, pressure, or others into an electrical signal, or vice versa.

- Examples of common transducers:
  - » A microphone converts sound into an electrical signal
  - » A speaker converts an electrical signal into sound
  - » An electronic thermometer converts temperature into an electrical signal

Common Transducers used on MTS Equipment

Transducer Type	Physical property measured
Load Cell	Axial Force
LVDT	Linear Displacement (Distance)
Temposonics	Linear Displacement (Distance)
Extensometer	Strain or Linear Displacement
Torque Cell	Torsional Force
RVDT	Angular Displacement (Rotation)
ADT	Angular Displacement (Rotation)
Encoder	Angular Displacement (Rotation)
Axial / Torsional Load Cell	Axial Force and Torsional Force in one transducer
Pressure Cell	Pressure
Thermocouple	Temperature

Terminology

- Excitation is the voltage sent from the controller to the transducer
  - This is used to supply power to the transducer
  - Can be ether an AC voltage or a DC voltage depending on the transducer
- Feedback is the voltage from the transducer
- Full Scale of the transducer is the maximum measurement capacity of the transducer
- Polarity indicates direction of force or travel
  - Polarity is selectable to meet customer requirement
- Sensitivity is the amount of signal output from the transducer at the rated capacity of the transducer

TEDS

- Controllers that use Series 494 Hardware support the use of MTS *TEDS (*transducer electronic data sheet) sensors.
- TEDS sensors have built-in memory chips that store basic TEDS information (manufacturer, model, number, and serial number).
- 793 software and 494 Hardware only supports Basic TEDS.
- Basic TEDS does not support any level of calibration information. However, it does provide a way to uniquely identify a transducer.
- In 793 V5.0 and later, the Basic TEDS information will be used to look up the sensor calibration file (.scf) that matches the information on the TEDS ID Module.
- The .scf file has to be stored locally on the customer's PC.

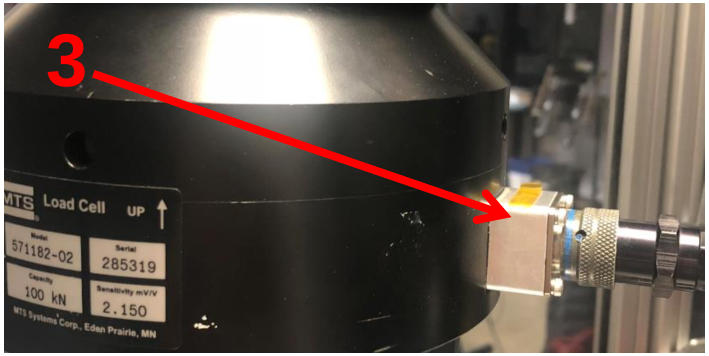
TEDS

» Displayed are some examples of TEDS ID Modules on devices.

1. LVDT's on actuators.

2. Adaptor cables for extensometers and any other devices that do not have TEDS ID Modules built in.

3. Load Cells.



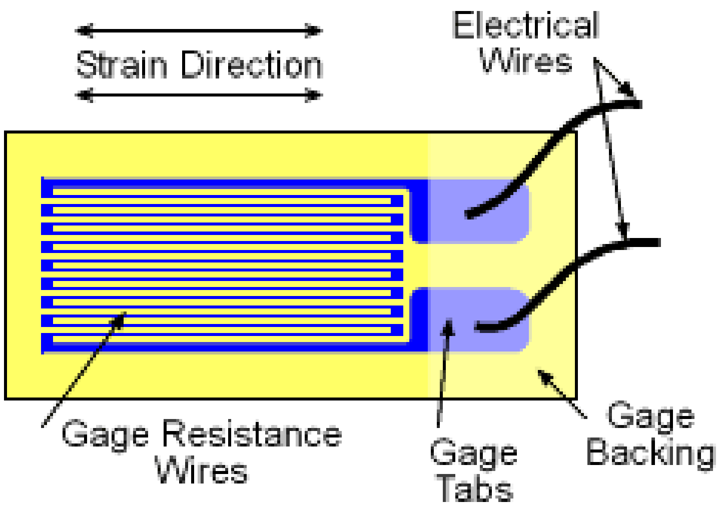
Axial Load Cell

» An axial load cell measures force in the direction of the primary axis of the transducer

» The output of the load cell is proportional to the amount of force applied

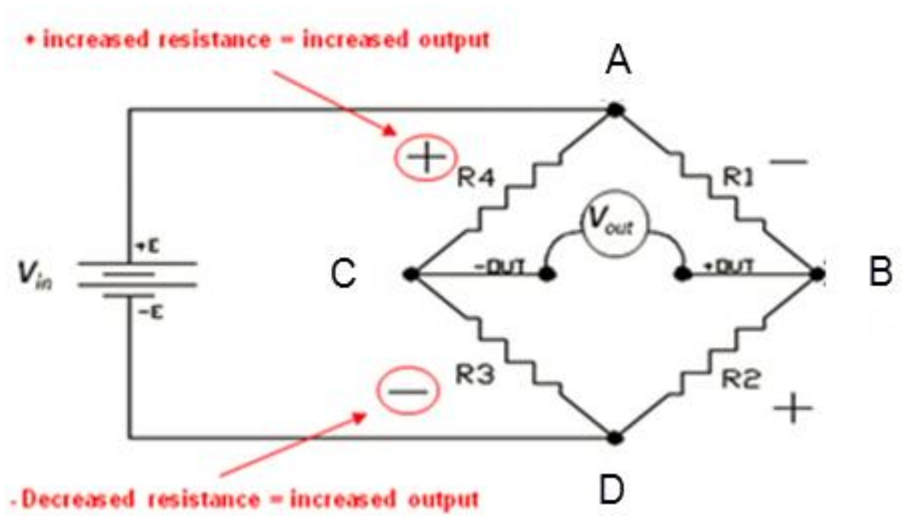
The Strain Gauge

- » A load cell has strain gages bonded to columns or beams inside the load cell
- » A strain gage is a very small device which is bonded to the metal and changes resistance as the load cell columns, beams, or webs expand and compress when force is applied.



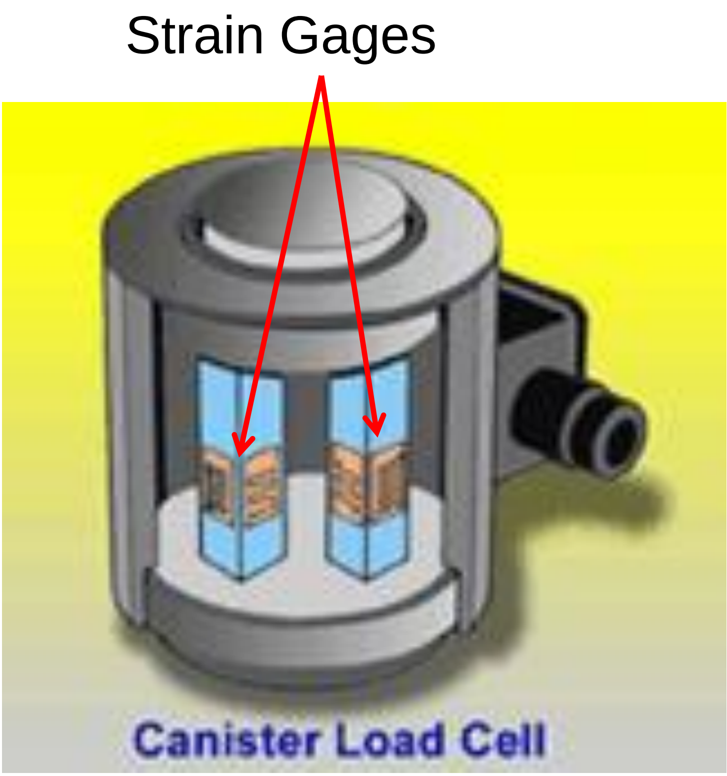
Load Cell Construction

» The strain gages are connected in a Wheatstone bridge configuration
  - The strain gages change resistance as force is applied which creates an imbalance in the bridge resulting in an electrical output proportional to the force applied
  - Excitation from the controller is applied to A and D
  - Feedback is measured at B and C



Load cells

» An example of the internal construction of a load cell with strain gages bonded to columns



Load Cell Sensitivity

» Load cells are specified using sensitivity
  - This is the output of the load cell at rated capacity
  - Typical sensitivity is 2 mV/V nominal
  - Outputs 2 mV for every volt of excitation at transducer full scale
  - Some low force load cells have a sensitivity of 1 mV/V nominal
  - High output load cells can be up to 5 mV/V nominal

» MTS uses DC excitation for these transducers
  - 10.000 VDC typical excitation

Load Cell Sensitivity Example

- Example: A 100 kN load cell is rated at 2 mV/V.
- With 1 volt DC excitation applied the load cell would output 2 mV DC when a 100 kN force is applied.
- Using the standard 10.000 volts excitation the load cell would output 20 mV when a force of 100 kN is applied (2 mV/V output X 10 volts excitation)
  - Since output is proportional to force this load cell configuration would output 2 mV at 10 kN, 10 mV at 50 kN, etc…
- This tiny voltage needs to be amplified by the conditioner or controller to a usable level. For a 2 mV/V cell the nominal gain is 500.
  - MTS controllers operate on +/- 10.000 Volts
  - 20 mV X 500 = 10000 mV or 10.000 Volts

Load Cell Polarity

» There is no standard for load cell polarity
  - Customer can select desired polarity

» The normal polarity for a load cell used on a load frame is a tensile force is positive and a compressive force is negative
  - Example: On a 100 kN load cell used on a load frame
  - + 100 kN is maximum tensile force
  - - 100 kN is maximum compressive force

» It is common in the automotive market for either up or into the vehicle to be positive force
  - This usually results in a compressive force being positive.
  - This is usually the opposite of a load frame implementation

Load Cell Types

» There are many types of load cell designs available.
  - Design depends on capacity and other requirements
  - All work on the same principle

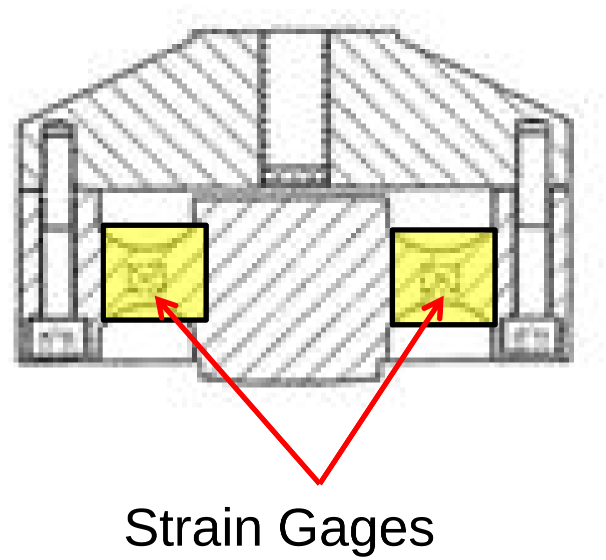
S-Beam Load Cell

» The S-Beam design load cell is one where the structure is shaped as an 'S' or 'Z' shape.
  - Used in low force applications
  - MTS model 661.09

» The strain gauges are bonded to the central sensing area.

Web type Load Cell

- The shear web design load cell is one of the most common load cells in use at MTS.
  - Used in medium force applications
  - MTS model 661.19 and 661.20
- The strain gauges are bonded to the web in the center of the sensing area.



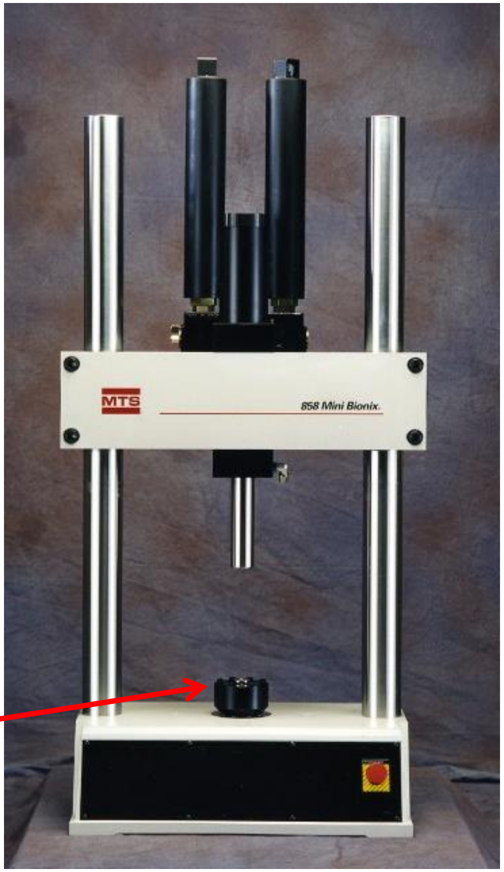
Column Type Load Cell

- » This type of load cell is used in high force applications
  - Typically 250 kN (55 kip) and larger
  - MTS model 661.22

Load Cell Installation

- Load cells should be installed on the stationary side of the test system opposite the actuator
- This is to eliminate measuring moving mass which causes false readings and stability problems with controlling the actuator

Load Cell mounted on stationary side of test system



Load Cell Installation

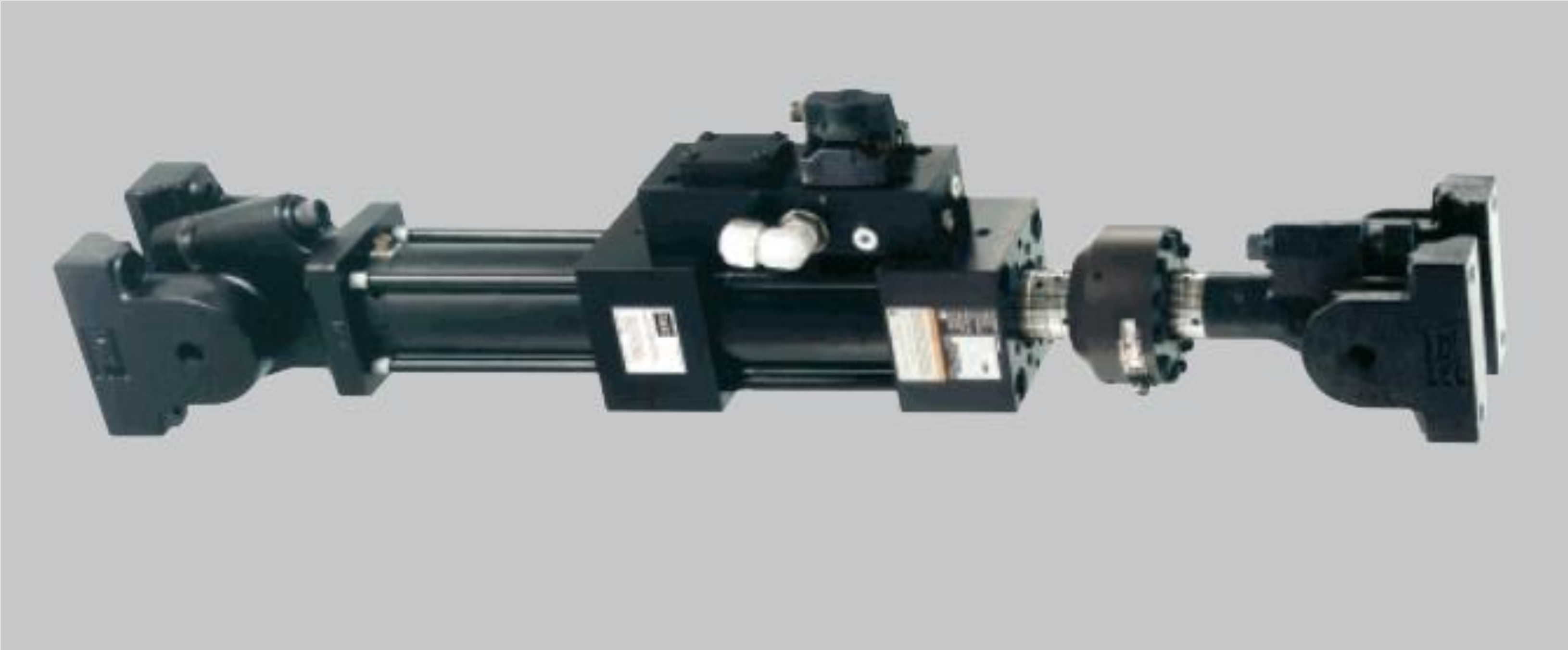
- Load cells have a mounting side and a reaction side.
- Mount the load cell so the specimen is connected to the reaction side of the load cell

Mounting Side – To Load Frame Crosshead

Reaction Side – To Specimen

Load Cell Installation

» If the load cell must be mounted on the actuator be sure to install with the mounting side (base) to the actuator rod and reaction side to the specimen



Load Cell Stud Installation

- When inserting a stud into a load cell it should never be inserted until it bottoms out. This will cause errors in the calibration

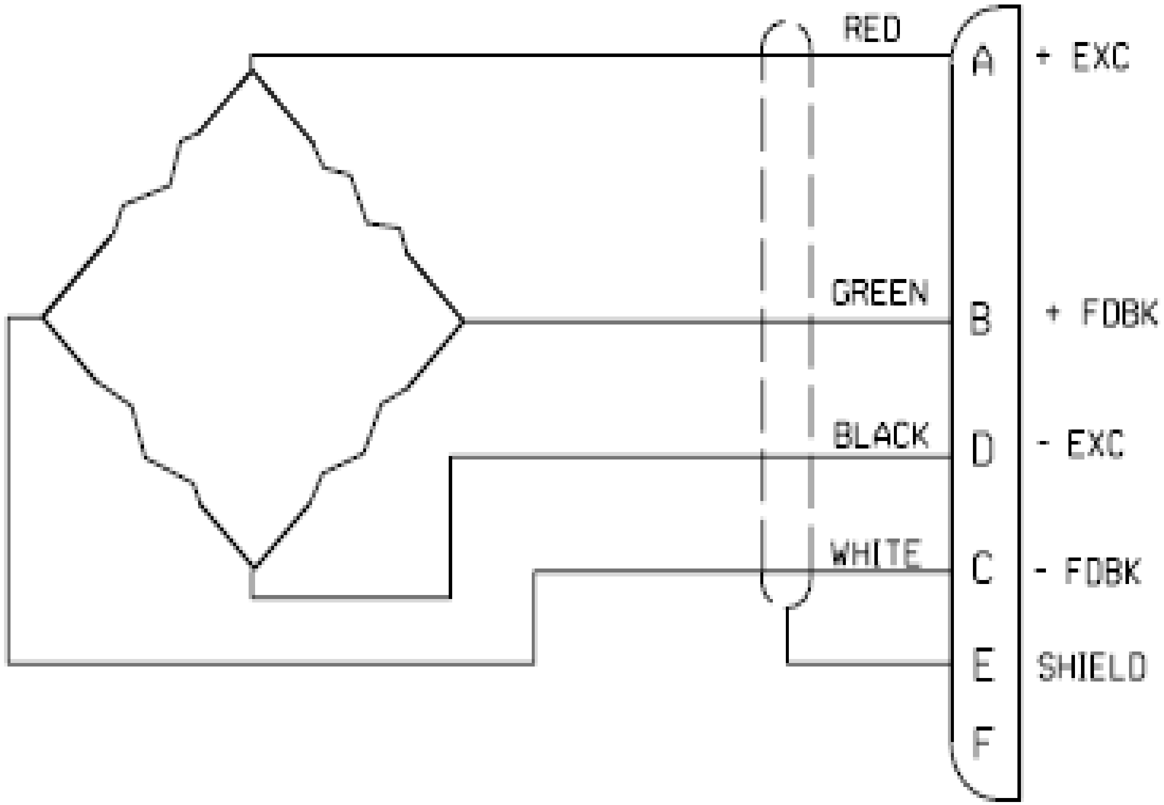
- Prior to installing a stud into a load cell you should insert a thin piece of compliant material such as cardboard into the load cell to prevent the stud from having direct contact with the bottom surface of the load cell threads.

- To ensure the stud does not pull out of the load cell the minimum thread engagement is 1 times the thread diameter of the stud.

- Example: A typical 100 kN load cell uses a 27 mm diameter thread. The stud must be inserted at least 27 mm deep to ensure it does not pull out when loaded to maximum capacity.

Typical Load Cell Wiring

» MTS 6 pin load cell connectors typically use the wiring shown below



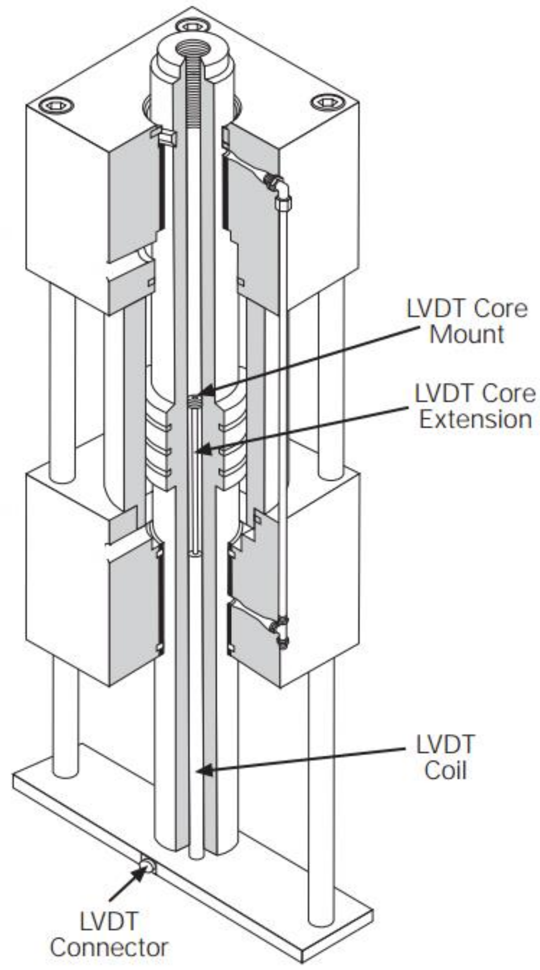
LVDT

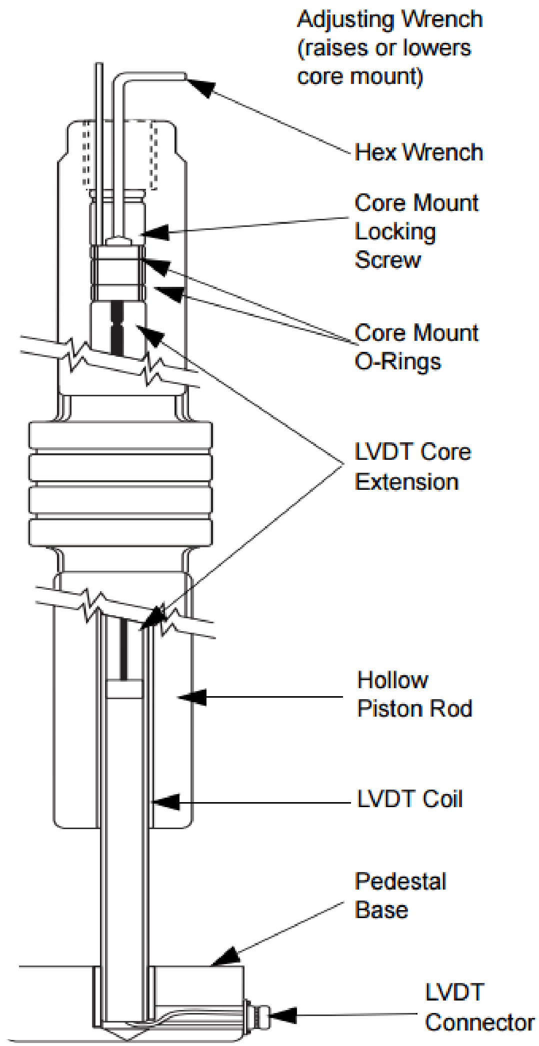
- Most MTS actuators use a LVDT to measure the distance the actuator rod has traveled
  - This is known as linear displacement
  - Some long travel actuators use a Temposonics transducer instead of a LVDT
- LVDT = Linear Variable Differential Transformer
  - As the name implies this is a transformer
  - A magnetic core is moved inside of a transformer to produce an output

LVDT

- The magnetic core is attached to the piston rod and moves with the actuator.

- The coil is stationary and is attached to the lower end cap of the actuator





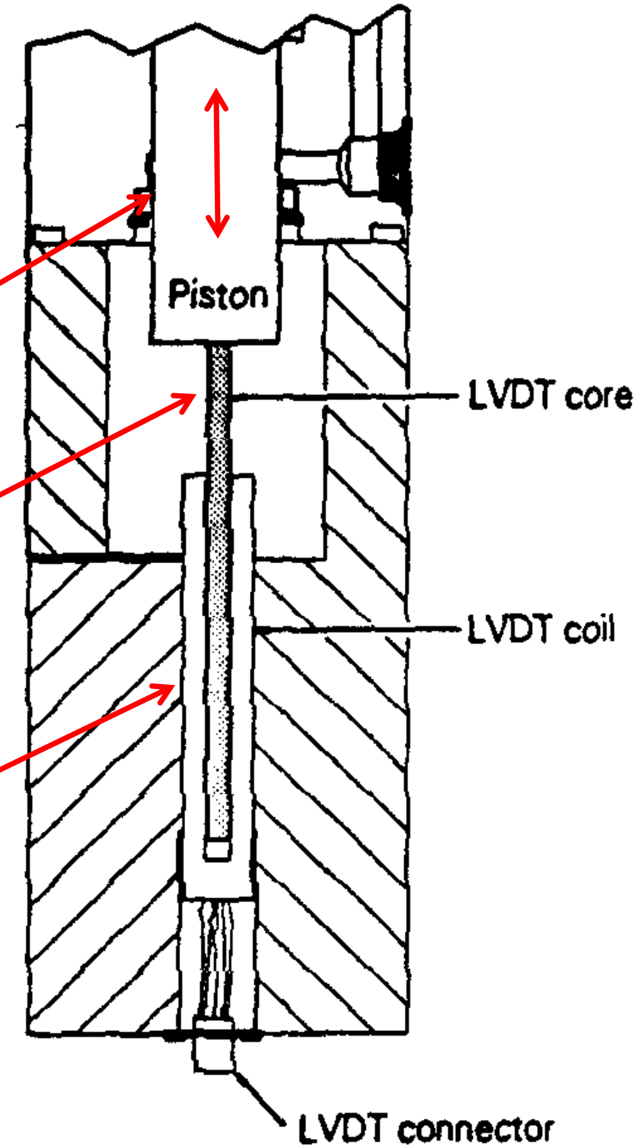
LVDT

- Here is close up of the LVDT core attached to the piston rod and the LVDT coil

Piston moves during test

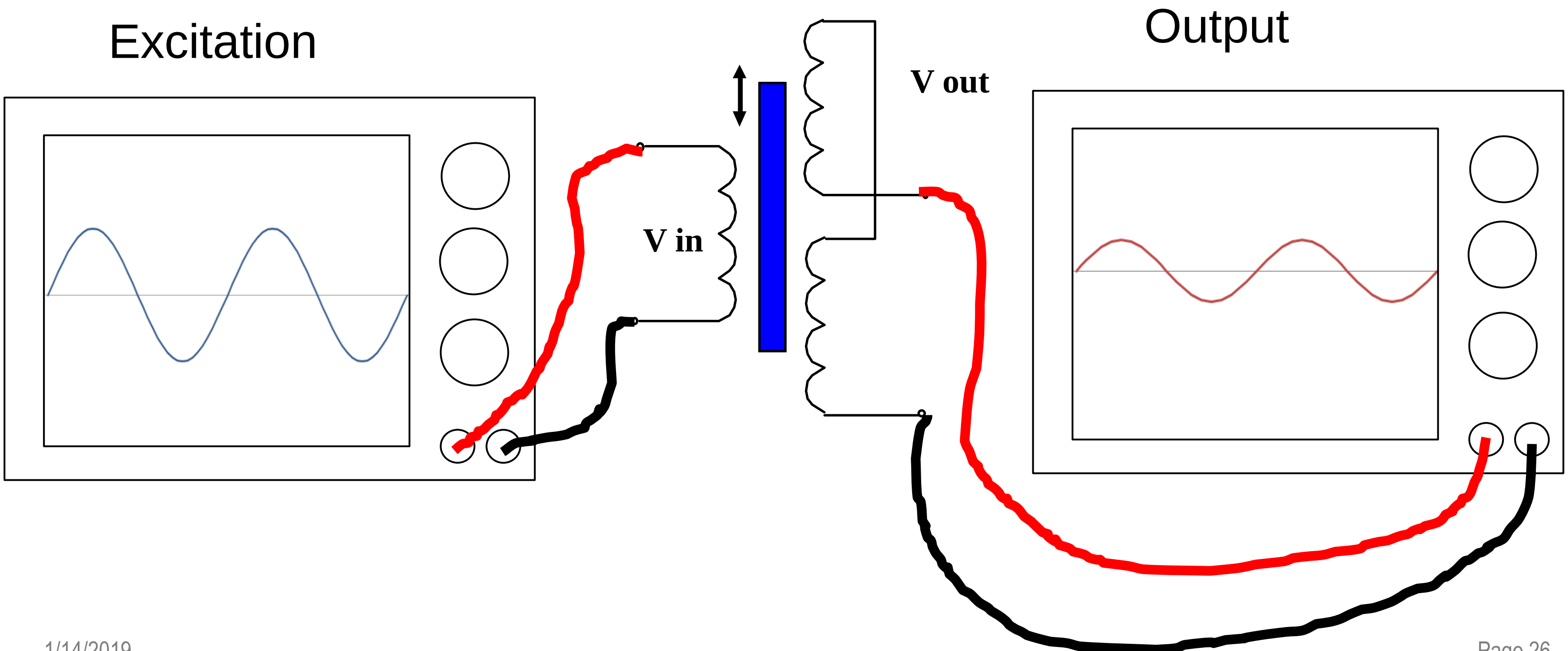
Core moves with piston

Coil is stationary



LVDT

- » Since this is a transformer it requires AC excitation
  - MTS LVDT's use a 10 kHz excitation
- » The output sine wave is demodulated in the controller and converted to a DC signal proportional to position.

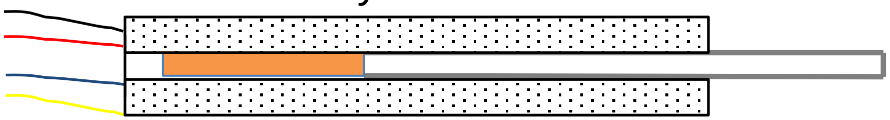


LVDT

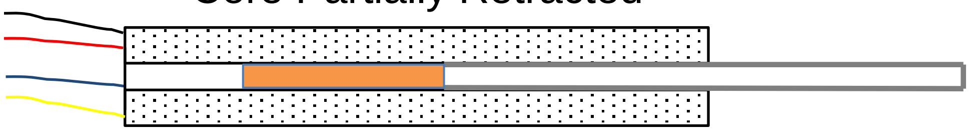
- Mid travel is null with no output from the LVDT
- The feedback amplitude is proportional to the distance travelled from the null position in the center
- The phase indicates which direction the LVDT has travelled from the center
- See examples on next page

LVDT Output

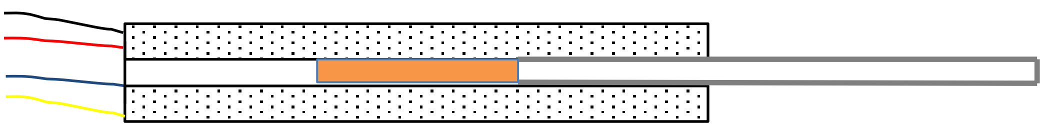
Core Fully Retracted



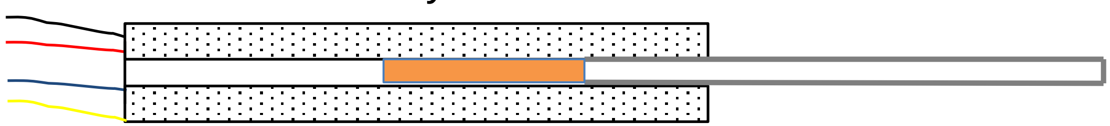
Core Partially Retracted



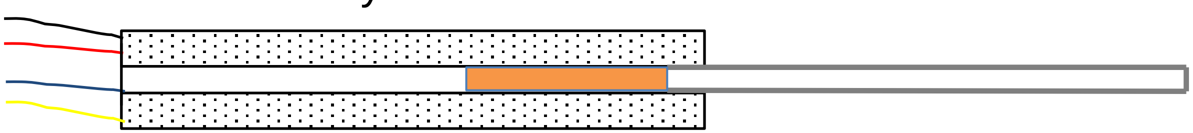
Core Centered (Null)

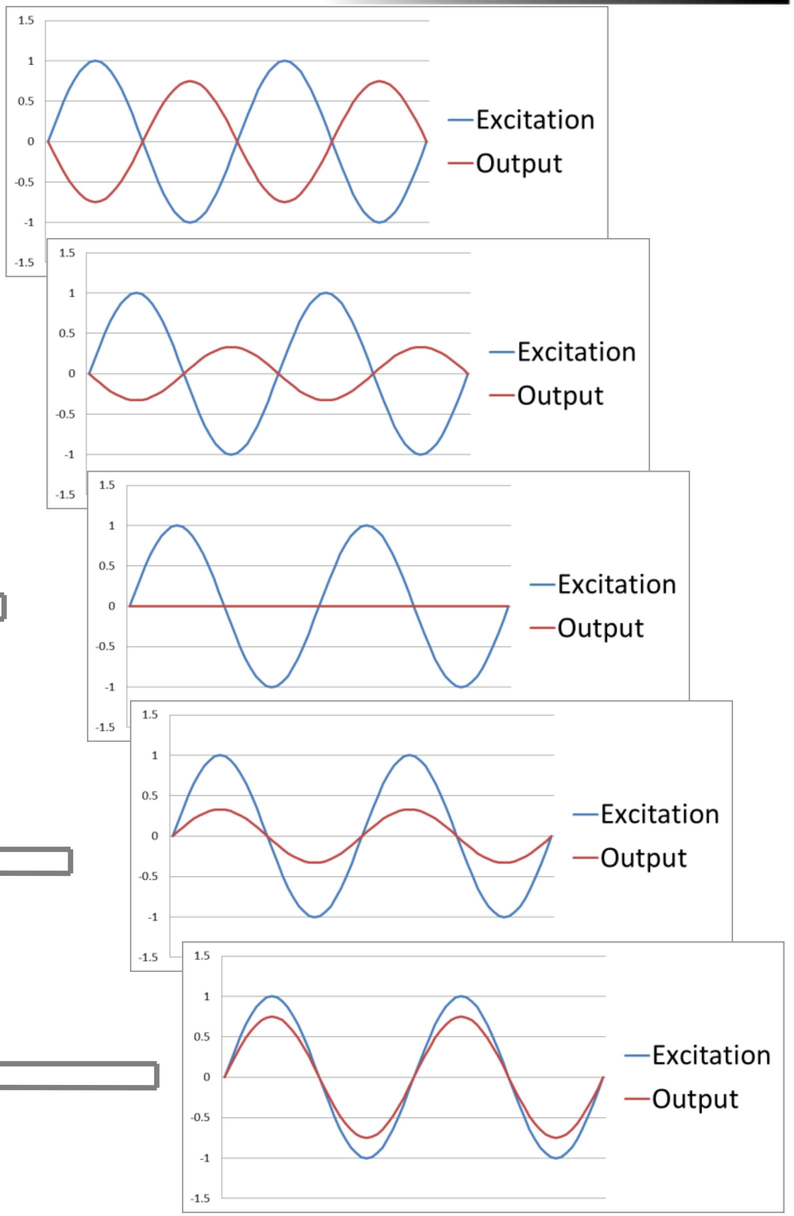


Core Partially Extended



Core Fully Extended





LVDT Polarity

- There is no standard for LVDT polarity
  - Customer can select desired polarity

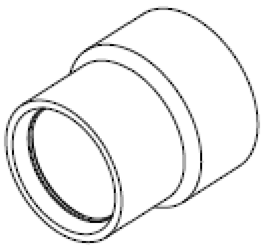
- The normal polarity for a LVDT used on a load frame is retraction is positive and extension is negative
  - Example: On a 100 mm LVDT used on a load frame
  - + 100 mm is maximum retraction of the piston into the actuator
  - - 100 mm is maximum extension of the piston out of the actuator

- It is common in the automotive market for either up or into the vehicle to be positive displacement
  - This is usually the opposite of a load frame implementation

LVDT

- When installing a new LVDT the core must be lubricated
  - Grease the area of the core that will be inserted into the coil with Molykote Gn paste

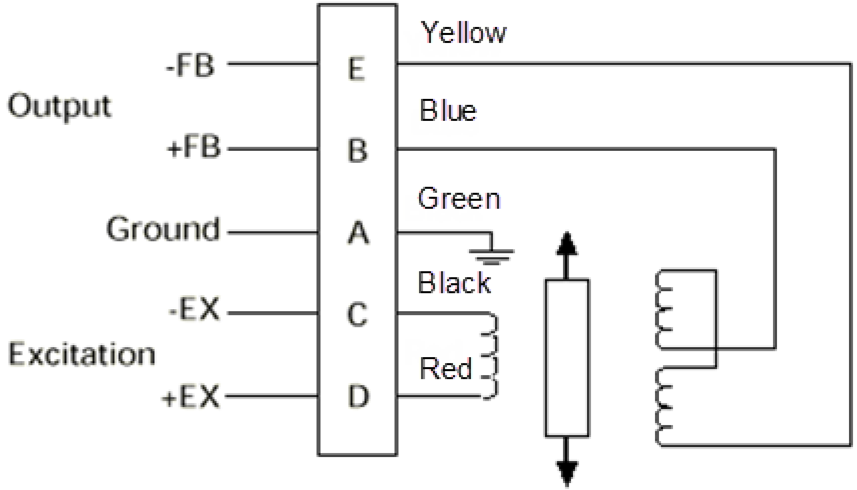
- MTS adds a white guide bushing installed on the end of the coil
  - This helps keep the core in the center of the LVDT and reduces wear
  - It is recommended to add this to replacement LVDT's
  - This is snapped onto the coil and the ridge in the bushing engages a groove in the LVDT
  - Part number 045-078-201



LVDT Cable connection

» The typical LVDT 6 pin connection at the actuator is shown below
  - When using a TED's 13 pin JT connector the wires are soldered directly to the TED's circuit board inside the connector to the terminals labeled with the signal name

6 pin Non-TEDs PT connector

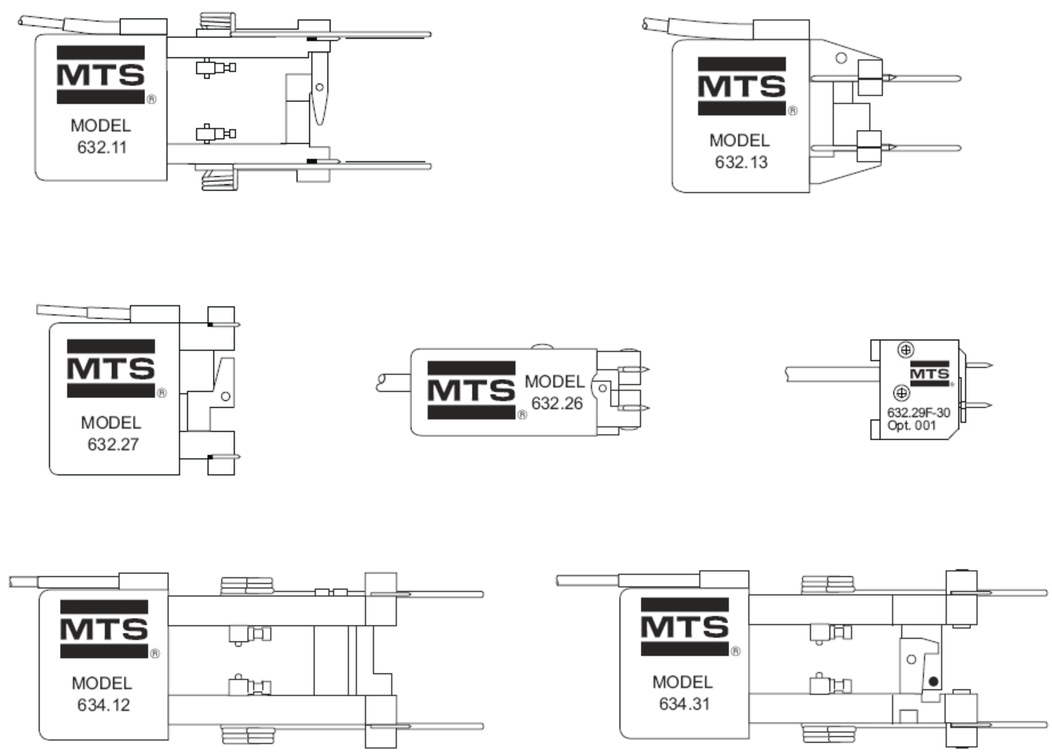


Temposonics

- » Some long travel actuators have a Temposonics transducer for measuring displacement.
- » The sensor uses a magnet attached to the actuator rod to determine the position

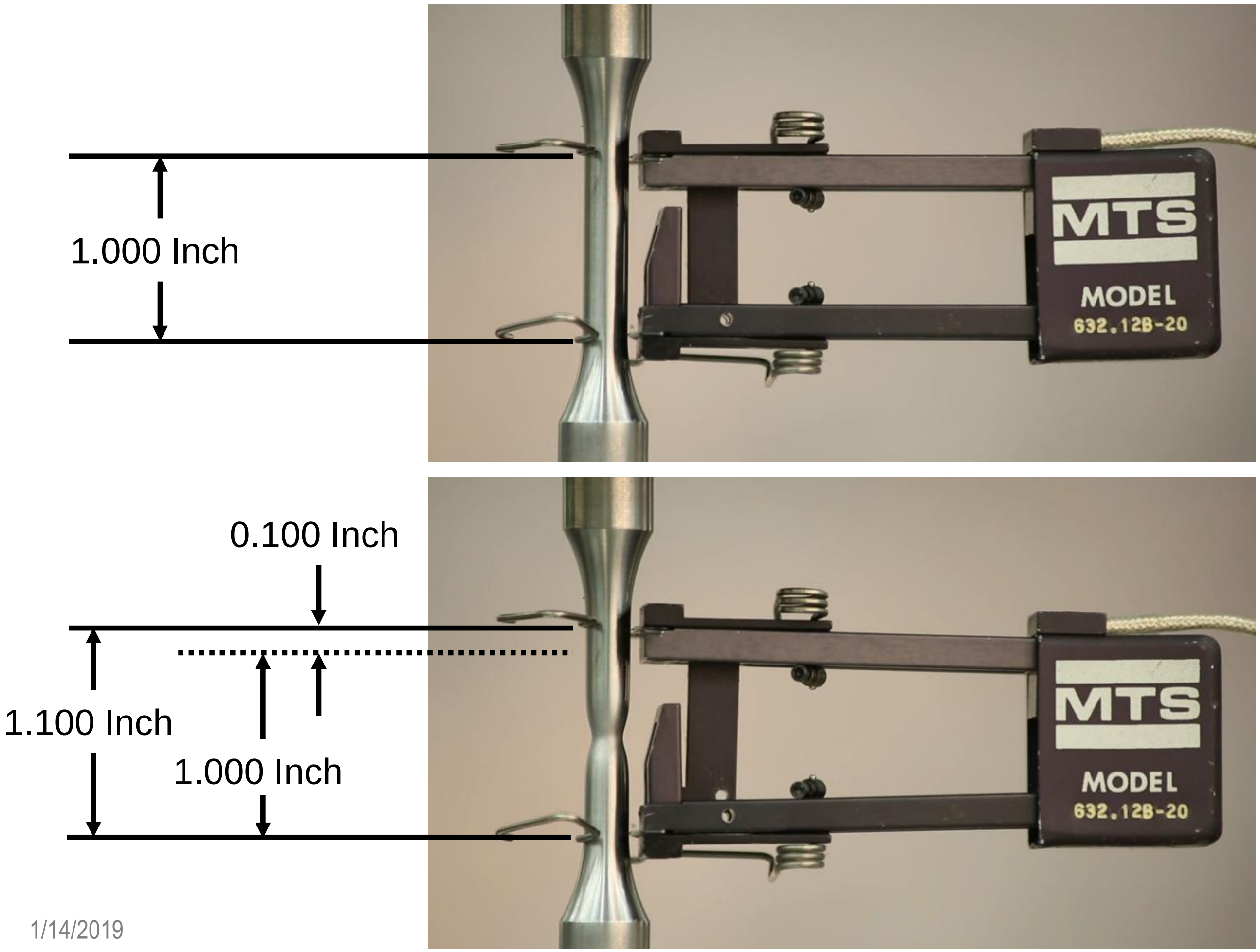
Extensometers

» Extensometers measure strain or displacement. There are many different styles available. Extensometers are specified by means of 2 parameters, gage length and amount of travel. The extensometer is attached to the test specimen. The arms move with the specimen as it is pulled in tensile or pressed in compression.



Extensometers

» Strain is defined as the change in length over the initial length. The example below is from a typical tensile test where the specimen is pulled in tensile until separation.



Start of Test

End of Test

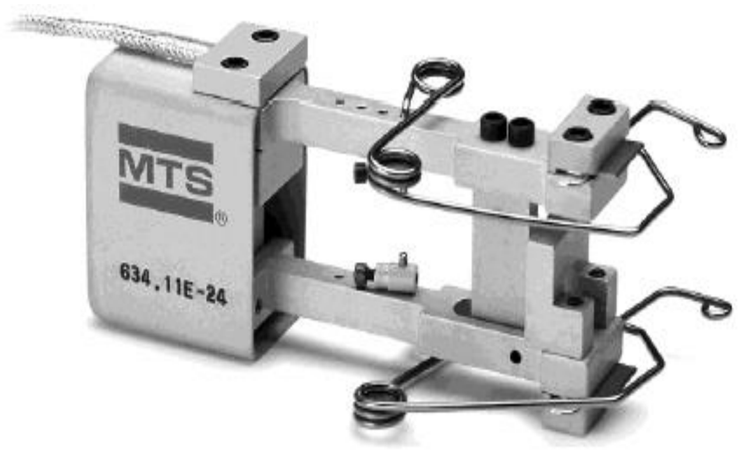
Extensometers

- Mathematically the formula is Strain=ΔL/L (mm/mm or in/in)
- ΔL = the change in length
- L = Gage Length (initial length)
  - Example from the previous page: The initial length of the measurement points on the test specimen is 1.000 Inch and the final length is 1.100 Inches
  - The change in length is 1.100 in – 1.000 in = 0.1 in
  - The strain is 0.100 in / 1.000 in = 0.10 in/in

- The gage length can be Metric or Imperial units.
- The extensometer measures the change in length.
  - The extensometer does not measure total length

Extensometer – Imperial units example

» Extensometers are specified using gage length and travel
  - Example: The extensometer pictured below, a 634.11E-24, is specified as follows.
  - 1.000 inch gage length, +0.2 inch, -0.1 inch
  - This means the extensometer can open 0.2 inches and compress 0.1 inches.
  - This is a strain of + 0.2 in/in Tensile or -0.1 in/in Compressive



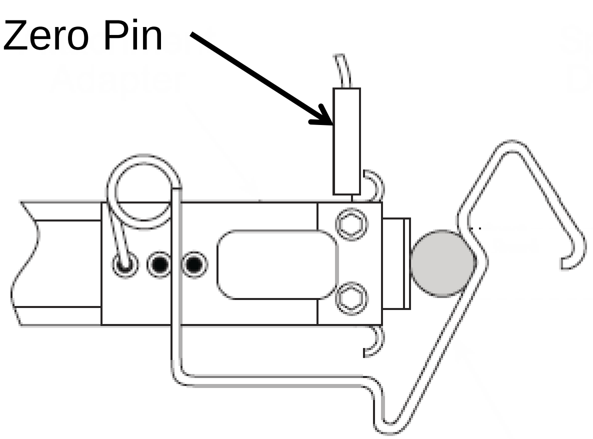
Extensometer – Metric units example

- Extensometers are specified using gage length and travel
  - Example: A metric extensometer, a 634.11F-24, is specified as follows.
  - 25 mm gage length, +5 mm, -2.5 mm
  - This means the extensometer can open 5 mm and compress 2.5 mm.
  - This extensometer is capable of measuring the following strain

  - Tensile: 5 mm / 25 mm = 0.2 mm/mm
  - Compression: -2.5 mm / 25 mm = -0.1 mm/mm

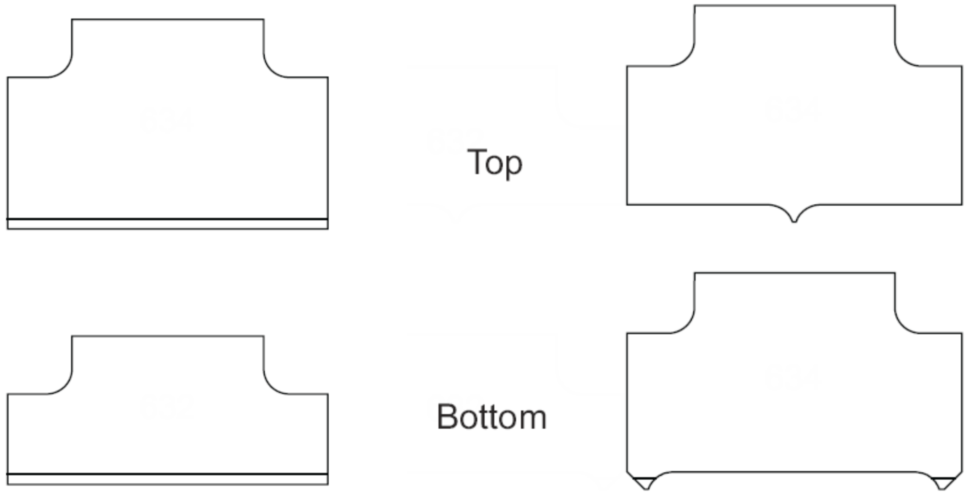
Extensometer Zero Pin

- Many extensometers have a “zero pin” to establish the gage length.
- The pin location is precision ground to set the gage length.
- Install the zero pin in the extensometer prior to mounting on the specimen.



Knife Edges

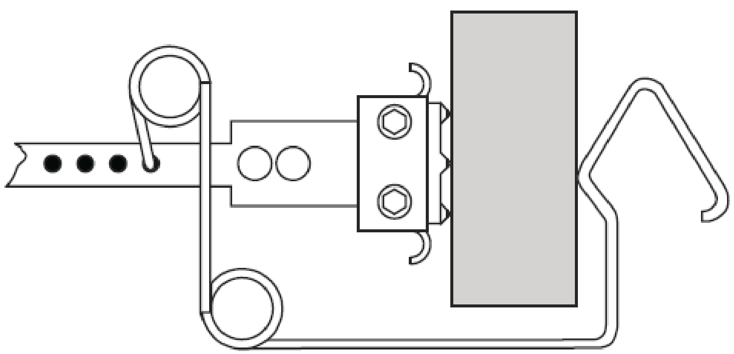
» The proper knife edges need to be selected to match the specimen type
» Round specimens use straight knife edges
» Rectangular specimens use 3 point contact knife edges
  - Attaches to a flat specimen similar to how a tripod sits on an uneven floor. With only 3 points of contact it can attach firmly to the specimen even if it is not perfectly flat



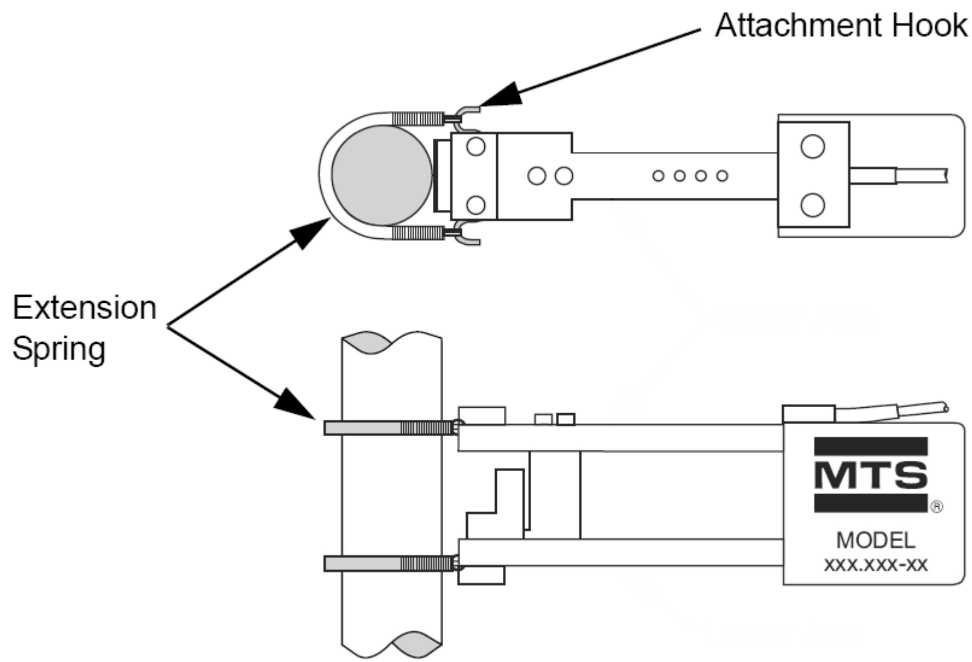
Straight Knife Edge **Three-Point Knife Edge Set**

Extensometer Attachment

» Extensometers are mounted to test specimens using a variety of methods. The most common are with quick attach springs, extension springs, or elastic bands.



Quick attach spring



Extension spring

Extensometer Attachment

» The quick attach springs need to be configured to match the specimen being tested.
  - Refer to the installation drawings included with every extensometer.
  - Link to example round specimen installation drawing
  - Link to example rectangular specimen installation drawing
» Select a spring type to match either round or rectangular specimen
» Select the A, B, or C anchor hole according to specimen diameter or thickness

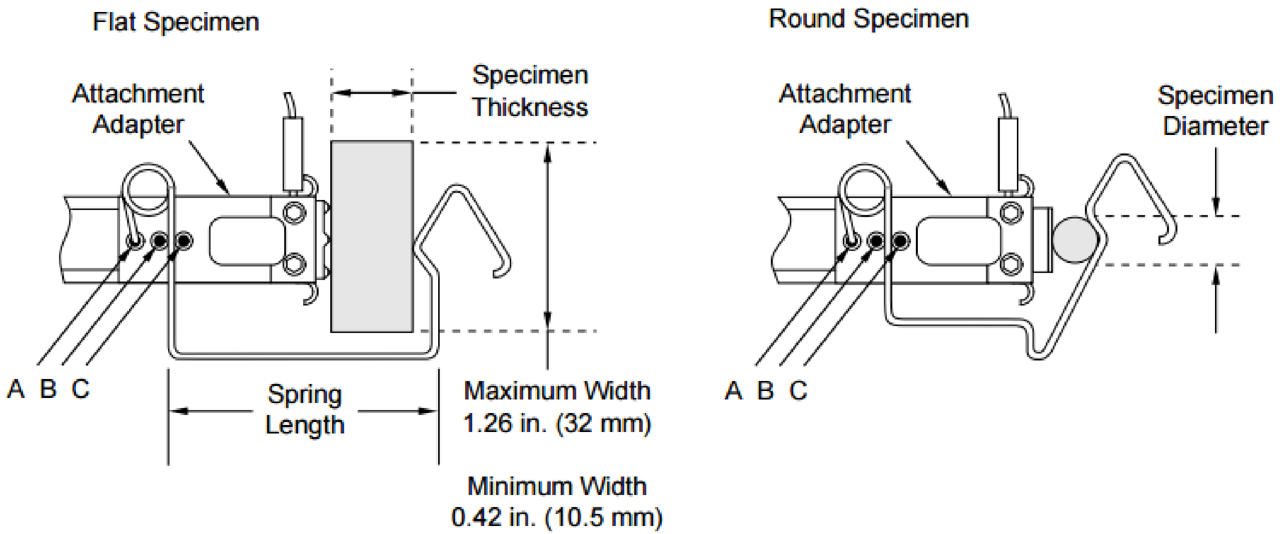
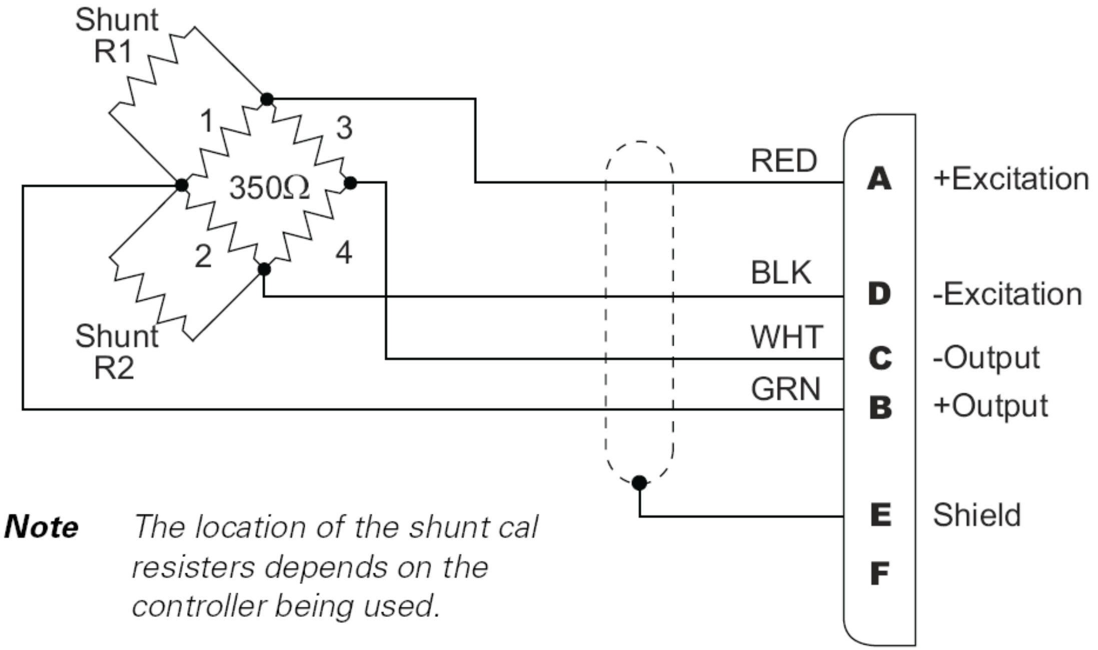


Figure 4-1. Quick Attachment Springs for Models 632.11, 632.12 and 632.25

Extensometer

- The extensometers measurement system internally contain strain gages in a Wheatstone bridge configuration similar to a load cell.
- Extensometers use DC excitation
- The typical wiring for an extensometer is shown below.



Note *The location of the shunt cal resisters depends on the controller being used.*

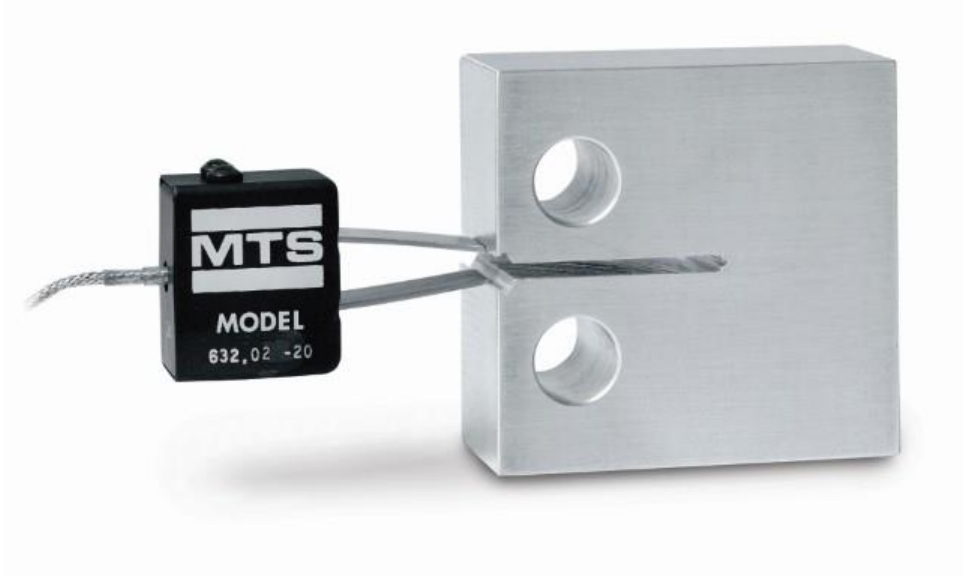
Extensometer Electrical Connections

Extensometer Field Repairs

- If the Extensometer is equipped with a Zero Pin:
- The zero pin for each extensometer is unique to that device. It is used in conjunction with a balancing wire that is in the connector of the Extensometer and used to set the gauge length of the device.
- If the zero pin is bent, broken or missing, the extensometer MUST be returned to MTS for repair.
- The connector contains additional components installed during manufacture including bridge balance resistors. The connector is not field repairable. The extensometer must be returned to MTS for connector repair.

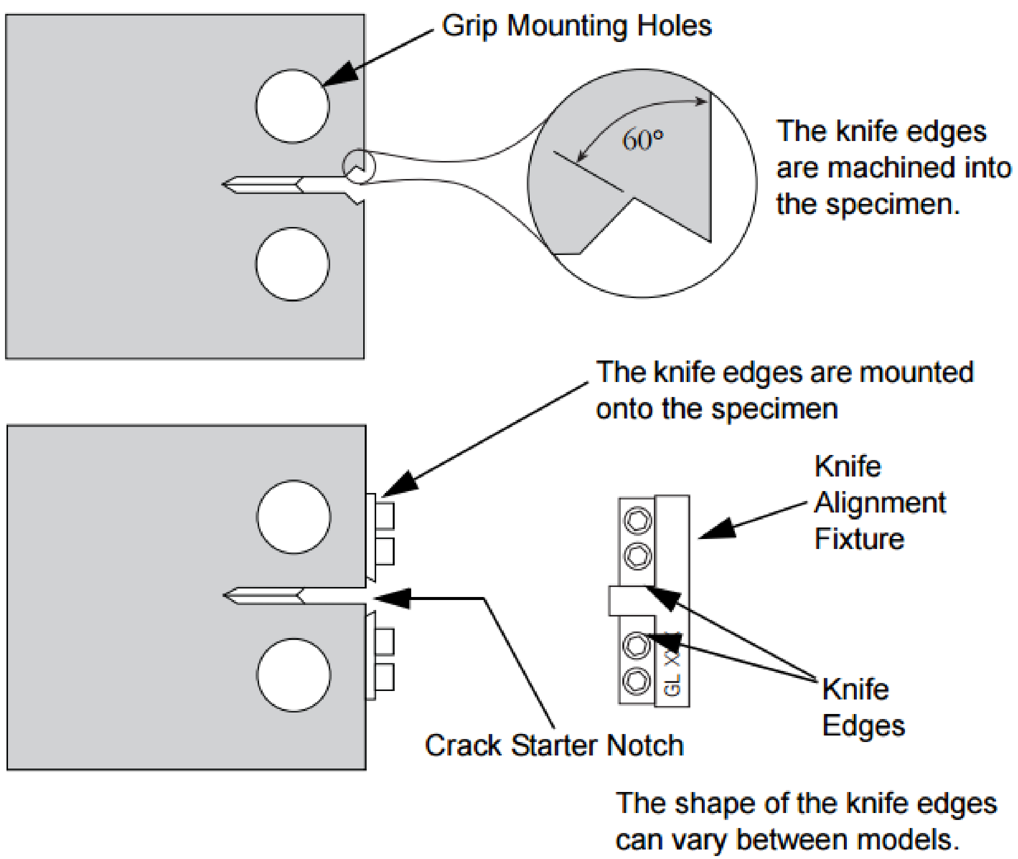
Clip on Gage

- A variation that is available in extensometers is the clip on gage.
- Designed specifically to measure the crack opening during fatigue and fracture testing.



Clip on Gage

» These are designed to be installed on a standard specimen



Displacement Gage

- » Another variation is the displacement gage.
- » Gage is placed in direct contact with specimen to measure deflection or displacement
  - Does not measure strain

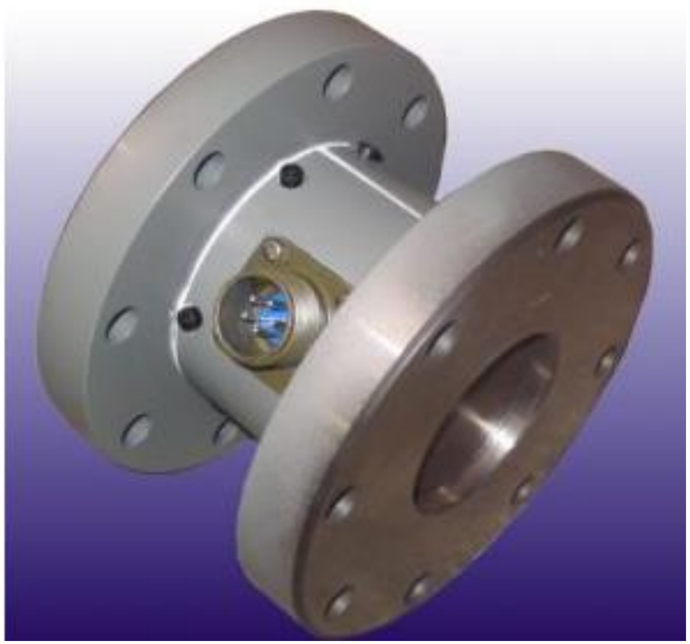
632.06H-20

Torque Cell

- A torque cell works on the same principle as a load cell measuring torsional force instead of axial force
  - Reaction torque model 663.xx
  - Uses DC excitation
  - Typical sensitivity of 2 mV/V nominal

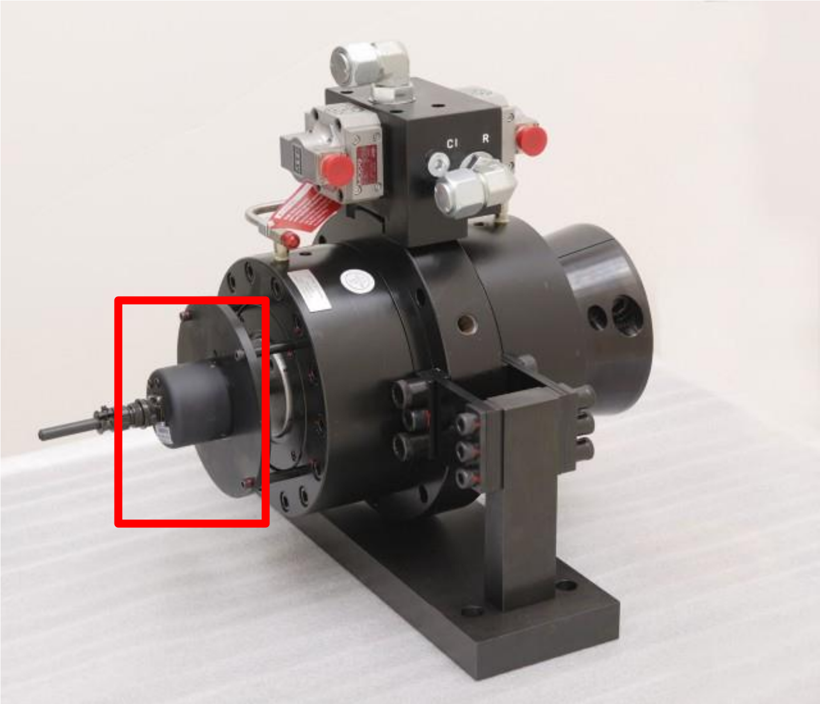
Torque Cell

- There is no standard for torque cell polarity
  - Common implementation is Clockwise is positive torque



Angular Rotation

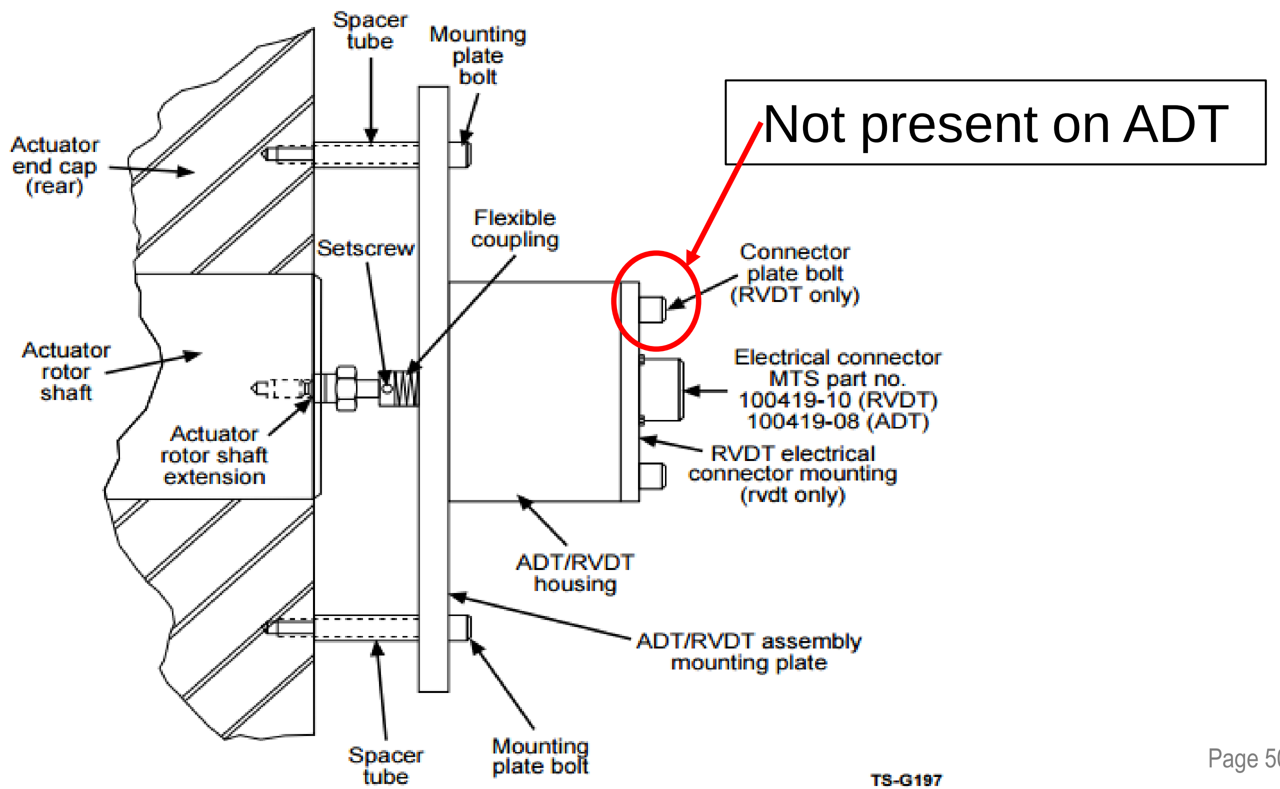
» To measure angular rotation MTS uses an ADT, RVDT, or encoder attached to the rear of the rotary actuator.
  - The transducer in the photo below is an ADT



RVDT

» An RVDT (Rotary Variable Differential Transformer) operates on the same principle as a LVDT. This device is a transformer which uses AC excitation at 10 kHz.

- The RVDT on a rotary actuator is mounted inside of a housing. You can identify a RVDT by the connector plate bolts. They are not present on an ADT

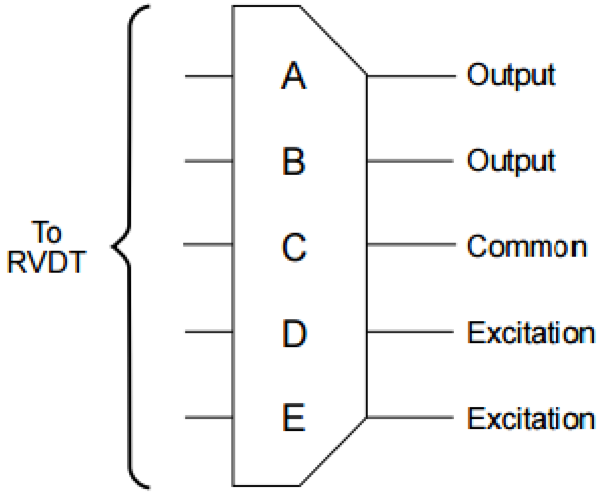


ADT

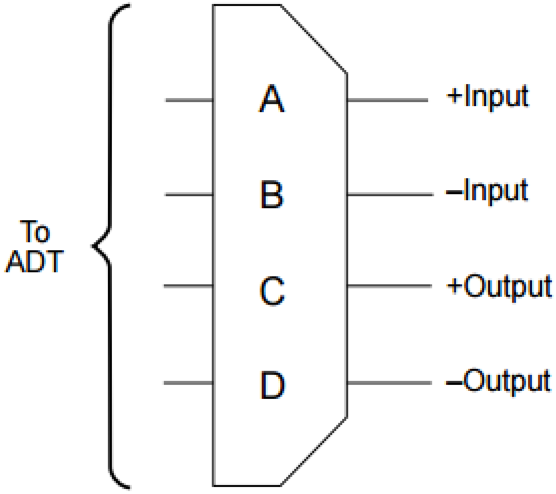
- An ADT (Angular Displacement Transducer) is a high level transducer with internal electronics.
  - Excitation is a DC source to power the electronics and transducer.
  - Typical excitation is +/- 15 VDC however there are some +/- 12 VDC transducers
  - Feedback is a DC signal.

RVDT and ADT Connection

- Another method to identify either a RVDT or ADT is by the connector.
  - The RVDT uses a 6 pin connector
  - The ADT uses a 5 pin connector



RVDT
Electrical Connector
(MTS Part no. 100419-10)



ADT
Electrical Connector
(MTS Part no. 100419-08)

Encoder

- Another angular rotation transducer in use is an Encoder.
  - Early Landmark 370.02 Table Top A/T load frames used an ADT
  - Current production Landmark 370.02 Table Top A/T load frame use an Encoder for angular position feedback

ADT

Encoder

Encoder

- The encoder is a digital device.
- This is a 17 bit absolute encoder
  - An absolute encoder remembers the position or value when powered off
- This is connected to an appropriate digital card in the controller

Axial Torsional Load Cell

- An Axial Torsional Load Cell can measure both Axial forces and Torsional forces in the same transducer.
- There are 2 connectors, one for the axial force and one for the torsional force.
- This uses DC excitation and functions using the same principles as an Axial load cell.

Pressure

- Pressure transducers are used to measure absolute pressure
- These are a Wheatstone bridge configuration using DC excitation

Delta P Cell

- A Delta P cell measures differential pressure between 2 sources.
- These are most commonly found on actuators which are used with a heavy mass such as a 4-Post road simulator
- It is used to measure the difference between the pressure in the C1 and C2 control ports
- This signal is used in the control loop to provide stability
- A Delta P cell is also occasionally used as a force or torque measurement transducer.
- These are a strain gage Wheatstone bridge using DC excitation

Thermocouple

- A thermocouple is used to measure temperature.
- A thermocouple is made from 2 wires of dissimilar metals bonded together.
- This generates a small voltage due to the thermoelectric effect
- This voltage is very small and requires a thermocouple conditioner
- Thermocouples can be found in Chambers, ovens, furnaces, and other MTS products where temperature measurement is required.