Sensors Converge

Case Study: Evaluating an Automotive User Interface Design

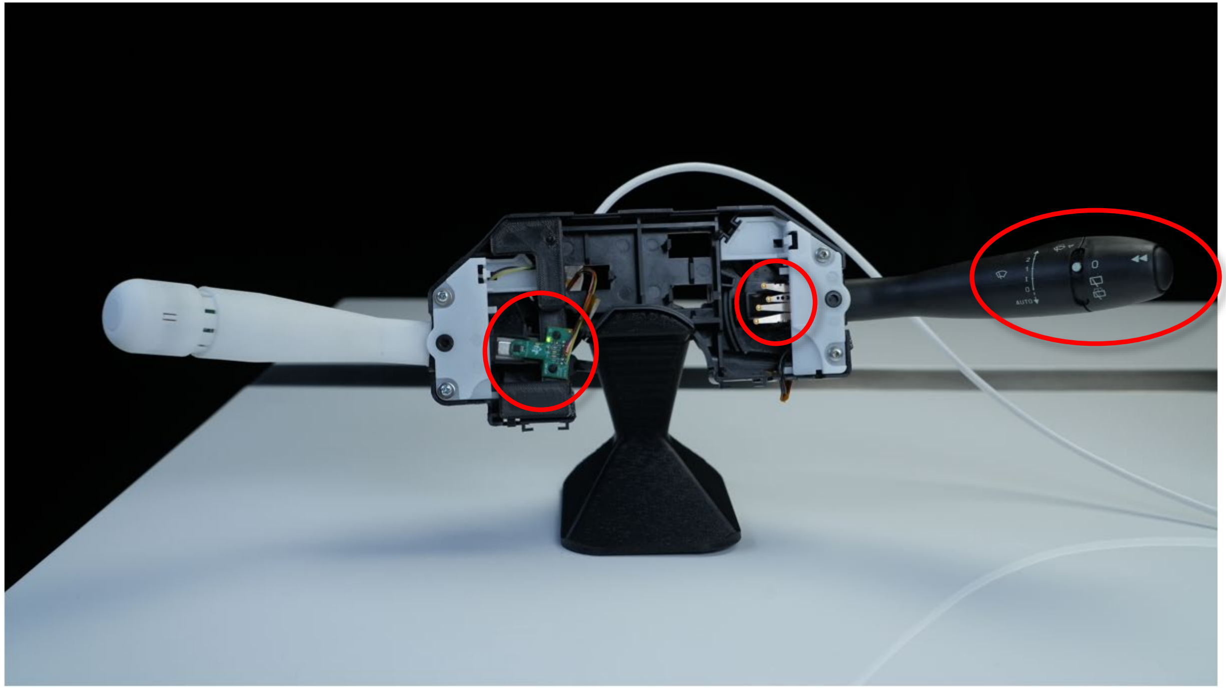
June 20–22, 2023 | Santa Clara, CA

#SensorsConverge

Agenda

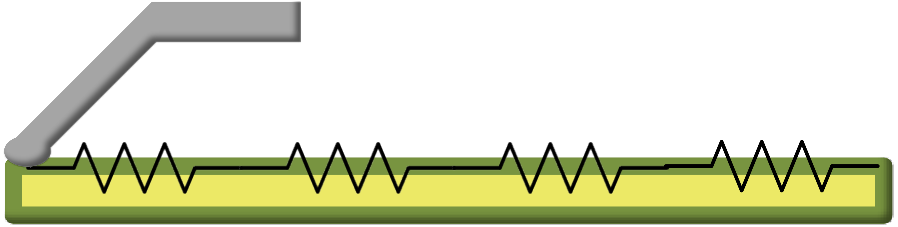
- **Overview**
- **Mechanical Switch Basics**
  - Typical operation
  - Failure modes
  - Maintenance
- **Design Goal**
- **Push-button Knob**
  - Sensor replacement
  - Simulation
  - CORDIC
- **Turn Indicator**
  - Sensor replacement
  - Simulation
  - Vector Angles
- **Test Results**
- **Demonstration**
- **Summary**

Steering column stalk module

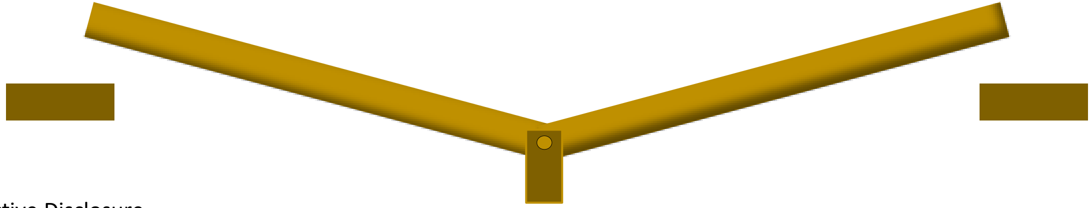


Mechanical wiper contact basics

- Wiper controls slide across a resistive surface and create a changing voltage divider

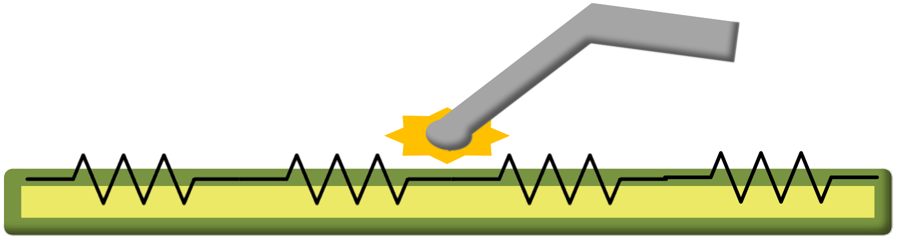


- Cantilevered throws toggle between open and closed positions to change electrical path

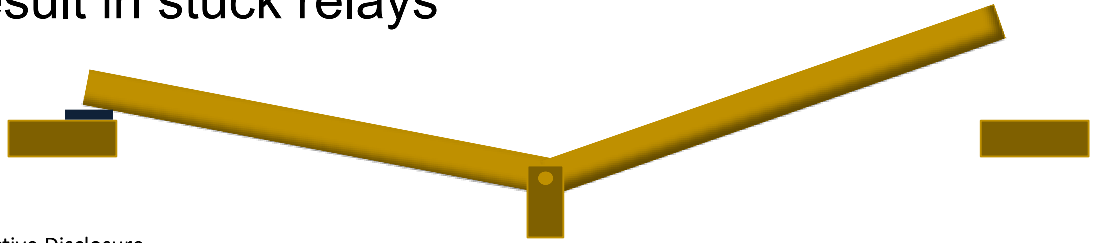


Mechanical wiper challenges

- Mechanical wear can result in slippage



- Oxidation and corrosion can prevent good contact or result in stuck relays



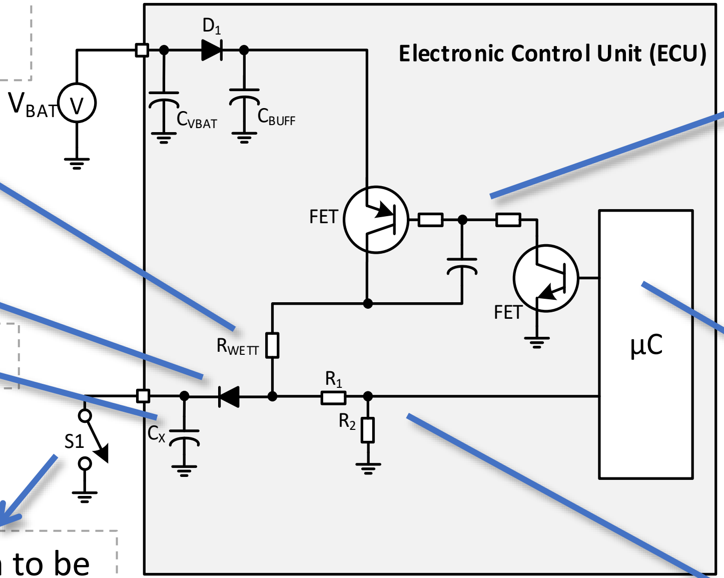
Wetting current and diagnostics

Wetting current: 1-15 mA

Wetting current adjustment resistor

Blocking diodes to prevent current back flow in shared ECU implementation

Input capacitor for ESD protection



FET + resistors for wetting current timing control

1 μC GPIO for every switch to be monitored

Switch to be monitored

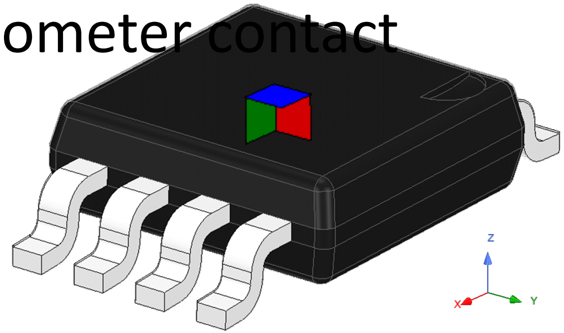
Components required to support each switch channel:

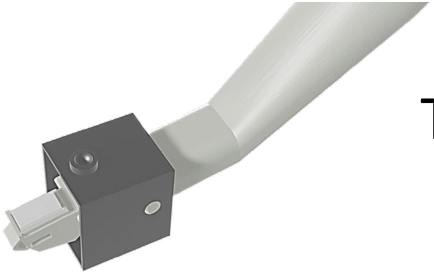
- 5 resistors
- 2 capacitors
- 1 diodes
- 2 FETs

Resistor divider to scale down the input voltage for the μC to sample

Three dimensional sensors

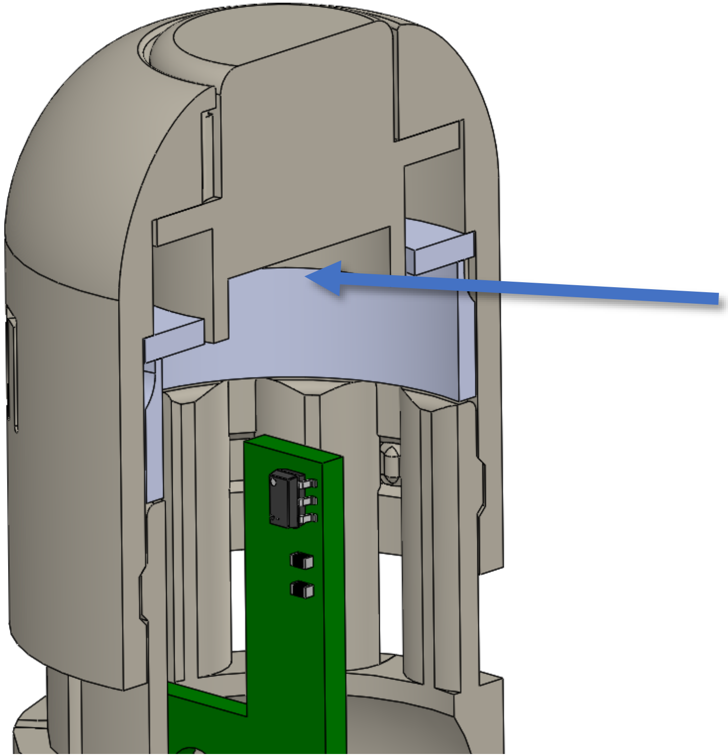
Push-button Knob: Potentiometer contact

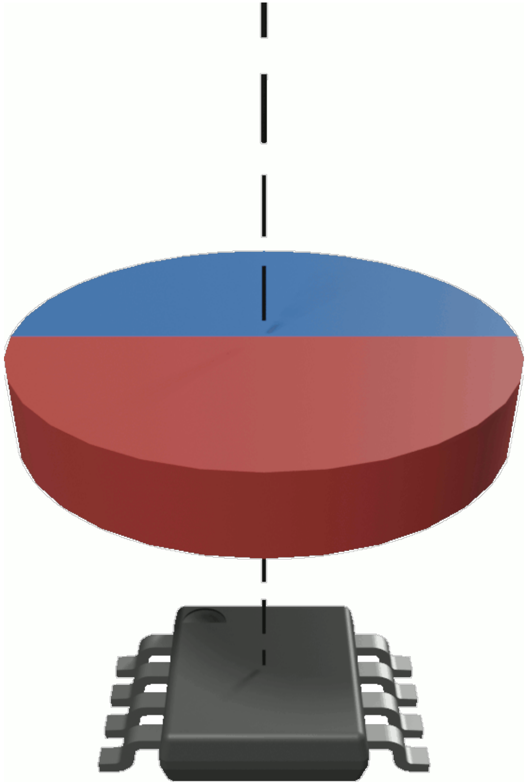




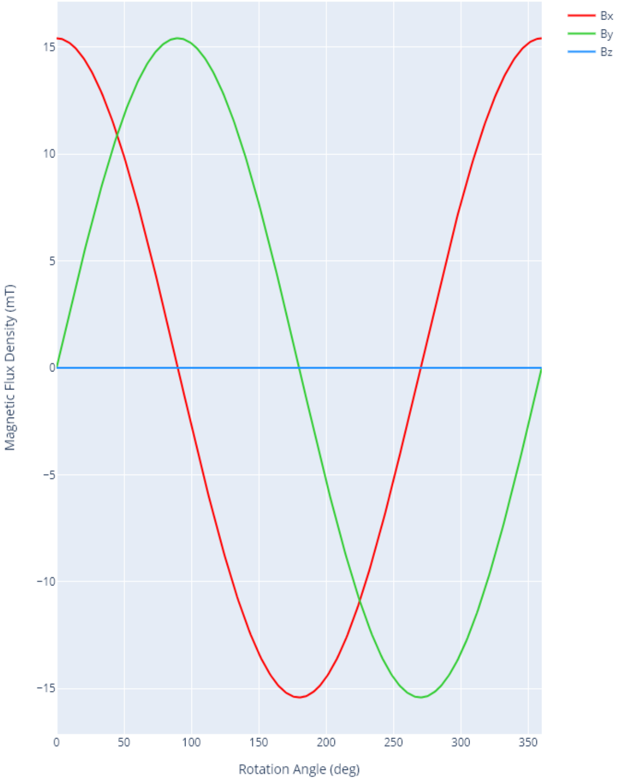
Turn Indicator: Multi-position relay contact

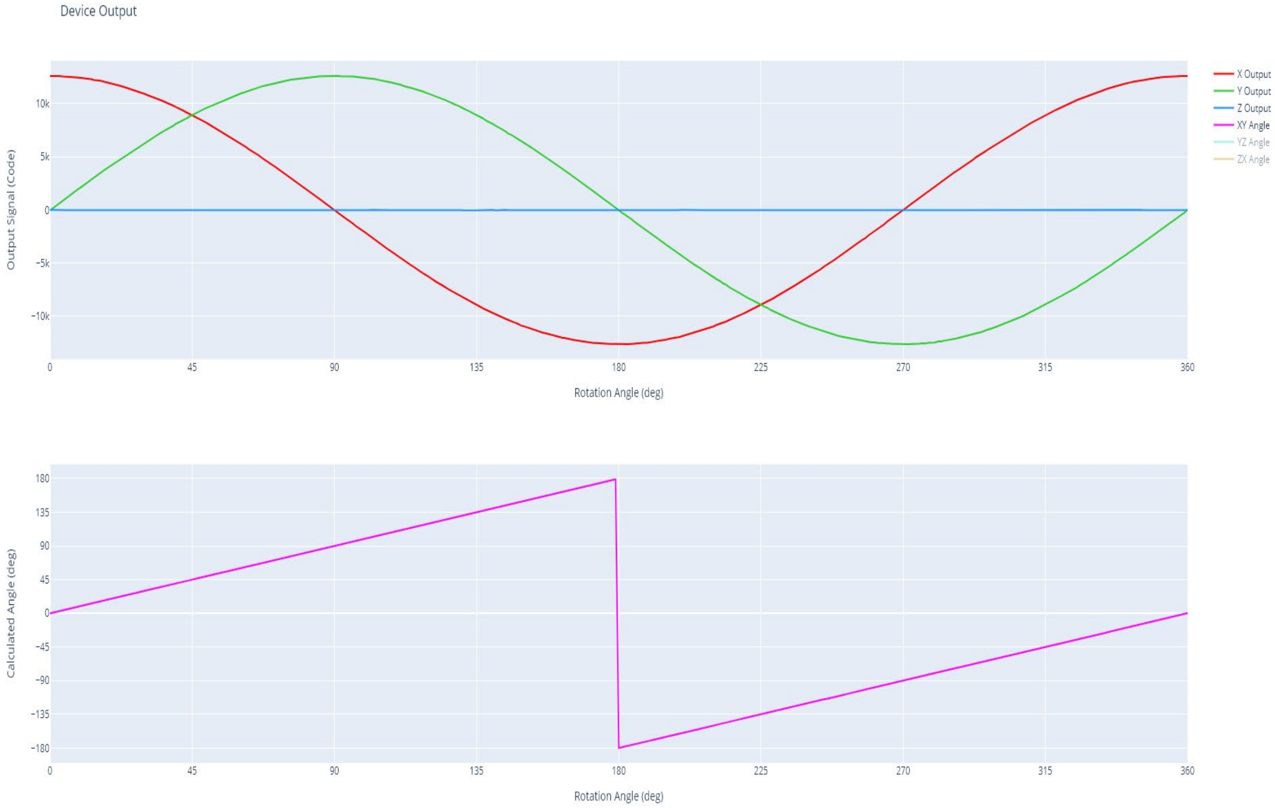
Push-button knob function





Unpressed Knob Simulation





Sensors Converge

CORDIC algorithm

Coordinate

Rotation

Digital

Computer

Error = 49.5°

- 45°

- 26.56°

+ 14.04°

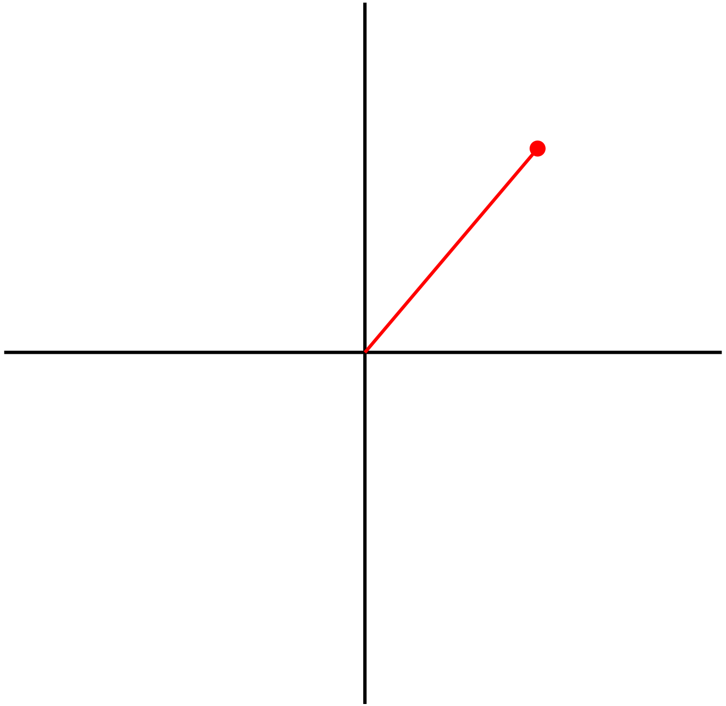
+ 7.13°

+ 3.58°

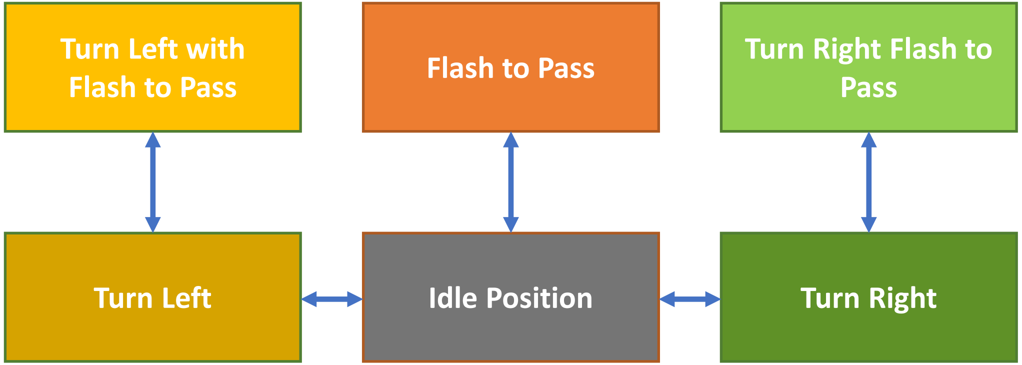
- 1.79°

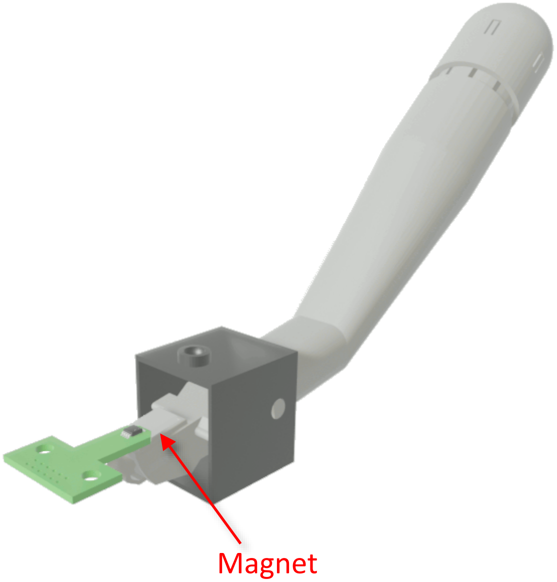
- 0.90°

$\cong$ 0°



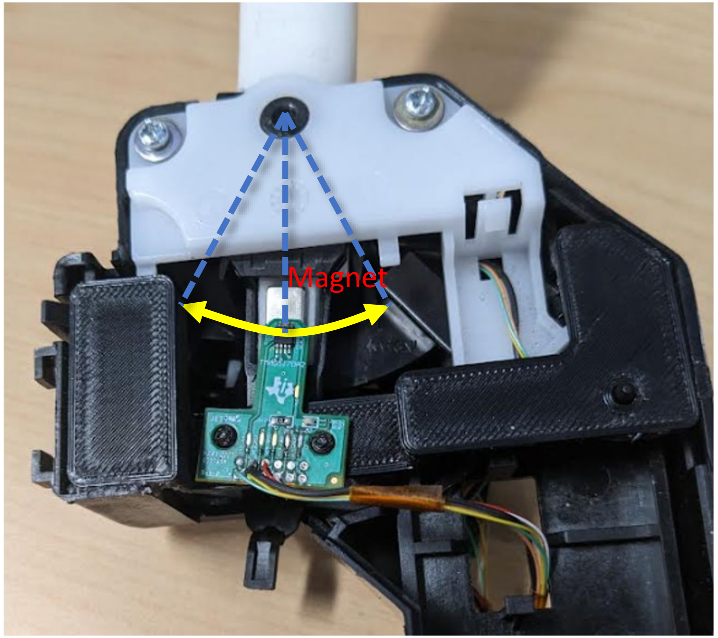
Turn indicator function



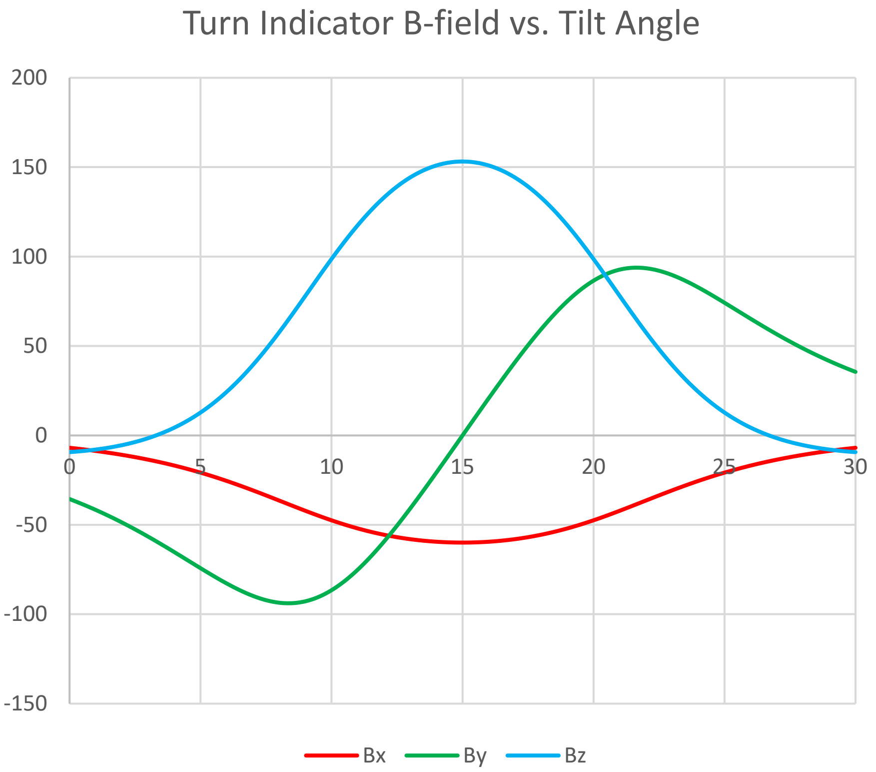


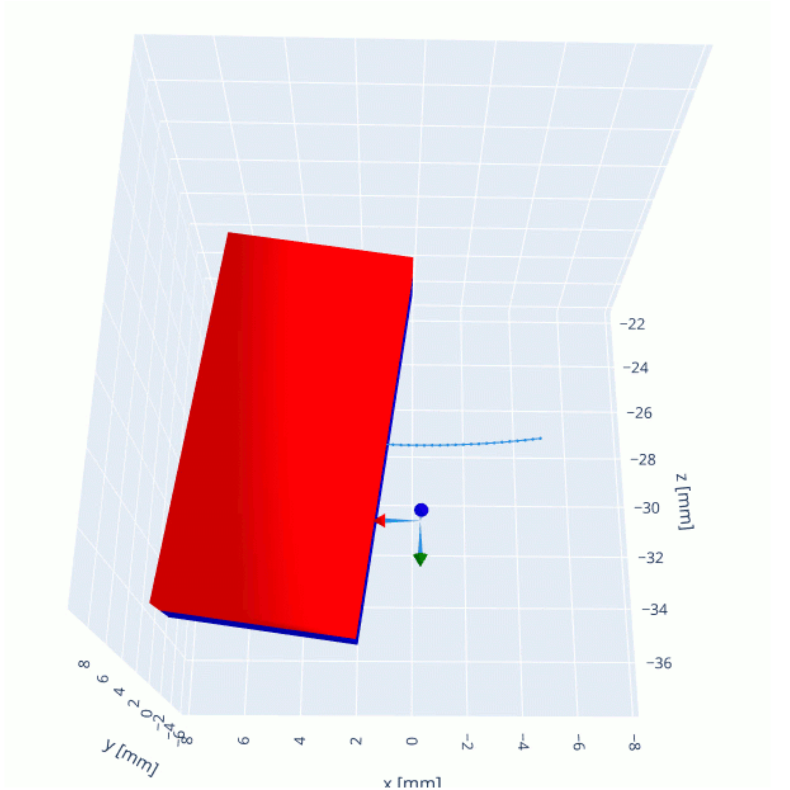
Turn indicator simulation

- Motion parameters
  - Lock into 3 horizontal positions: -8, 0, +8 degrees
- Magnet Selection:
  - N52
  - 12.7mm x 6.35 mm x 3.175 mm
    - (0.5 in x 0.25 in x 0.125 in)
  - Default tilt at 5 degrees
  - Magnet Center 30 mm from fulcrum
- Sensor placement
  - Tilted 10 degrees on bracket align to magnet
  - 34 mm from fulcrum



Turn indicator simulation



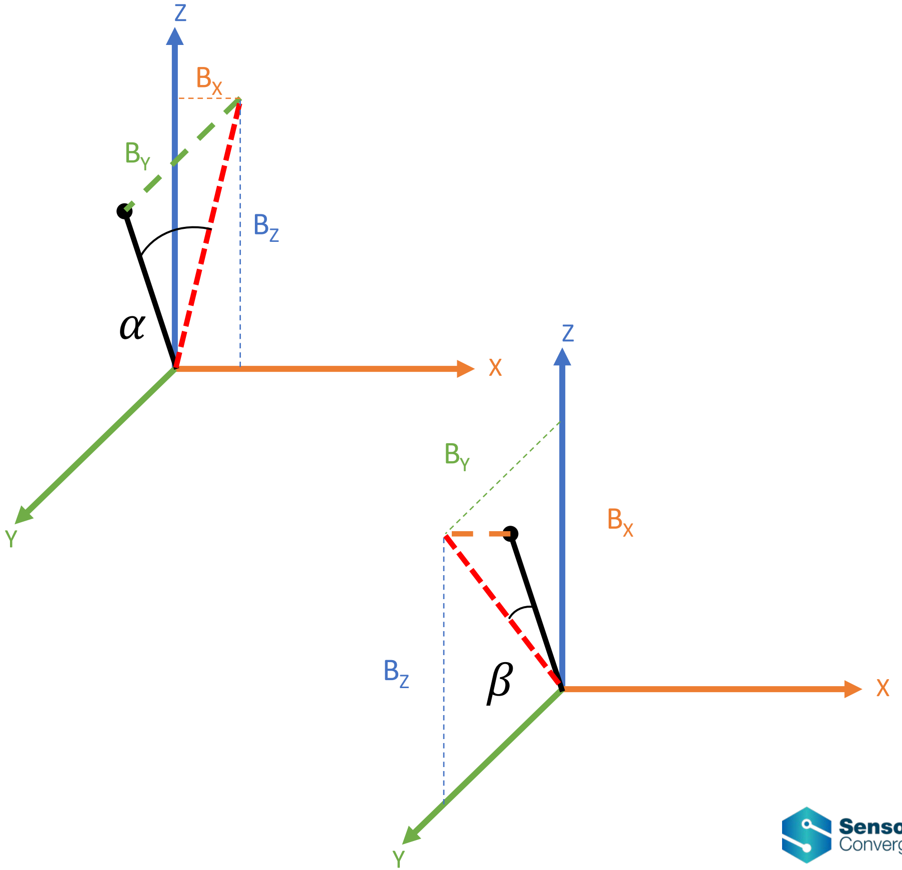


Alpha and Beta angles

$$\alpha = \text{atan}\left(\frac{\sqrt{{B_z}^2 + {B_x}^2}}{B_y}\right)$$

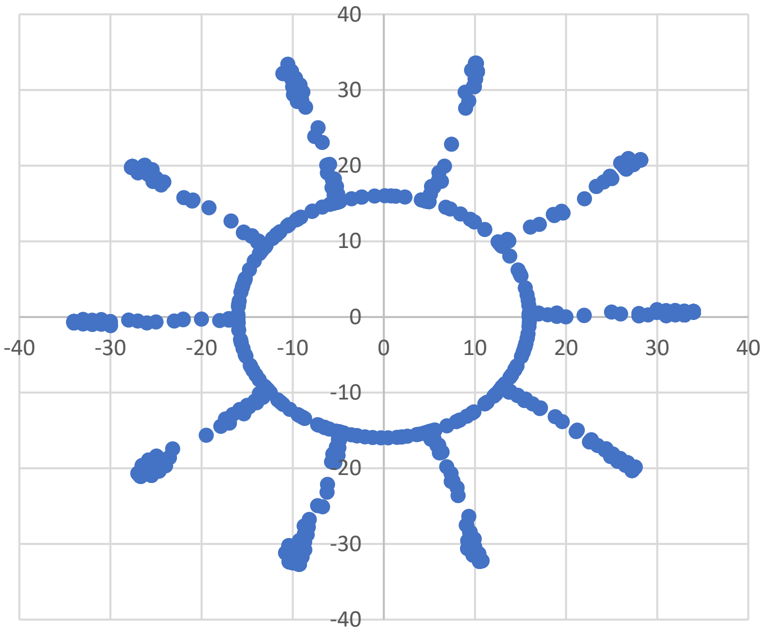
$$\beta = \text{atan}\left(\frac{\sqrt{{B_z}^2 + {B_y}^2}}{B_x}\right)$$

$$magnitude = \sqrt{{B_x}^2 + {B_y}^2 + {B_z}^2}$$

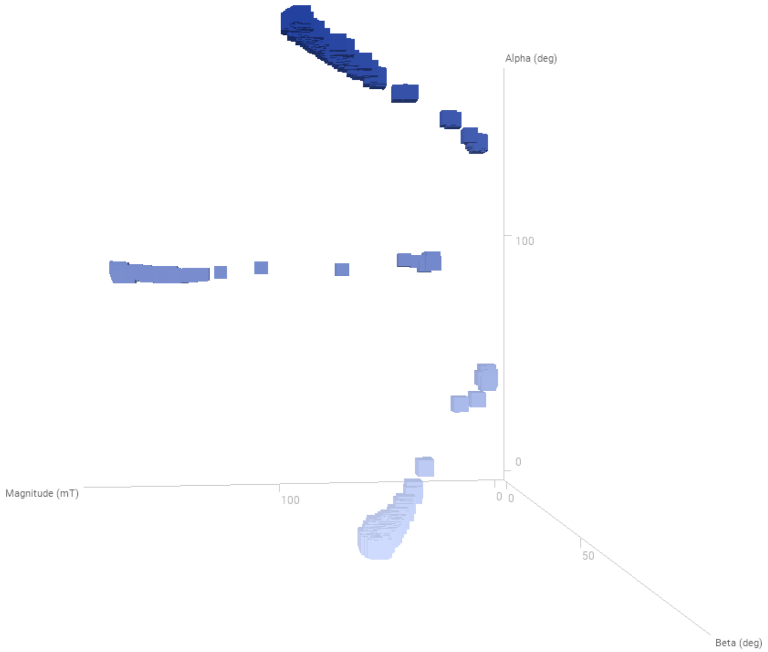


Test data

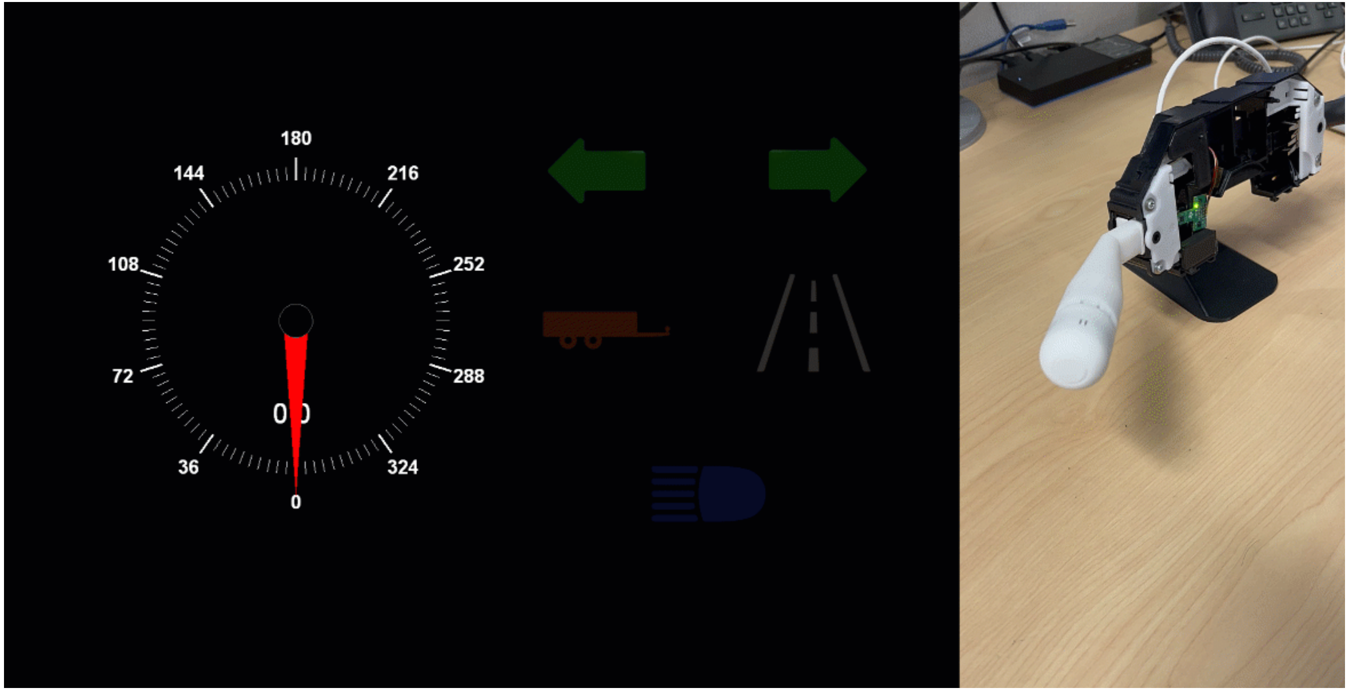
Push-button Headlamp / Wiper Speed Control Knob



Steering Column Stalk Position



Functional demonstration



Summary of results

- 3D Magnetic Hall-effect sensors track angular position for magnets in both lever and knob controls
- Integrated diagnostics reduced additional circuitry
- Contact free form factor eliminates need to maintain contact using wetting current
- Measurements are primarily limited by mechanical tolerances
- Invalid data can be used to indicate a mechanical fault in the system
- Integrated angle calculations using CORDIC algorithm can free up microcontroller instructions

Questions ?