The LVDT Series

Compact Linear Displacement Sensors

The LVDT family of compact linear displacement sensors provides a rapid response in rugged packaging, maintaining the high level of accuracy and durability customers expect from LORD Sensing displacement sensors. With a strong, lightweight, and corrosion-resistant free-sliding transducer core, the sensing head is capable of total submersion in aqueous environments. The cores are precision-ground to ensure a close-sliding fit within the open bore of the stainless steel-lined LVDT body, allowing the sensor to achieve extremely high repeatability.

These sensors are ideal for linear control and precision measurement applications. Cutting-edge features may include micron resolution, linear analog output, flat dynamic response to kHz levels, and/or very low temperature coefficients.

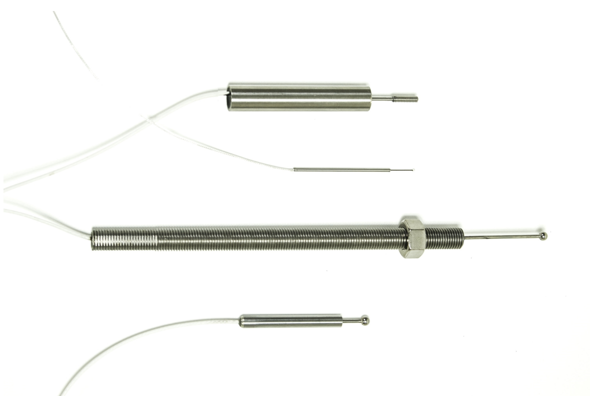


Figure 1 - The LORD Sensing LVDT Series

LORD Sensing LVDT sensors are designed to be connected to one of the following LORD Sensing signal conditioners: DEMOD-DC-2, DEMOD-DVRT-2,DVRT-Link, or DEMOD-DVRT-TC housed in either a motherboard chassis or smart motherboard chassis.

Figure 2 - LORD Sensing Signal Conditioners

1. Cable Connections

The LVDT connector cable terminates in a four-pin hermaphroditic LEMO connector. The following mating cables are required to connect to an LVDT:

- DEMOD-DVRT-TC: CBL1, CBL2, or CBL25 mating cables have a four-pin keyed locking LEMO connector with a red dot for alignment.
- DEMOD-DVRT-2 : DEMOD-DVRT-2 sensor cable

No mating cable is required for the DEMOD-DC-2 or the DEMOD-DVRT-TC .

2. Sensor Connections

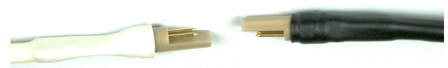
Connecting the LVDT and a DEMOD-DC-2

1. Attach the Micro-DB9 connector with pigtail leads to the mating connector on the DEMOD-DC-2.

2. Provide 6-16 V dc to the RED wire, and connect the **BLACK** lead to ground. The output of the DEMOD-DC-2 is 0-5 V dc on the **WHITE** wire. Refer to the Certificate of Calibration for the conversion to displacement.
3. Plug the LEMO connector on the LVDT directly in to the LEMO on the DEMOD-DC-2. Refer to the Certificate of Calibration for the conversion to displacement.

Connecting the LVDT and a DEMOD-DVRT-2

1. Plug the LEMO connector on the LVDT into the sensor cable.



2. Connect the sensor cable to the DEMOD-DVRT-2.

3. Plug the power supply into a standard outlet, and connect to the barrel jack on the DEMOD-DVRT-2.

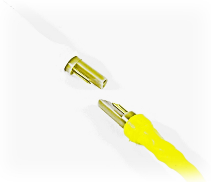
4. Connect the mini-BNC end of the output cable to the DEMOD-DVRT-2, and connect the standard BNC end to the system. The output of the DEMOD-DVRT-2 is 0-10 V dc. Refer to the Certificate of Calibration for the conversion to displacement.

Connecting the LVDT and a DVRT-Link

1. The LVDT connector cable is plug-compatible with the DVRT-Link. Connect the LVDT directly to the DVRT-Link.
2. Use the DVRT-Link with the USB Base Station and SensorConnect software. Refer to the Certificate of Calibration for the conversion to displacement.

Connecting the LVDT and a DEMOD-DVRT-TC

1. Connect the LVDT to the CBL1, CBL2, or CBL25 cable.



2. Connect the CBL cable to the four-pin LEMO connector on the DEMOD-DVRT-TC by aligning the red dots and pushing the connector in until it locks.

3. Connect the Data Acquisition (DAQ) device to the Bayonet Connector (BNC) on the DEMOD-DVRT-TC.

4. Plug in power supply for the motherboard chassis. Refer to the Certificate of Calibration for the conversion to displacement.

3. Locate Linear Range

After connecting the LVDT, powering up the signal conditioner, and connecting the DAQ, the next step is to locate the core within the body and establish the linear range by moving the core back and forth, observing the sensor's output on the DAQ. In some cases it is possible to insert the wrong end of the core into the body. If there is less than a 50 millivolt reading on the DAQ, the core is in backwards.

DEMOD-DC-2

- Volts output: 0.0 V to +5.0 V
- LVDT Linear region: +0.5 V to +4.5 V
- Output without core installed : +2.5 V
- Output at null position: ±2.5 V

1. Carefully insert the core into the body, and observe the output.
2. When the core is initially inserted, the voltage will first show 0 V.
3. Continue inserting the core, and the voltage will increase to +2.5 V, indicating it is passing the mid-point of its specified linear region.
4. Continue inserting the core, and the voltage will continue increasing to +5.0 V.

Using the LORD Sensing 8 mm S-DVRT-8 for an example, if the linear slope from the Calibration Certificate is 2 mm/V, the linear region would be between +0.5 V and +4.5 V. The 4 V range reflects the 8 mm measurement range.

DEMOD-DVRT-2

- Volts output: 0.0 V to +10.0 V
- LVDT Linear region: +0.5 V to +9.5 V
- Output without core installed: +5.0 V
- Output at null position: +5.0 V

1. Carefully insert the core into the body and observe the output.
2. When the core is initially inserted, the voltage will first show 0 V.
3. Continue inserting the core and the voltage will increase to +5.0 V, indicating it is passing the mid-point of its specified linear region.
4. Continue inserting the core and the voltage will continue increasing to +10.0 V.

DVRT-Link

- Bits output: 0.0 to 4096
- LVDT Linear region: 48 to 4048 bits
- Output without core installed: 2048 bits
- Output at null position: 2048 bits

1. Carefully insert the core into the body, and observe the output.
2. When the core is initially inserted, the voltage will first show 0 bits.
3. Continue inserting the core, and the output will increase to 2048 bits, indicating it is passing the mid-point of its specified linear region.
4. Continue inserting the core, and the output will continue increasing to 4096 bits.

Using the LORD Sensing 8 mm S-DVRT-8 for an example, if the linear slope from the Calibration Certificate is 2 microns/bit, the linear region would be between 48 and 4048 bits. The 4000 bits range reflects the 8 mm measurement range.

The DVRT-Link is shipped with its calibration already programmed into non-volatile memory. The Calibration Certificate will contain the conversion factor for bits to displacement.

DEMOD-DVRT-TC

- Volts output: -5.0 V to +5.0 V standard, -10.0 V to +10.0 V optional
- LVDT Linear region: - 4.5 V to +4.5 V
- Output without core installed: 0 V
- Output at null position: 0 V

1. Carefully insert the core into the body, and observe the output.
2. When the core is initially inserted, the voltage will first show a negative reading.
3. Continue inserting the core, and the voltage will increase to 0 volts, indicating it is passing the mid-point of its specified linear region.
4. Continue inserting the core, and the voltage will continue increasing to a positive voltage.

Using the LORD Sensing 8 mm S-DVRT-8 for an example, if the linear slope from the Calibration Certificate is 1 mm/V, the linear region would be between -4.0 V and +4.0 V. The 8 V range reflects the 8 mm measurement range.

4. Calibration

To achieve the highest levels of accuracy, every LORD Sensing displacement sensor is paired and calibrated at the factory with its own signal conditioner. A Certificate of Calibration is provided for each pair and is **only** valid for the units matching the serial numbers listed on the certificate. For sensors with non-captive cores it is also important to keep cores paired with their respective sensors.

CERTIFICATE OF CALIBRATION

This document certifies that the equipment referenced below meets published specifications.

Model: 6116-1000 Calibration Date: 3/20/2017
Serial Number: EXAMPLE Calibration Tech.: PJL
Description: HSG-DVRT-6

LORD SENSING MicroStrain

459 Hurricane Lane, Suite #102 www.microstrain.com
Williston, VT, USA 05495 sensing_support@lord.com
Ph (802)862-6629 Fax (802)863-4093

For any questions concerning this certificate, please call MicroStrain for a support engineer.

LORD SENSING MicroStrain System Information

Sensor Model	6116-1000	Signal Cond. Model	6130-0010
Sensor S/N	EXAMPLE	Signal Cond. S/N	EXAMPLE
Linear Slope (mm/V)	1.26290	-3dB Bandwidth (Hz)	800
Linear Offset (mm)	-3.16991	Supply Voltage	6-16 VDC
Calibration Freq.	Static (< 2Hz)	Calibration Temp.	22 °C

Customer:
Note:

* For the calibration to be valid the fixture material must be a polymer.
* For maximum stability please allow 5 minutes warm-up after the system is initially powered.

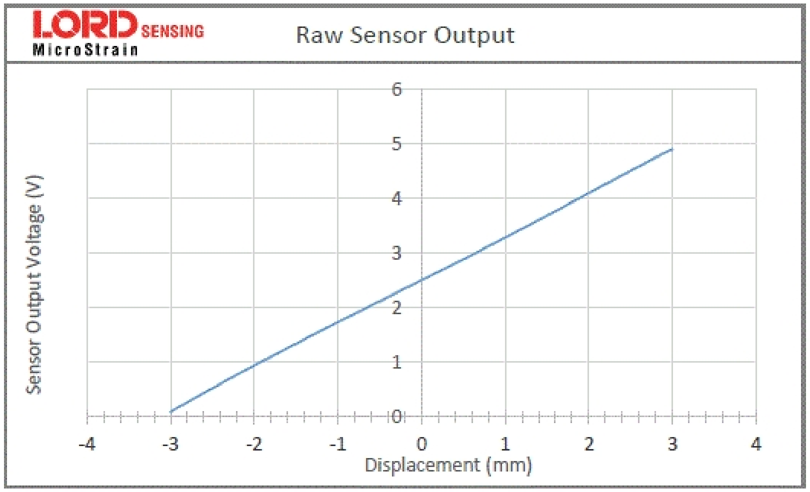
Statement of Traceability: LORD Microstrain certifies that this calibration is traceable to NIST Standards. The reported data are kept on file. This calibration report was performed in accordance with current product configuration and LORD's Quality Assurance system.

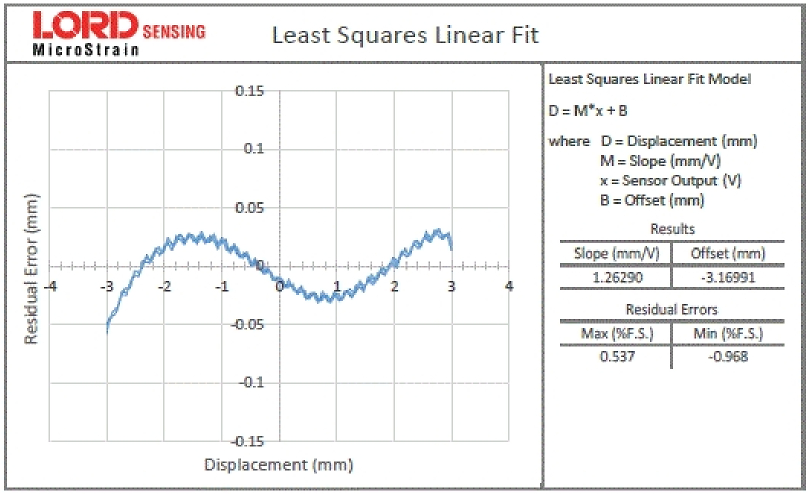
The Part referenced above has not been approved by the U.S. Food and Drug Administration or any other governmental agency. This part has not been approved, and should not be used, for human trials or medical procedures involving humans. Except for any express warranty provided by LORD with respect to this Part in any document signed by LORD, LORD hereby disclaims any and all other warranties, express or implied, including, without limitation, the implied warranties of merchantability and fitness for a particular purpose.

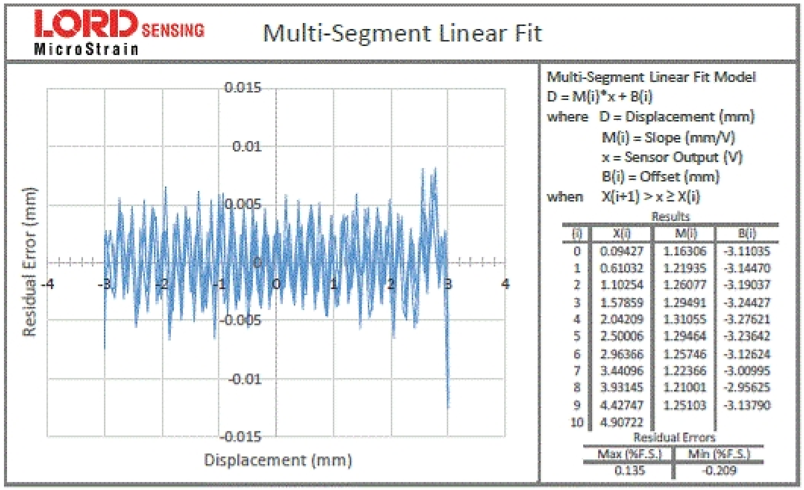
Signoff: Tech QC Revision -

NOTE

For the calibration to remain valid during operation for **contact type sensors**, the fixture material must be a non-magnetic material. For **non-contact type sensors**, the fixture material must be non-magnetic and non-conductive.

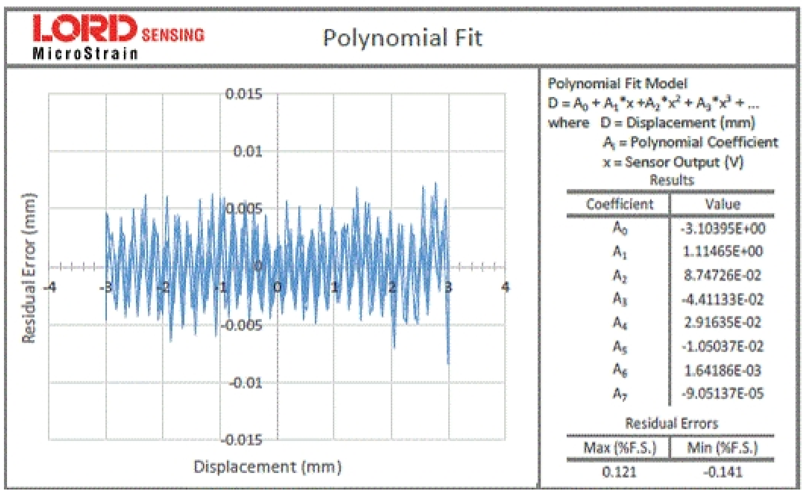






(i)	X(i)	M(i)	B(i)
0	0.09427	1.16306	-3.11035
1	0.61032	1.21935	-3.14470
2	1.10254	1.26077	-3.19037
3	1.57859	1.29491	-3.24427
4	2.04209	1.31055	-3.27621
5	2.50006	1.29464	-3.23642
6	2.96366	1.25746	-3.12624
7	3.44096	1.22366	-3.00995
8	3.93145	1.21001	-2.95625
9	4.42747	1.25103	-3.13790
10	4.90722		

Max (%F.S.)	Min (%F.S.)
0.135	-0.209



Coefficient	Value
A_0	-3.10395E+00
A_1	1.11465E+00
A_2	8.74726E-02
A_3	-4.41133E-02
A_4	2.91635E-02
A_5	-1.05037E-02
A_6	1.64186E-03
A_7	-9.05137E-05

Max (%F.S.)	Min (%F.S.)
0.121	-0.141

5. Scaling Volts to Displacement

The Calibration Certificate provides three calibration models to scale the voltage output of the LVDT into a Linear Fit, Multi-Segment Fit, or Polynomial Fit displacement measurement.

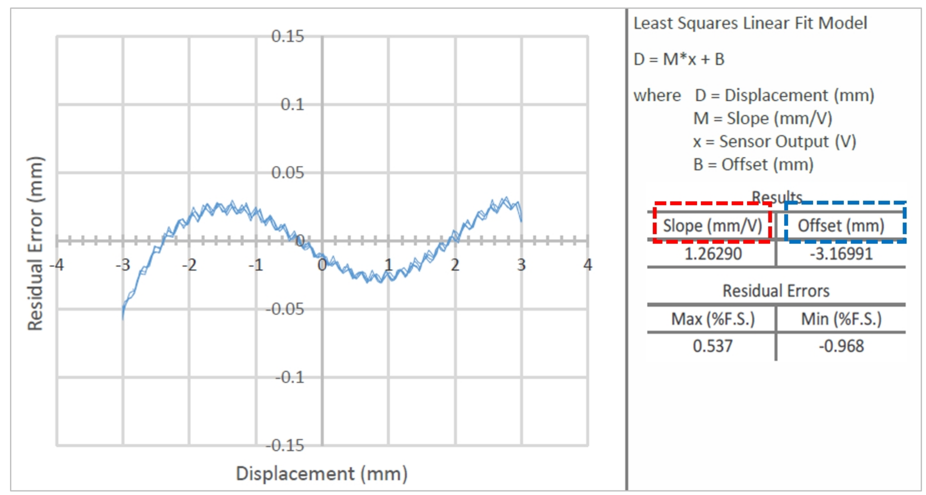
Be aware that some sensors have additional travel beyond the calibrated range. The fits detailed here have been generated **only** for the intended stroke of the sensor. Applying the fits to a voltage outside the calibrated range is likely to result in an inaccurate measurement.

Applying the Linear Fit

The linear fit is the simplest model to derive displacement from the LVDT. To apply the linear fit, enter the Slope shown on the calibration certificate into the equation of a line as "M", and the Offset shown on the calibration certificate as "B".

Displacement = Slope *Voltage + Offset

Or D = M*x+B



Slope (mm/V)	Offset (mm)
1.26290	-3.16991

Max (%F.S.)	Min (%F.S.)
0.537	-0.968

Figure 3 - Linear Fit Values

Using the coefficients in the example above, the linear equation for this sensor is:

$$D = 1.26290\frac{mm}{V} * x - 3.16991mm$$

Where D is displacement in mm and x is the voltage output from the DEMOD.

Enter the voltage from the DEMOD as "x" in the equation and solve for the displacement, "D". Be aware that the displacement measurement from all LORD Sensing LVDTs is from the mid-point of the stroke. The sensor above is a 6mm model, so the displacement measurements will range from +3 to -3mm.

Applying the Multi-Segement Fit

The multi-segment fit is a compromise between the accuracy of the polynomial fit and the simplicity of the linear fit. In this model, the output from the sensor is divided into 10 individual straight lines, forming a "piecewise- continuous" function. To apply the multi-segment fit, enter the Slope shown on the calibration certificate into the equation of a line as "M", and the Offset shown on the calibration certificate as "B".

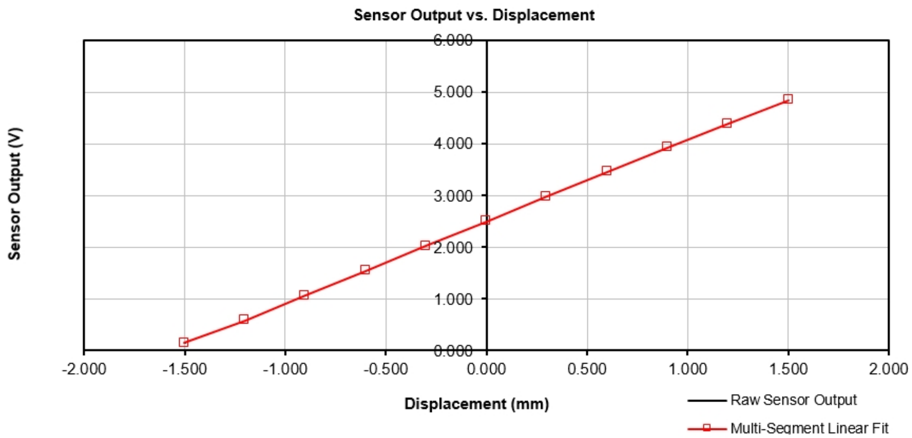
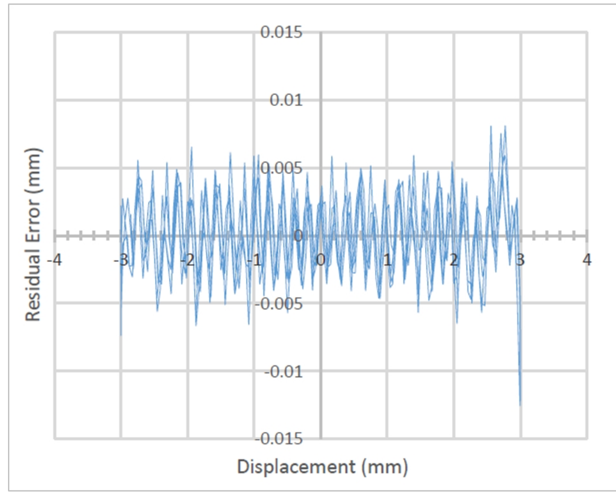


Figure 4 - Sensor Output vs. Displacement

Figure 4 - Sensor Output vs. Displacement shows the sensor output divided into 10 equal lines. From left to right, each point is given an index "i" starting with i=0. This is important for how the multi-segment coefficients are reported on the calibration certificate.



Multi-Segment Linear Fit Model

D = M(i)*x + B(i)

where D = Displacement (mm)

M(i) = Slope (mm/V)

x = Sensor Output (V)

B(i) = Offset (mm)

when X(i+1) > x ≥ X(i)

Results

(i)	X(i)	M(i)	B(i)
0	0.09427	1.16306	-3.11035
1	0.61032	1.21935	-3.14470
2	1.10254	1.26077	-3.19037
3	1.57859	1.29491	-3.24427
4	2.04209	1.31055	-3.27621
5	2.50006	1.29464	-3.23642
6	2.96366	1.25746	-3.12624
7	3.44096	1.22366	-3.00995
8	3.93145	1.21001	-2.95625
9	4.42747	1.25103	-3.13790
10	4.90722		

Residual Errors

Max (%F.S.)	Min (%F.S.)
0.135	-0.209

Figure 5 - Multi-Segment Fit Values

Figure 5 - Multi-Segment Fit Values shows the values of Voltage "x", Slope "M", and Offset "B" are expressed in terms of "(i)"; where "i" is the index for each point shown in the first image. To calculate the displacement at any given voltage, from the top of the table down, find the first value in column "X(i)" that **exceeds** the voltage reading. One row up on the table should be a value that is **lower** than your voltage reading. The row that is **lower** than the voltage reading shown contains the Slope "M(i)" and Offset "B(i)" used to determine the current position.

For example, if the readout from the signal conditioner is 3.2 volts, the first row in column "X(i)" that **exceeds** this value is row 7, with a value of x(7)=3.44096 V. The value in Row 6 should be less than the current value, which is the case (x (6)=2.96366 V). From row 6, refer to the Slope "M" and Offset "B" in the columns to the right: Slope M(6) =1.24746 mm/V and Offset B(6) = -3.23642 mm. Plugging these values into the linear fit line, as shown below, with a voltage of 3.2 V gives a displacement of 0.7874 mm. Be aware that the displacement measurement from all LORD Sensing LVDTs is from the mid-point of the stroke.

$$D = 1.25746\frac{mm}{V} * 3.2V - 3.23642mm$$

$$D = 0.7874mm$$

If the ouput of the DEMOD is **exactly** one of the values of "x(i)" listed in the table, use the Slope and Offset in that row.

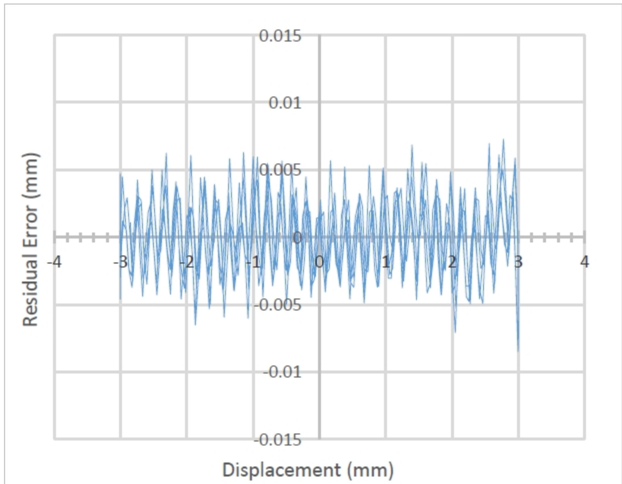
Applying the Polynomial Fit

The polynomial fit is typically the most accurate model, but also requires the computation of high-order terms. For post-processing on modern computers this not an issue, but in applications where a digital readout or independent programmable device is reading the DEMOD output, the ability to compute high-order terms is not always supported.

The polynomial fit uses a 7-order term to relate the sensor output to displacement in mm. The full form of the equation is shown below.

$$D = A_0 + A_1x + A_2x^2 + A_3x^3 + A_4x^4 + A_5x^5 + A_6x^6 + A_7x^7$$

The coefficients A_0 through A_7 are listed in the calibration certificate. Insert the values into the matching term in the equation above, paying close attention to the power of the exponent for each term. The notation "E" is interchangeable with "*10^", so "E-02" is the same as $*10^{-2}$.



Polynomial Fit Model
$D = A_0 + A_1*x + A_2*x^2 + A_3*x^3 + \ldots$
where D = Displacement (mm)
A_i = Polynomial Coefficient
x = Sensor Output (V)

Results

Coefficient	Value
A_0	-3.10395E+00
A_1	1.11465E+00
A_2	8.74726E-02
A_3	-4.41133E-02
A_4	2.91635E-02
A_5	-1.05037E-02
A_6	1.64186E-03
A_7	-9.05137E-05

Residual Errors

Max (%F.S.)	Min (%F.S.)
0.121	-0.141

Figure 6 - Polynomial Fit Values

After entering the coefficients into the equation, the displacement at any point along the stroke can be solved by replacing "x" with the voltage from the DEMOD.

6. Legacy Signal Conditioners

Connecting the sensor and the DEMOD-DVRT

1. Connect the sensor to the CBL1, CBL2, or CBL25 cable.
2. Connect the CBL cable to the four-pin LEMO connector on the DEMOD-DVRT by aligning the red dots and pushing the connector in until it locks.
3. Connect the Data Acquisition (DAQ) device to the Bayonet Connector (BNC) on the DEMOD-DVRT.

Connecting the sensor and the DEMOD-DIN

1. Connect the sensor to the CBL1, CBL2, or CBL25 cable.
2. Connect the CBL cable to the four-pin LEMO connector on the DEMOD-DIN by aligning the red dots and pushing the connector in until it locks.
3. Connect the Data Acquisition (DAQ) device to the V Out and GND connectors on the DEMOD-DIN.

Powering and Wiring the DEMOD-DIN

- GND from power source
- +12 V from power source
- -12 V from power source
- V Out to DAQ
- GND to DAQ

Locate the LVDT's Linear Range with a DEMOD-DVRT or DEMOD-DIN

- Volts output: -10.0 V to +10.0 V
- LVDT Linear region: ± 4.5 V
- Output without core installed: 0 V

1. Carefully insert the core into the body, and observe the output.
2. When the core is initially inserted, the voltage will first show a negative reading.
3. Continue inserting the core, and the voltage will increase to 0 volts, indicating it is passing the mid-point of its specified linear region.
4. Continue inserting the core, and the voltage will continue increasing to a positive voltage.

Using the LORD Sensing 8 mm S-DVRT-8 for an example, if the linear slope from the Calibration Certificate is 1 mm/V, the linear region would be between -4.0 V and +4.0 V. The 8 V range reflects the 8 mm measurement range.

LORD Corporation
MicroStrain® Sensing Systems
459 Hurricane Lane , Suite 102
Williston, VT 05495 USA

ph: 802-862-6629
sensing_sales@LORD.com
sensing_support@LORD.com

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