Position Measurement, Deriving Velocity and Acceleration

Rick Sellens

Potentiometer Concept

- Potentiometers vary resistance with linear or rotary position
- Eo varies linearly with angle or displacement
- Can go more than 360 degrees, e.g. 10 turns 10K precision pot

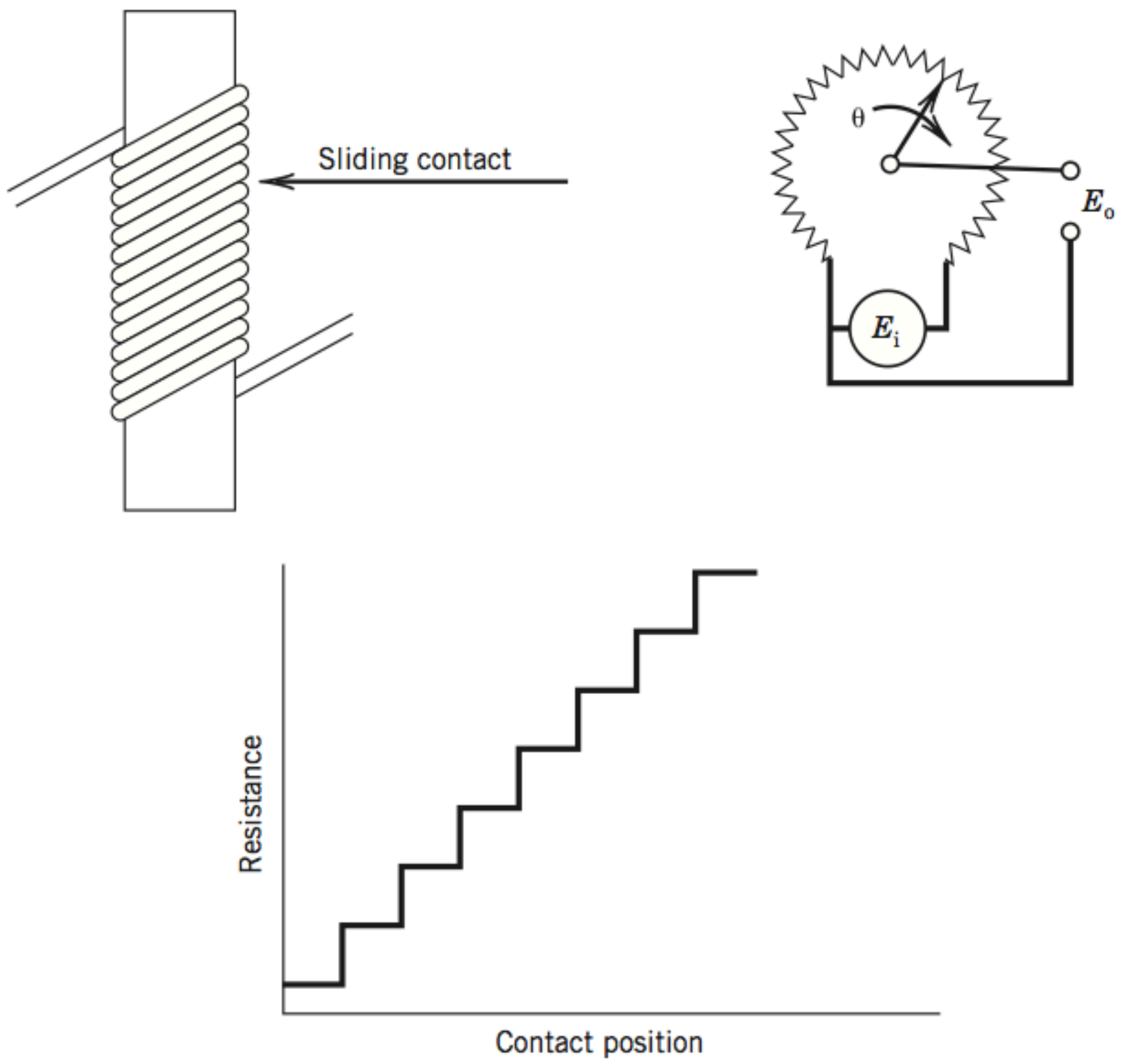


Figure 12.1 Potentiometer construction.

ASM®

Products | Co

Tape extension turns potentiometer against a recoil spring

Linear position sensor / belt / potentiometer / rugged

WB17KT

Potentiometer

- Advantages: simple, linear, cheap,
  - easy analog interface, large range
  - retains position registration without power
- Disadvantages: analog, needs calibration,
  - mechanical wear limits cycle life
  - limited range, e.g. 10 turns, not perfectly linear

LVDT (Linear Variable Differential Transformer)

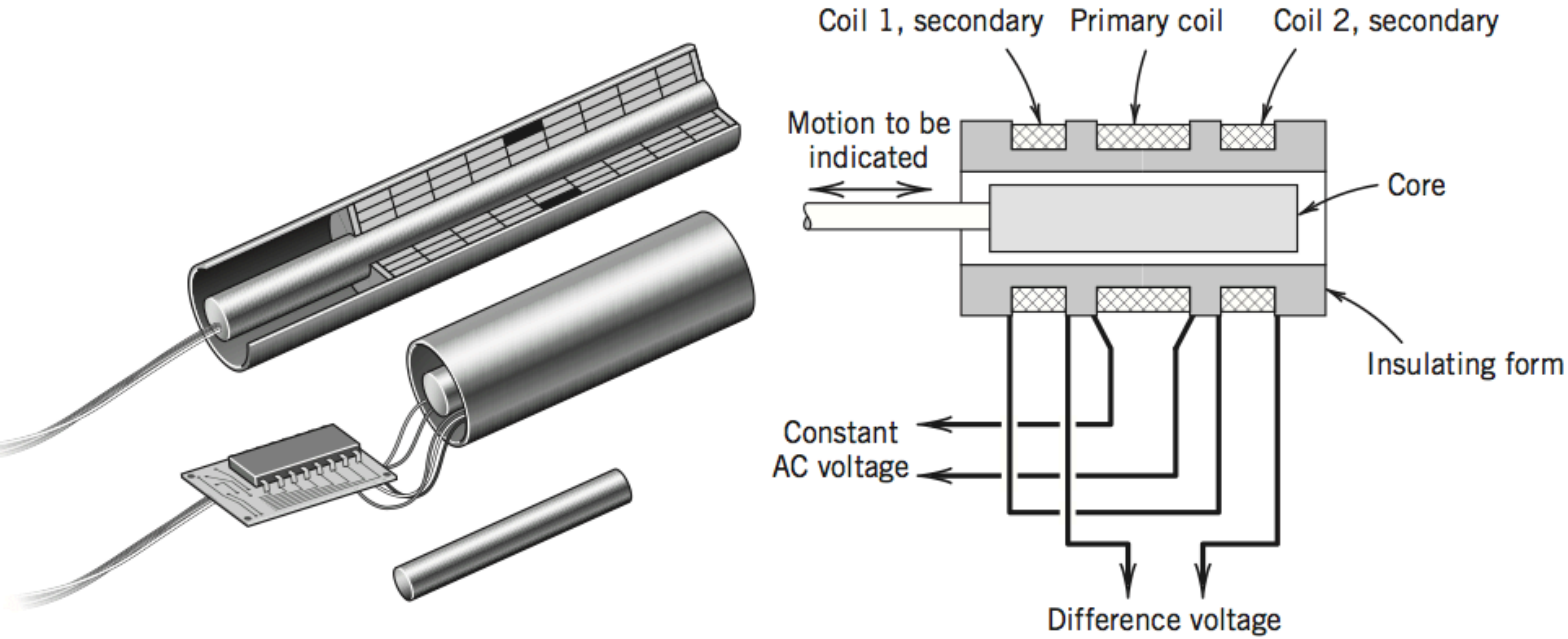


Figure 12.3 Construction of a linear variable differential transformer (LVDT).

LVDT (Linear Variable Differential Transformer)

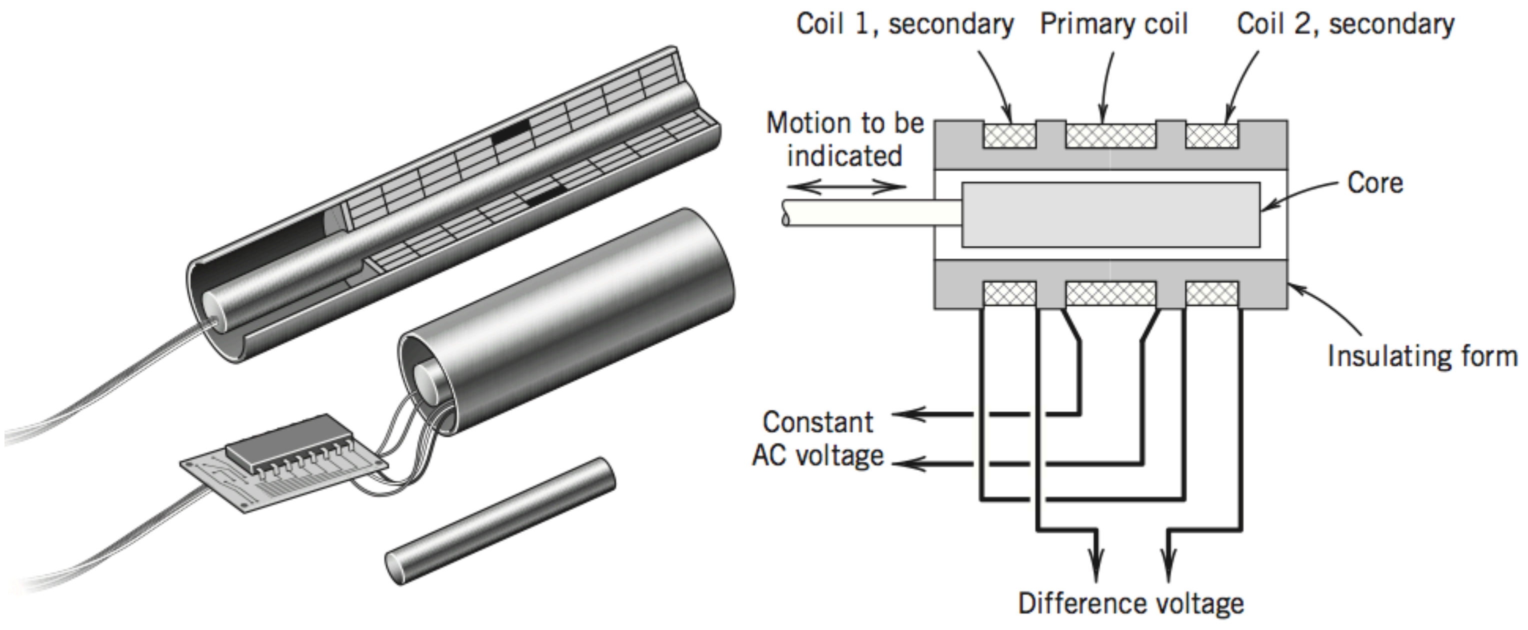


Figure 12.3 Construction of a linear variable differential transformer (LVDT).

- Core motion changes AC coupling between coils
- Linear over small range
- Frictionless, non-contact, so no cycle limitations
- Range limited by size of coils and core

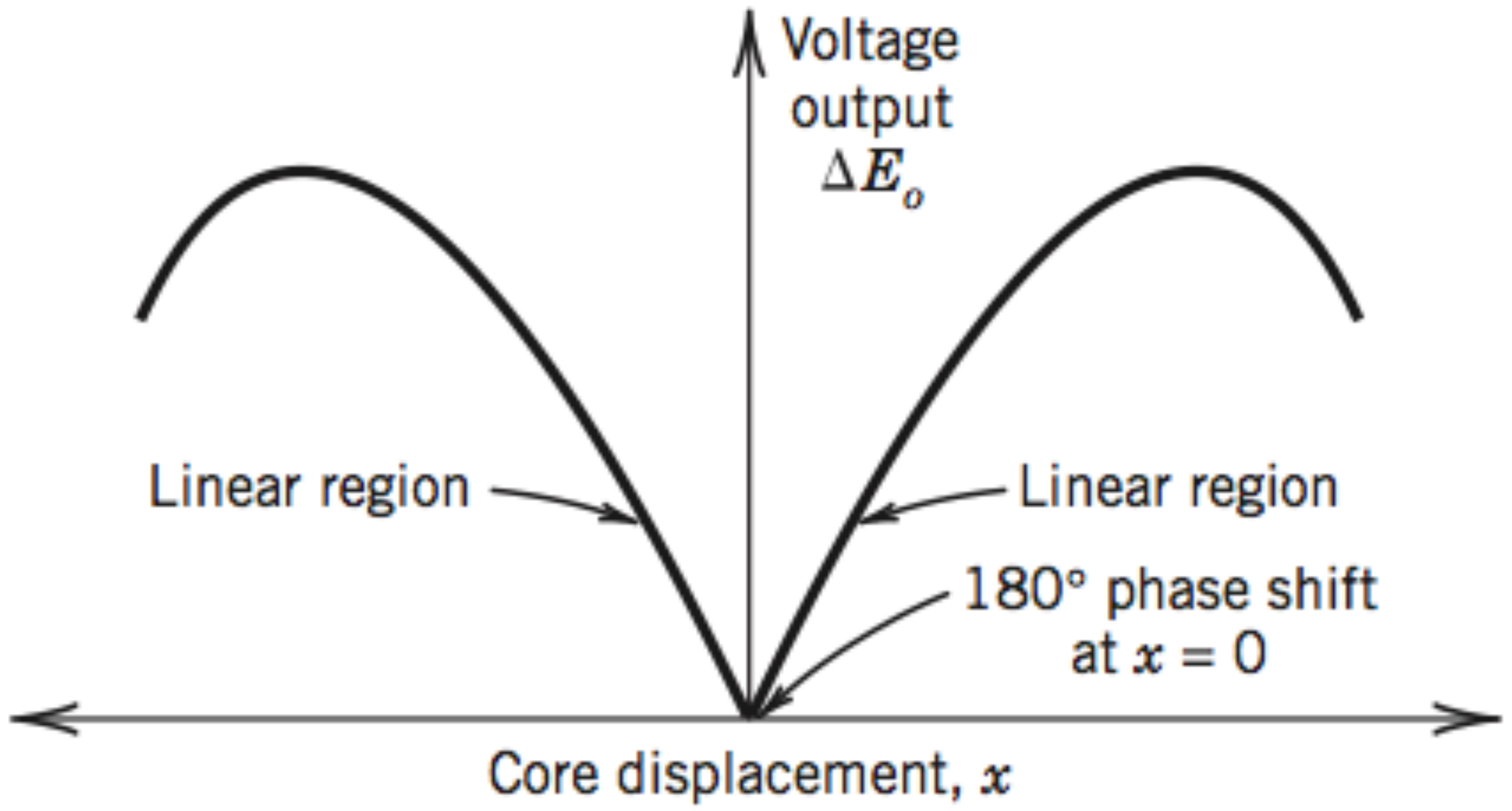
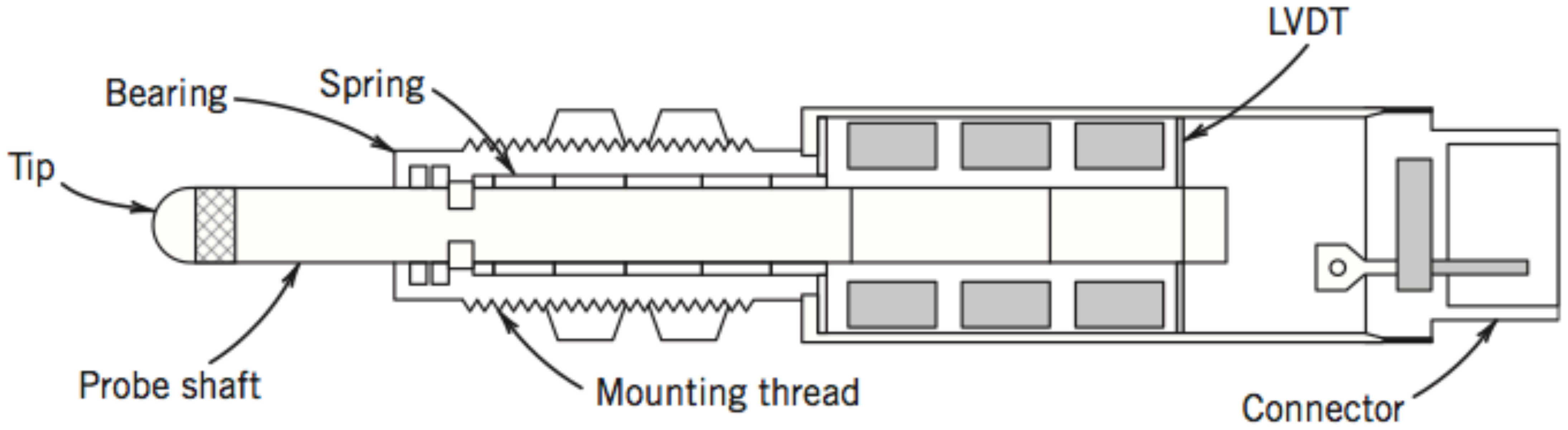


Figure 12.4 LVDT output as a function of core position.



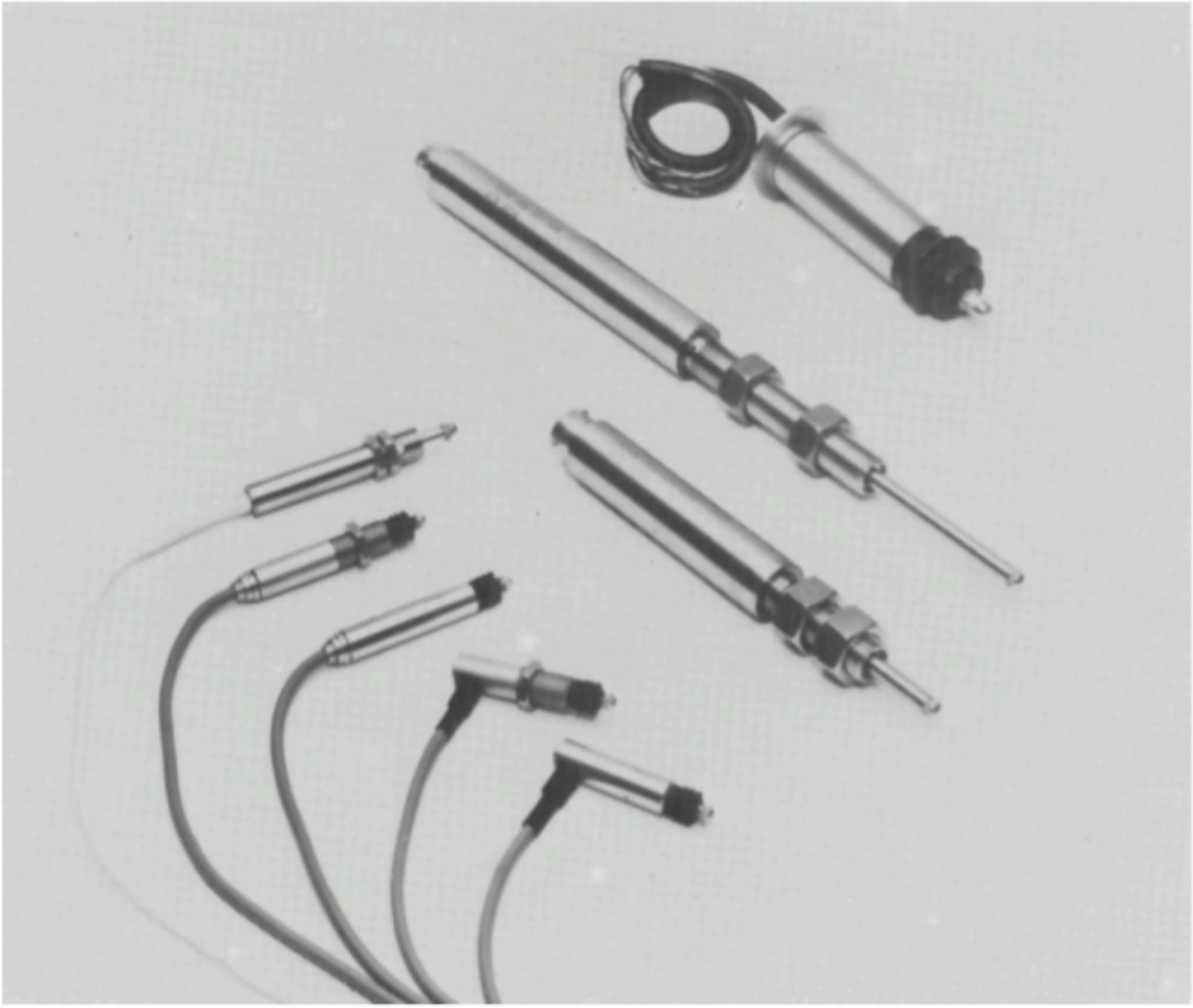


Figure 12.5 LVDT gauge head. Top: Cross section of a typical LVDT gauge head. (Courtesy of Measurement Specialties, Inc.; from reference 2. Used with permission.)

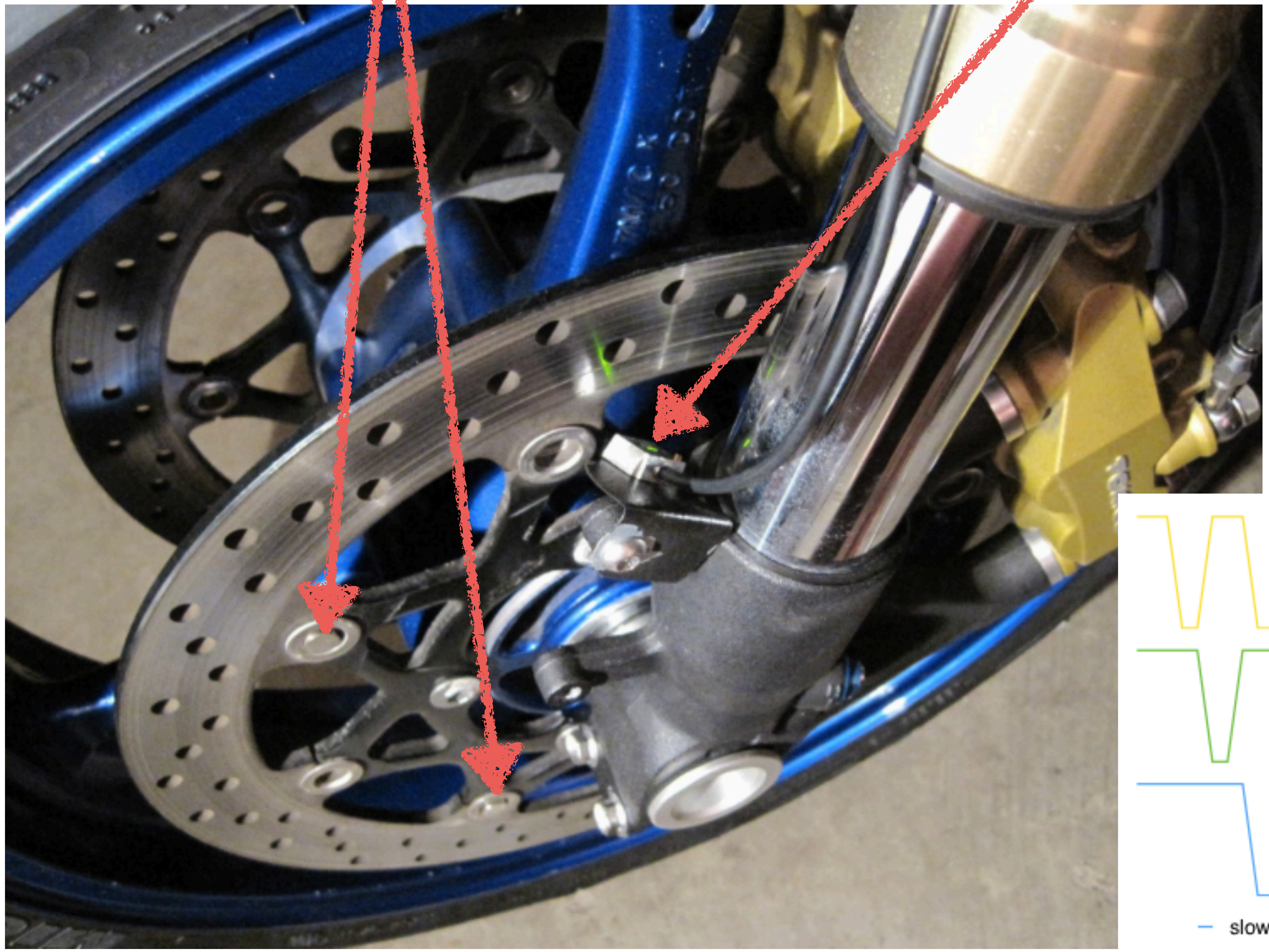
LVDT

- Advantages: high accuracy, unlimited cycles
    - holds position registration without power
- Disadvantages: calibration, phase for direction
    - limited range of position

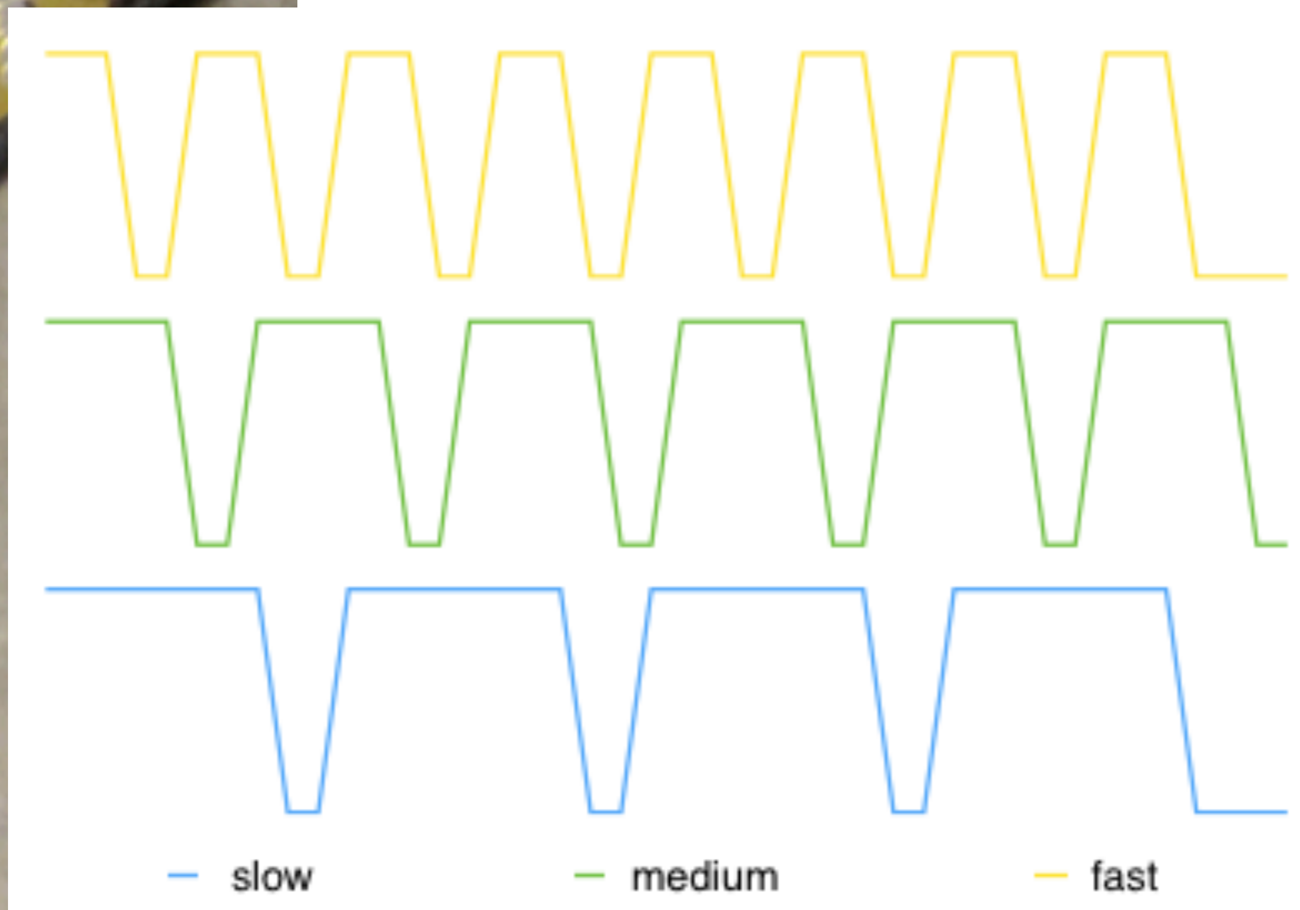
Digital Encoding

- Detect position by binary state of a sensor
  - optically by either transmitting or blocking light
  - conductively by either connecting or not connecting a circuit
  - magnetically by detecting presence or absence of a magnetic field
- Largely independent of noise and easy to follow with micro controller DIO pins, and interrupts

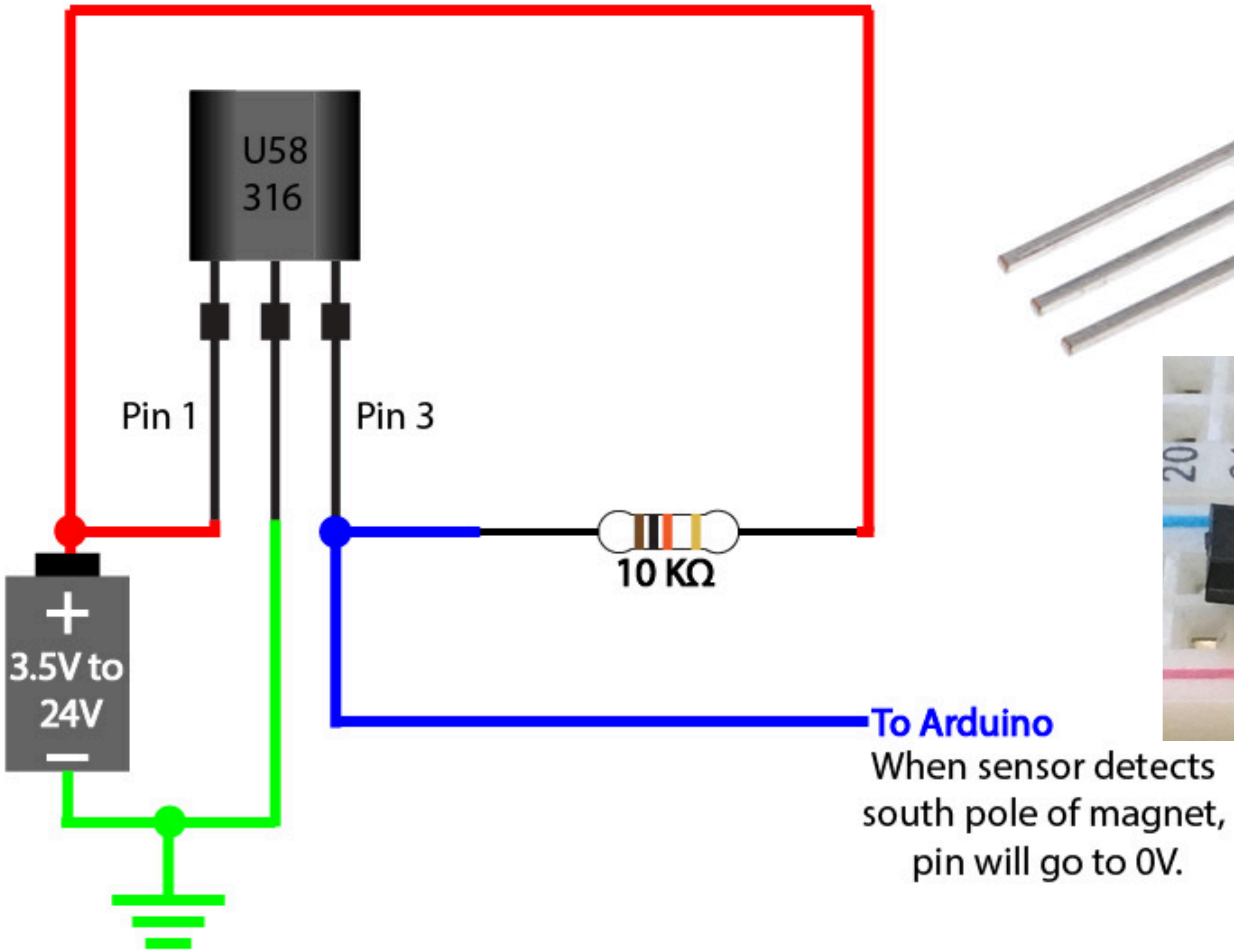
Detect position / passage of magnets with Hall effect sensor

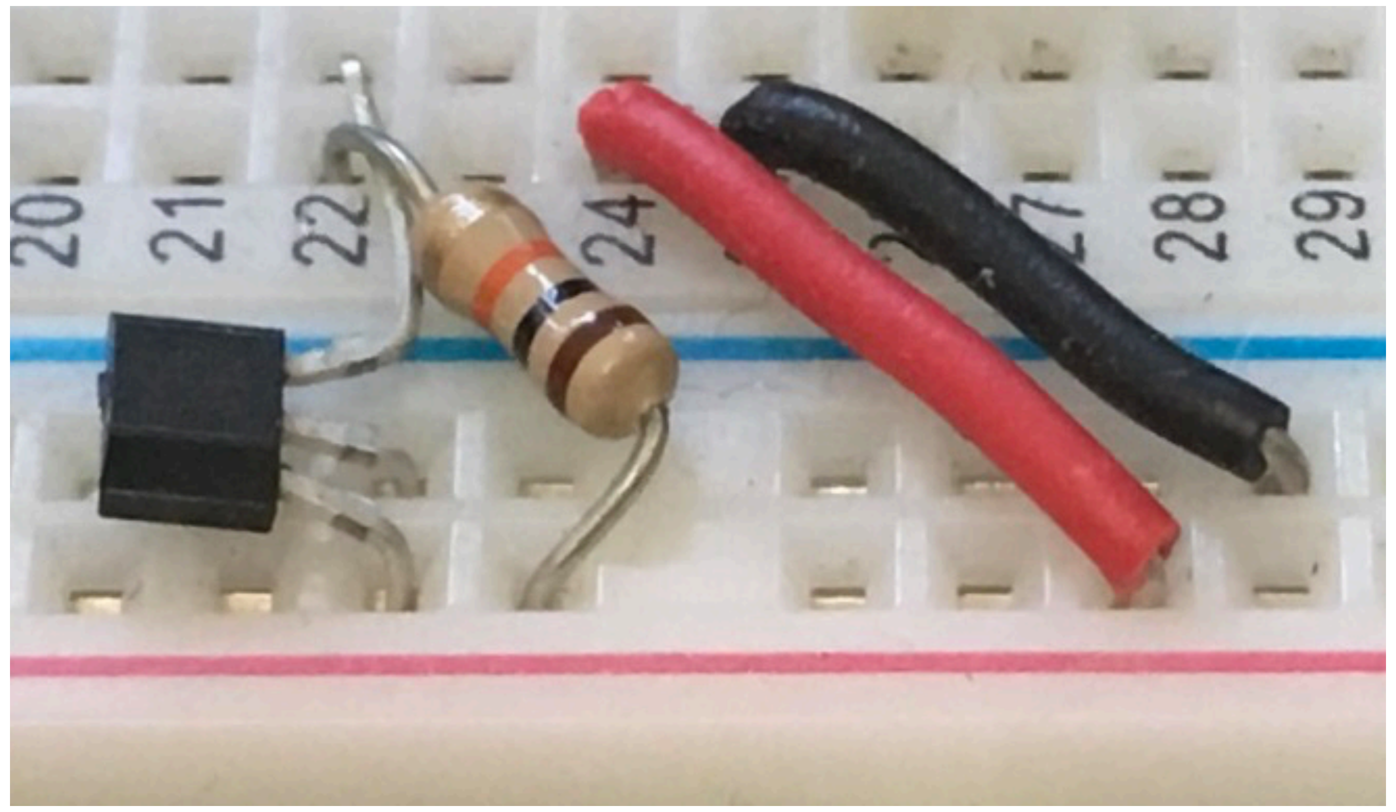


Active Low
when magnet
passes sensor



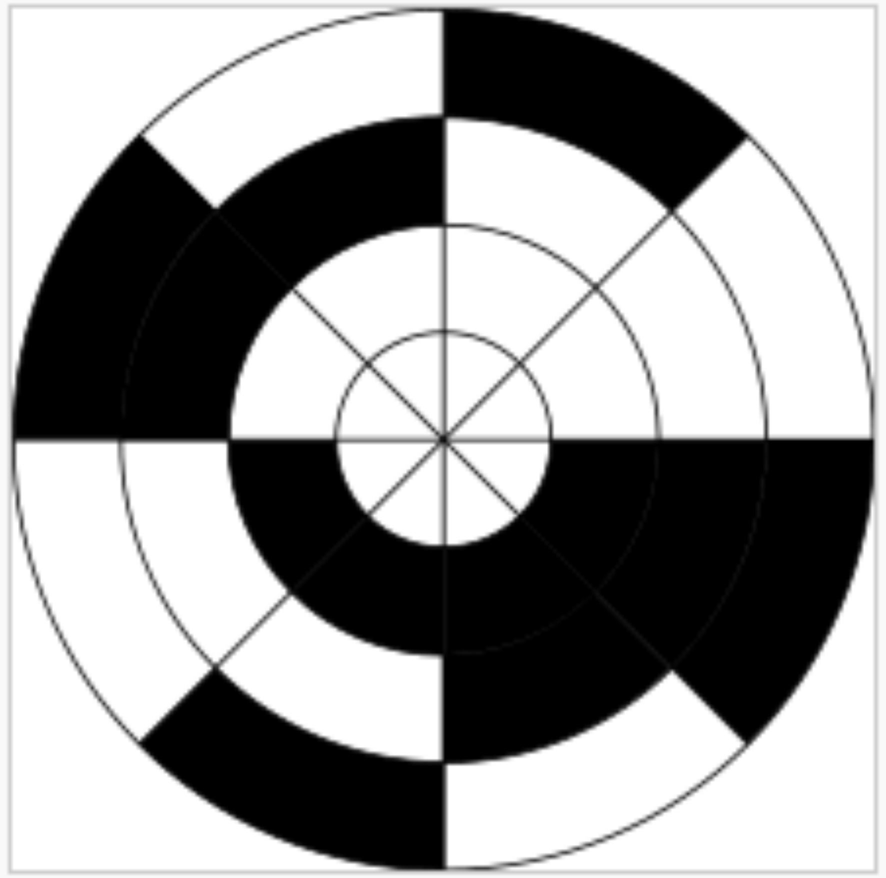
Hall Effect Sensor



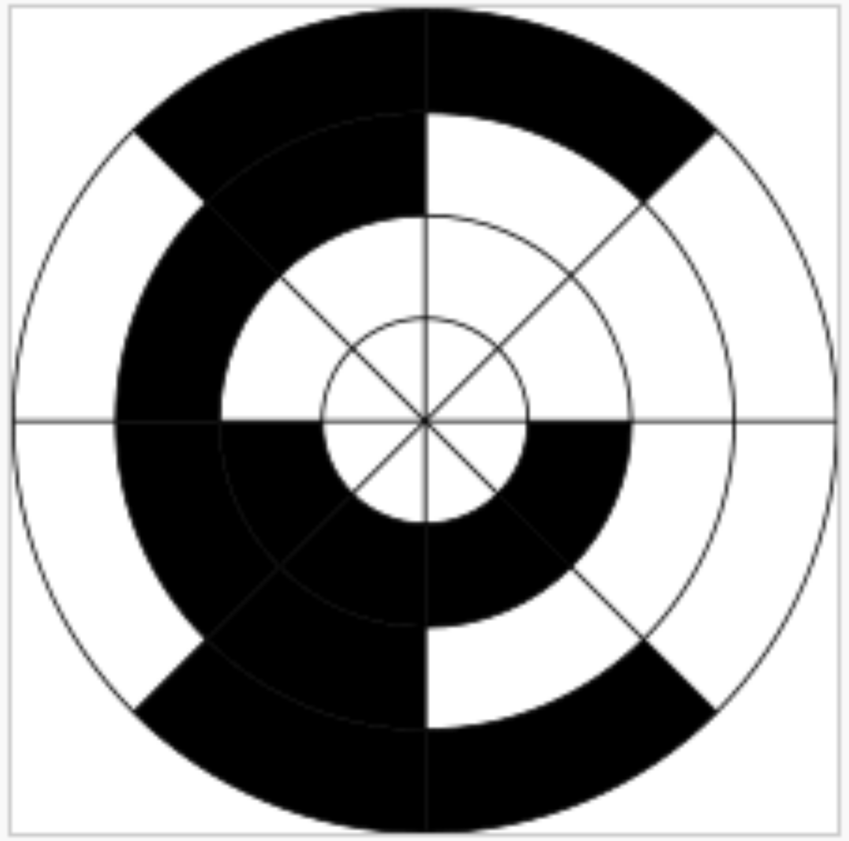


Absolute Rotary Encoder

- 3 bit for example only distinguishes octants
- 16 bit splits circle into 0.0055 degree segments
- 10/12 bit more affordable (around $40 / unit)
- Retains registration without power



Rotary encoder for angle-measuring devices marked in 3-bit binary. The inner ring corresponds to Contact 1 in the table. Black sectors are "on". Zero degrees is on the right-hand side, with angle increasing counterclockwise.



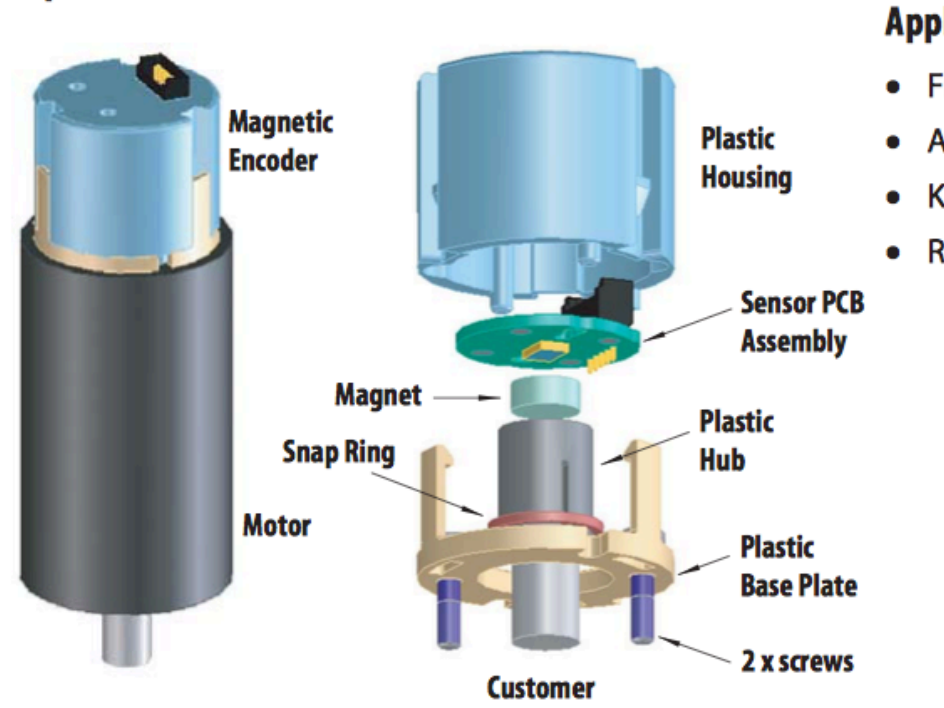
Rotary encoder for angle-measuring devices marked in 3-bit binary-reflected Gray code (BRGC). The inner ring corresponds to Contact 1 in the table. Black sectors are "on". Zero degrees is on the right-hand side, with angle increasing counter-clockwise.

AEAT-6010/6012 Magnetic Encoder

10 or 12 bit Angular Detection Device

AVAGO TECHNOLOGIES

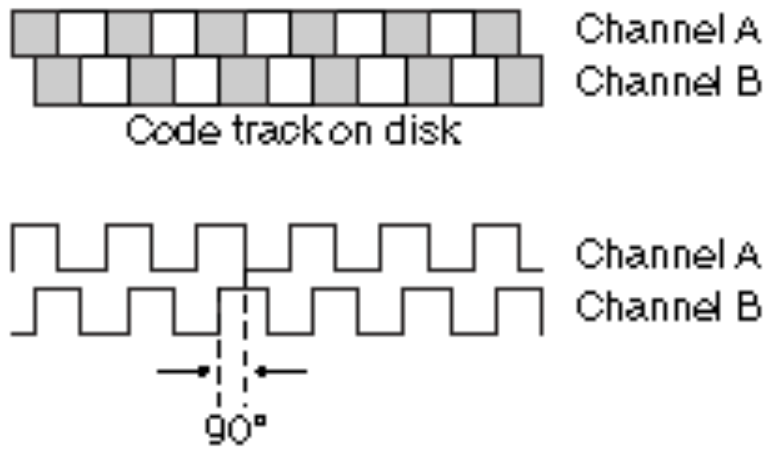
Exploded View

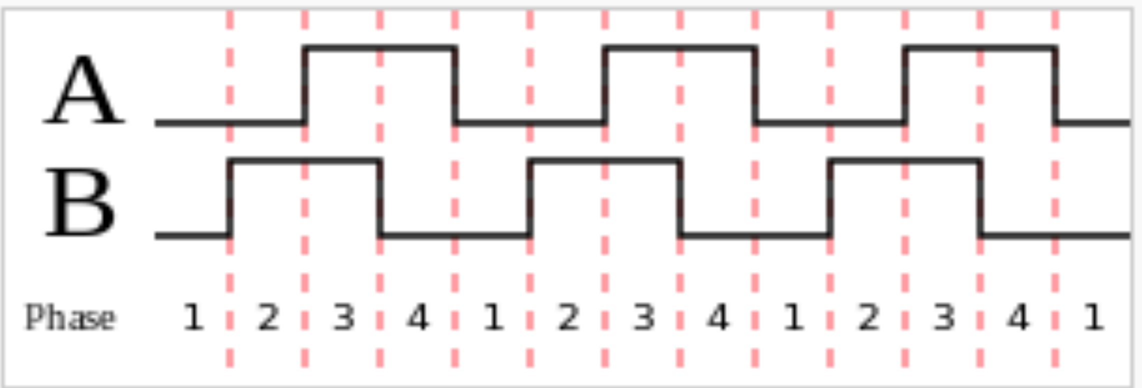


Applications

- Flow meter
- Angular detection
- Knob control
- Rotary encoder

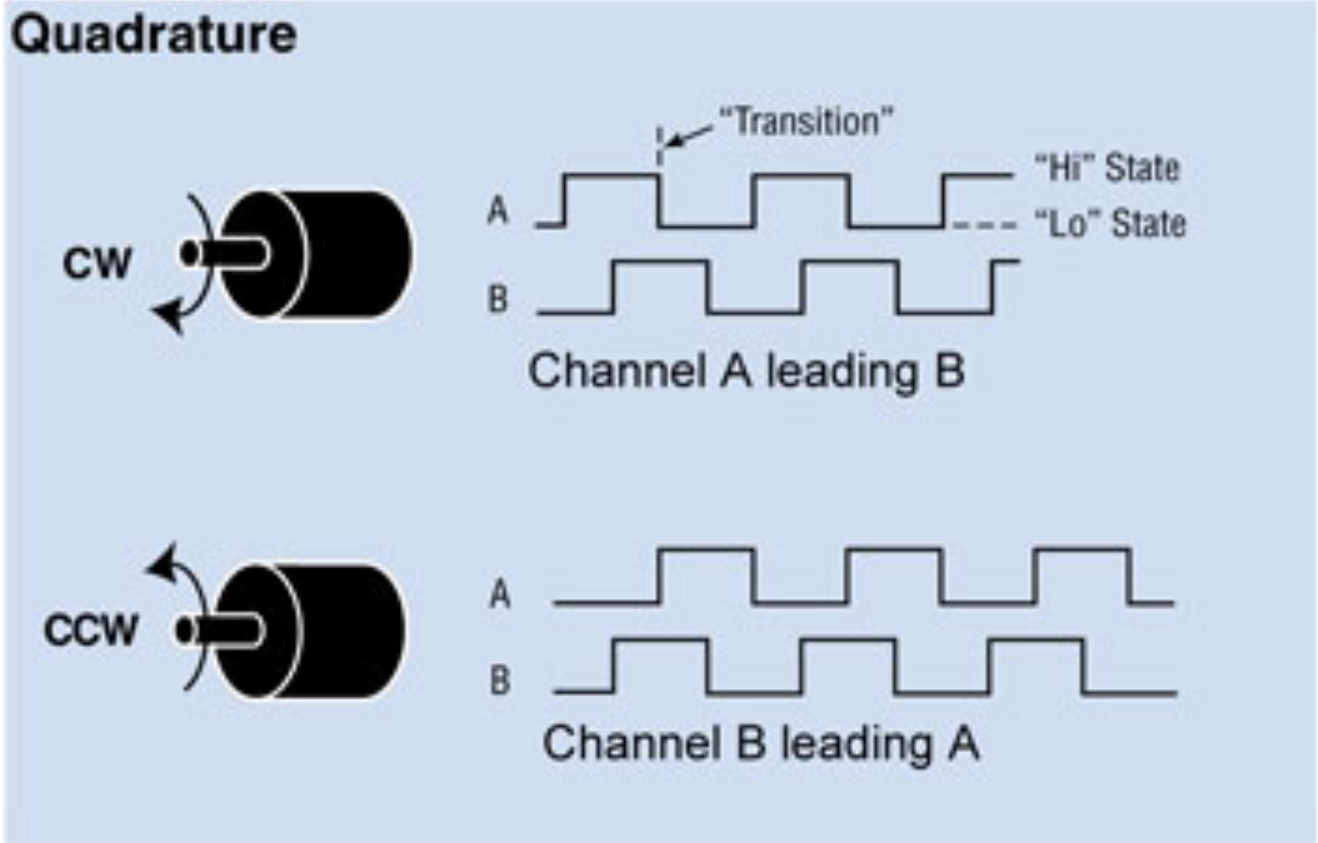
Incremental Rotary Encoders in Quadrature

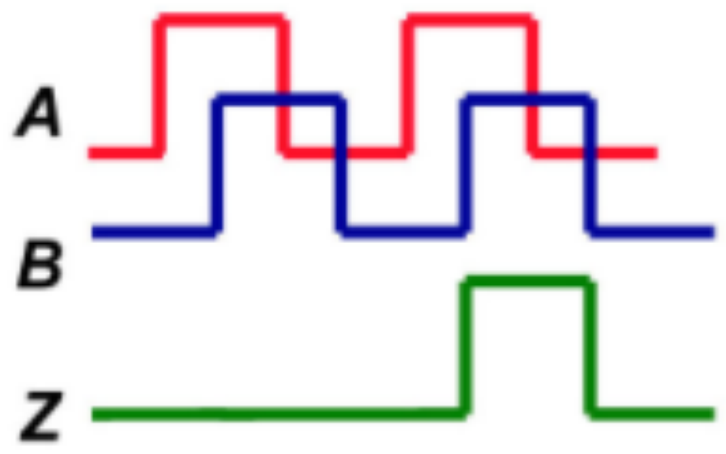




Two square waves in quadrature (clockwise rotation).

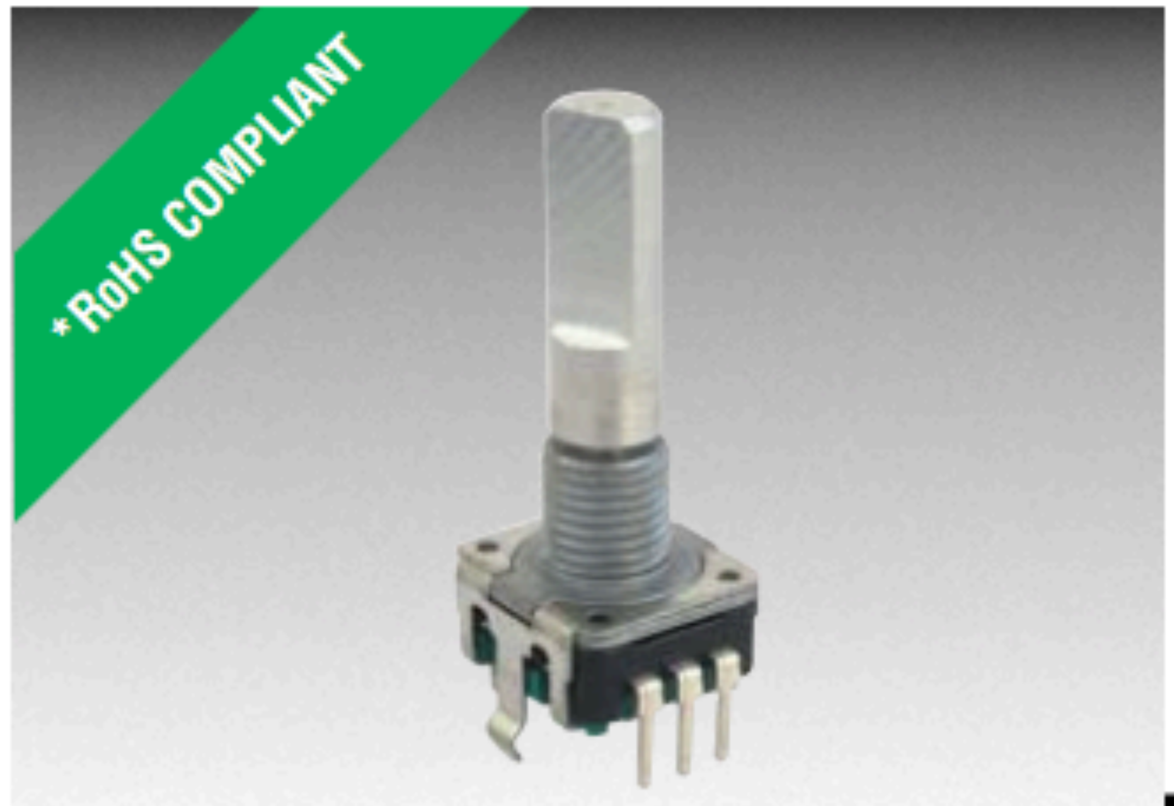
- provides two outputs that are 90 degrees out of phase (quadrature)
- which one is leading will tell you direction of motion
- An additional marker track Z is needed to recover registration after power loss





Mechanical Encoders

- On the front panel of your car stereo, etc., about $2
- Won't last as long as optical



BOURNS®

Features

- Push switch option
- Compact, rugged design
- High reliability
- Metal bushing/shaft

BOURNS® PRO AUDIO

PEC11 Series - 12 mm Incremental Encoder

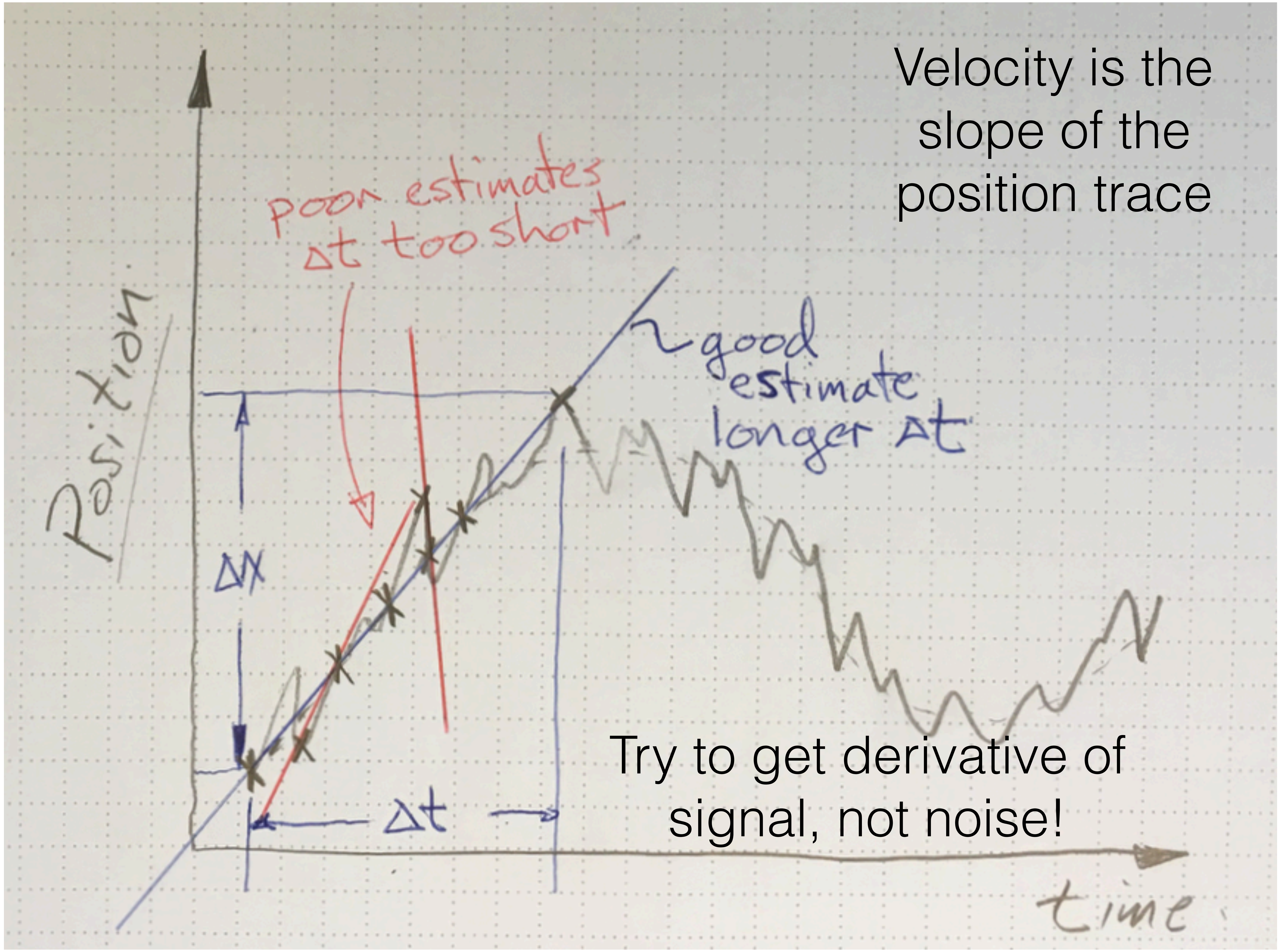
Electrical Characteristics

Output	2-bit quadrature code
Closed Circuit Resistance	3 ohms maximum
Contact Rating	1 mA @ 5 VDC
Insulation Resistance	100 megohms @ 250 VDC
Dielectric Withstanding Voltage	
Sea Level	300 VAC minimum
Electrical Travel	Continuous
Contact Bounce (15 RPM)	5.0 ms maximum**
RPM (Operating)	60 maximum**

Velocity

- Usually calculated from delta x / delta t
- Numerical differentiation depends on the accuracy and resolution of delta x and delta t
- For example: Measure RPM by detecting 1 pulse of a hall sensor per revolution and counting for 1 second gives discrete steps of 60 RPM in your measurement — ask the people on the car teams
    - 60 line incremental encoder would give you 1 RPM resolution

Velocity is the slope of the position trace



Try to get derivative of signal, not noise!

Differentiating Analog Noise

- Really need some smoothing on that data!

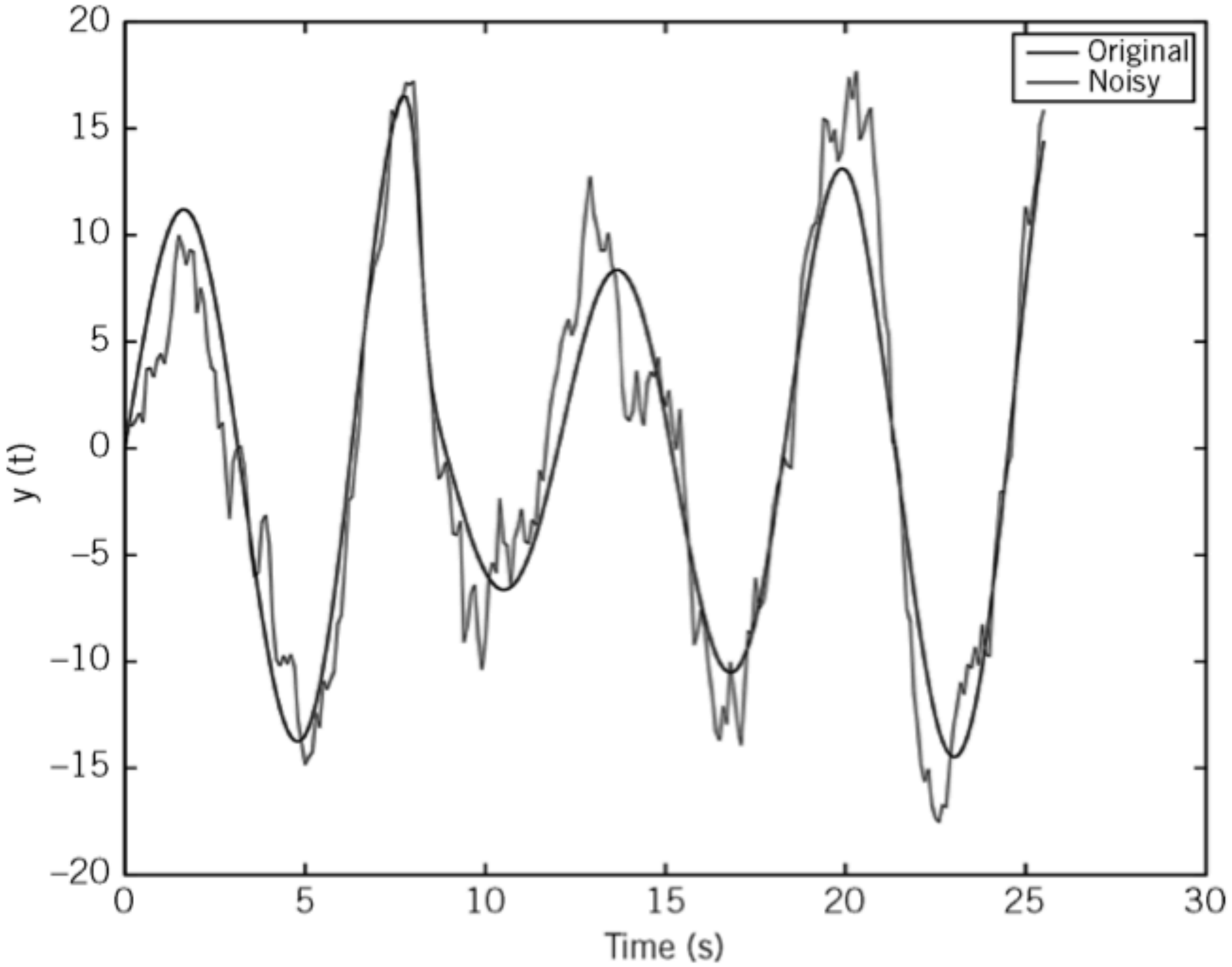


Figure 12.12 Deterministic signal with added noise.

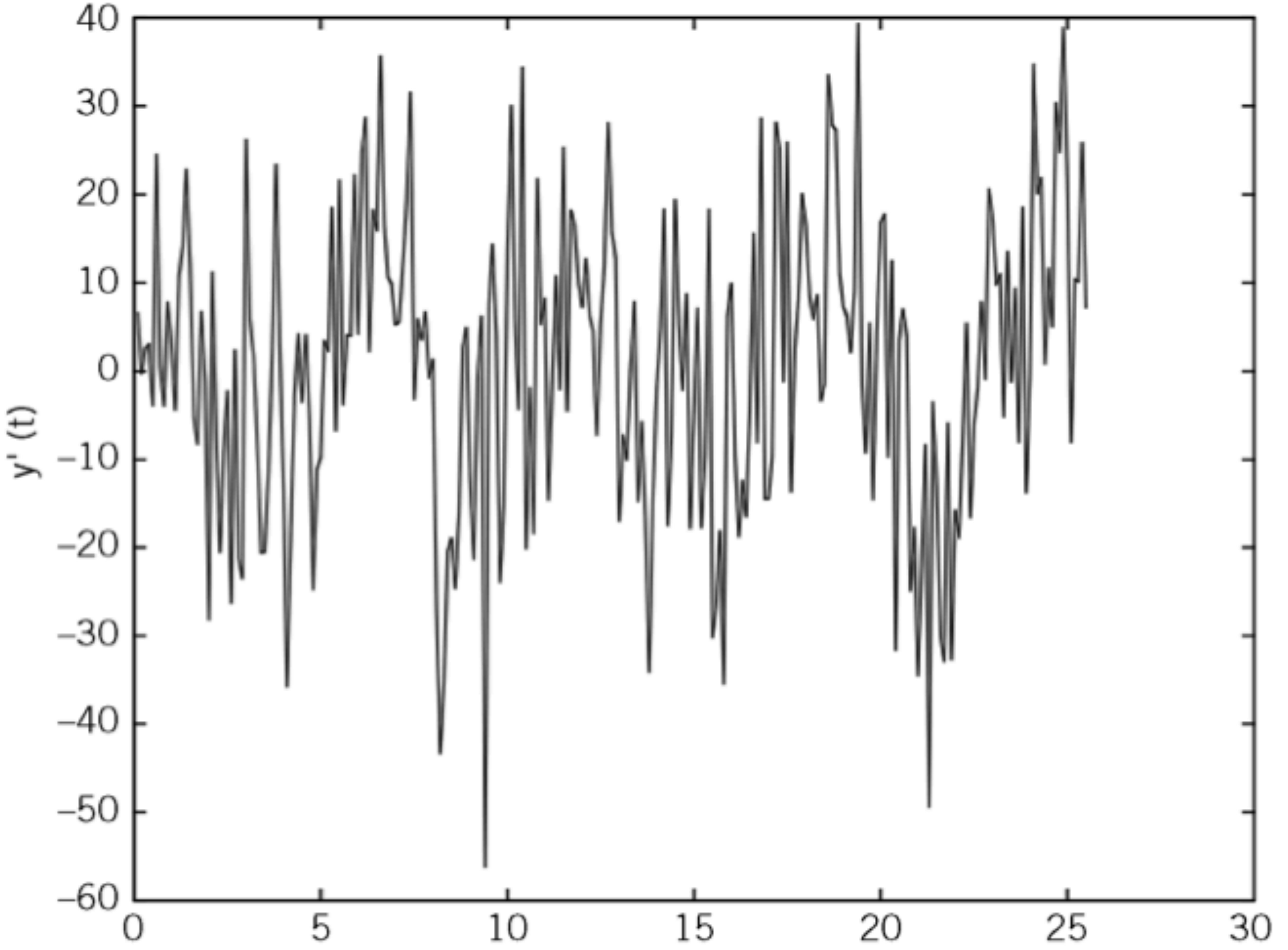


Figure 12.14 Result of numerical differentiation of the noisy signal from Figure 12.12.