Linear Variable Differential Transformers (LVDTs)

Advanced Sensors and Instrumentation (ASI) Annual Program Webinar
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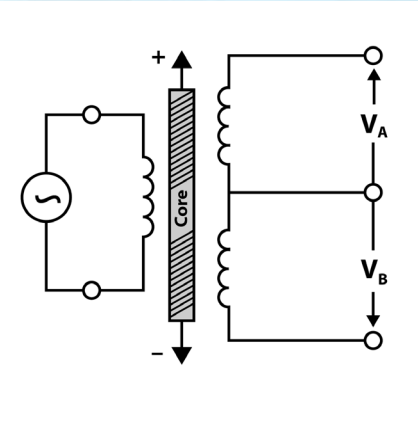
Project Overview

Background

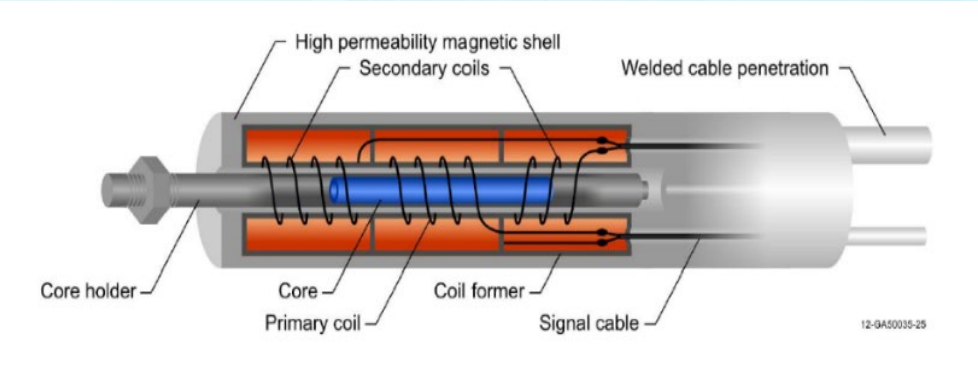
- An LVDT (Linear Variable Differential Transformer) is an electromechanical transducer that converts the motion of an object into a corresponding electrical signal. Submicron motions are resolvable.
- Many phenomena produce, or can be used to produce, length changes which in turn can be measured and converted into a measurement of the phenomenon (e.g., pressure, temperature).
- The commercial LVDT has proved to be a robust and versatile sensor, but it falls short when used at elevated temperatures, fluctuating temperatures, or when irradiated because of the materials used in construction.
- Since 1965, IFE under the Halden Reactor Project has been developing irradiation resistant high-temperature LVDTs. They are the world leader when it comes to manufacturing LVDTs for irradiation testing.



$$D = (Va–Vb) / (Va+Vb)$$

$$L = (Xm–Xc) / Stroke * 100\%$$

Halden LVDT

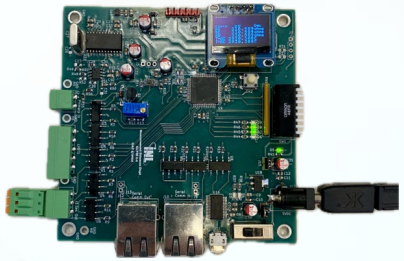


Project Overview

Scope

Performance Test of Mini LVDTs plus Task 1 - Develop miniature LVDT with inherent temperature monitoring capabilities

Milestone M3CT-24IN0703032



Qualification Testing of Commercial LVDTs Provided by Newtek Sensor Solutions

Milestone M3CT-24IN0703031

Participants

Idaho National Laboratory

Kurt Davis, Geran Call, Chase Case, Joshua Daw, Austin Fleming, Malwina Wilding, and Bibo Zhong

NEWTEK Sensor Solutions
Providing Custom Sensor Solutions

Michael Marciante

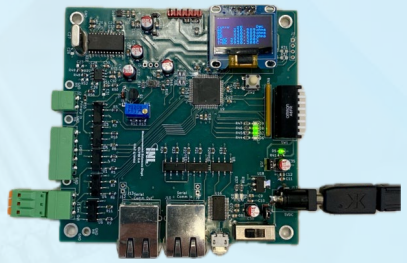
Technology Impact

NEWTEK Sensor Solutions
Providing Custom Sensor Solutions

- Testing complete (Prototype 1 and 2)
- Performance goal 500° C
  - Prototype 1 – 400° C
  - Prototype 2 – 450° C (chemical interaction MI cable), coils removed, successfully tested to 700° C
- Planned use in TREAT sodium loop testing

Technology Impact

- Task 1 - Develop miniature LVDT with inherent temperature monitoring capabilities.



NEWTEK Sensor Solutions
Providing Custom Sensor Solutions

- NDA
- Patent License
- TCF

IFE

- NDA

sckcen

cea

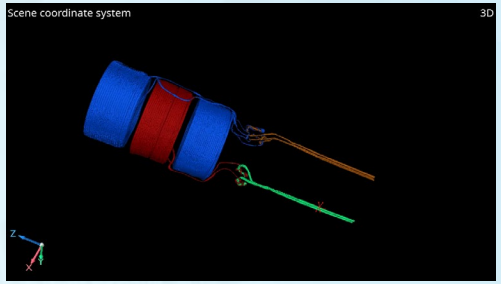
- NDA
- Deployment
- Data Sharing

Results and Accomplishments

Miniature LVDT Performance

Single Mini LVDT failure during ELVIS I testing

- IR break down (> 10 G ohm required < 20 M ohm measured)
- LVDT returned to IFE for evaluation
- IFE found chemical interactions (ceramic glue) caused magnetic coil wire insulation breakdown. Material supply changed and issue corrected.



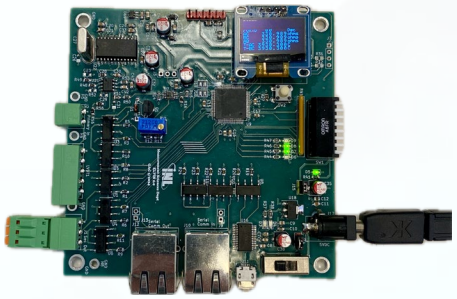
Performance Data

INL use of Mini LVDTs. Linearity and sensitivity reported at 20°C.

Experiment/Test	Measurement	Linearity (%)	Sensitivity (V/V/mm)
THOR	Pressure	0.6	0.139
THOR-C3	Pressure	1.0	0.133
THOR-M	Pressure	0.9	0.136
THOR-MOXTOP-1	Pressure	0.9	0.159
THOR-MOXTOP-2	Pressure	0.8	0.137
ELVIS I	Temperature	N/A	N/A
ELVIS II	Temperature/Displacement	0.3	0.201

Results and Accomplishments

- Task 1 - Develop miniature LVDT with inherent temperature monitoring capabilities.



ELVIS II (Enhanced Linear Variable Intrinsic Sensor II) Updates

- Changed from 10-bit Analog to Digital convertor (ADC) to 24-bit ADC to increase resolution
- Changed from 2-layer PCB board to 4-layer PCB board to reduce noise on analog signals
- Active filters added to reduce noise on analog signals
- Add dedicated reference voltage to ADC
- Increased driving current capacity through the LVDT
- Increased filtering of noise on power lines throughout the board
- Increased screens number of digits displayed

ELVIS II Test Results

TC (°C)	ELVIS II (°C)	Error (°C)	Error (%)
24.9	25.3	0.35	1.4
294.0	288.6	-5.36	-1.8
685.3	678.4	-6.98	-1.0

* Post processing required.

Concluding Remarks

Evaluation of Newtek Sensor Solutions' Prototype 1 and Prototype 2 LVDTs provided valuable insights for in-pile testing applications.

Prototype 1:

- Demonstrated commendable performance.
- Met desired linearity and sensitivity requirements up to 400° C.

Prototype 2:

- Designed to withstand temperatures up to 500° C.
- Promising results in linearity and sensitivity to 450° C. Post INL testing at Newtek suggests performance past 700° C.

Report: Qualification Testing of Commercial LVDTs Provided by Newtek Sensor Solutions, INL/RPT 24 80070, August 2024

Concluding Remarks

IFE's Mini LVDT and ELVIS prototypes are suitable for demanding environments in material test reactors.

- Mini LVDT offers high sensitivity and linearity in a compact size, ideal for space-constrained applications.
- ELVIS I and II, with integrated temperature sensing, provide accurate real-time data and addressing nuclear fuel research challenges.
- Future improvements to ELVIS will reduce noise and will enhance its utility for broader commercial applications.
- Mini LVDT and ELVIS series can advance measurement capabilities in high-radiation, high-temperature environments, contributing to safer and more efficient nuclear research and other industries

Report: Performance Test of Mini LVDT – ELVIS, INL/RPT 24 80631, September 2024

Patent: Attorney Docket 2939-P17909US (BA-1553), LVDT INTRINSIC TEMPERATURE MEASUREMENT, February 2024.

Thank You