Oxygen Sensor Calibration

Softwares: RSLogix 500, RSEmulate 500, RSLinx Classic
Inputs: Simulated Analog Input (O2 Sensor)
Outputs: Recalibrated Scaling Values for Oxygen Measurement, 0% O2 Calibration Gas Valve, 30% O2 Calibration Gas Valve
Key Instructions Used: Timers, Counters, Math Instructions, Float Averaging

Project Overview

This project simulates a calibration sequence for an oxygen concentration sensor that requires periodic recalibration due to signal drift. The calibration process uses two known gas concentrations (0% and 30% O2). The system samples the sensor's output for 30 seconds at each known concentration, averages the readings, and uses math to update the sensor's scaling parameters.

System Behavior

Upon requesting sensor calibration, the sequence of events is as follows:

- **Phase 1**: 0% O2 valve opens for 30 seconds. Sensor readings during phase 1 are sampled for 30 seconds and the average value is stored.
- **Phase 2**: 0% O2 valve closes, 30% O2 valve opens for 30 seconds. Sensor readings during phase 2 are sampled for 30 seconds and the average value is stored.
- After both phases, the PLC recalculates the sensor's input scaling range using the formulas below.

Formulas for new input range

New input minimum = Phase 1 Sample Average

New input maximum = (O2 Maximum Concentration / O2_Calibration Gas Concentration) x

(Phase 2 Sample Average - Phase 1 Sample Average) + Phase 1 Sample Average

Where:

O2 Maximum Concentration = 40%

O2 Calibration Gas Concentration = 30%

How Calibration Works (more in depth explanation)

Over time, due to things like contaminants, environmental factors, or aging, sensors can start to “drift,” meaning their readings become less accurate. To correct this, we expose the sensor to gases with known oxygen concentrations so we can see how far off its unscaled outputs are.

For example, during phase 1, we supply a gas that we know has 0% oxygen. The sensor doesn’t know that, but we do. If it averages a raw output value of 100 units instead of 0, then we know it’s reading 100 units too high.

In phase 2, we do the same thing with a gas that has exactly 30% oxygen. If the sensor outputs an average of 11,000 units during this phase, then to the sensor, 30% oxygen equals 11,000 units. That’s fine as long as we update the scaling to reflect it.

To put it a bit more simply, if the original scaling range is 0 to 16383 mapped to 0% and 40%, 0% is 0 units and 30% is ~12288 units. However if the sensor drifts and now thinks 0% O_2 is 100 units and 30% O_2 is 11,000 units, the 0 to 12288 range that used to reflect 0% to 30% is inaccurate and we need to adjust the range to where 100 to 11000 units reflects 0% to 30%. Since we are scaling the outputs to a range from 0% to 40%, we can simply move the phase 1 average to the new input minimum, but the phase 2 average cannot be moved to the maximum, as it represents 30% not 40%, so a bit more math must be applied to find the input maximum.

By comparing the sensor’s raw outputs to known reference points, we can recalibrate its input range so that its readings once again match the actual oxygen concentration in the environment.