Compliance Matrix Calculations - Table Approximation

Technical Requests

1. **70khz bandwidth capacity requirement for each sensor on MCU**

With the recommendation of two sensors to a single microcontroller, the new requirements are as follows. According to Nyquist, the minimum requirement for sampling frequency from bandwidth is given.

$f_s = 2 \times 70\, kHz = 140\, ksps$

$T_{Available} = \frac{1}{140E3} = 7.14\, \mu s$

Given our maximum MCU clock frequency:

$T_{period} = \frac{1}{252E6} = 3.97\, ns$

According to the microcontroller, the maximum SPI Clock frequency is 50 MHz and our ADC Clock frequency is 100 MHz. So we are limited by the microcontrollers SPI Clock rate.

$Cycles_{SPI} = 16$ for 2 bytes of data

$SPI\ Clock = 50\, MHz$

$T_{sampling} = T_{acquisition} + T_{conversion} = 1\, \mu s$

$T_{SPI} = 16 \times \frac{1}{50E6} = 320\, ns$

$T_{total} = T_{sampling} + T_{SPI} = 1\, \mu s + 320\, ns = 1.32\, \mu s$

Thus the total time commitment to sample and receive data is:

$T_{total} = T_{SPI} + T_{sampling} = 1.32\, \mu s$

Since I will be using dedicated SPI modules for each sensor, for 2 sensors:

$T_{total} = T_{SPI} + 2T_{sampling} = 2.32\, \mu s$

$T_{compensation} = T_{available} - T_{total} = 4.82\, \mu s$

This yields an acceptable amount of leftover time to complete MCU logic for compensation.

2. **16-bit Resolution ADC and DAC**

According to the data sheet

$INL_{Max} = \pm 6$

$INL_{typical} = \pm 2$

$ENOB = 16 - log_2(\frac{INL}{0.5})$ = [12,14] bits

This ultimately gives an effective resolution of at worst 12 bits to at best 14-bits, which are low estimates from the equation above.

Going with the worst case 12 bits, the effective resolution when taking into account the reference voltage of 2.5V yields:

$$Resolution = \frac{[-2.5, 2.5]}{2^{12}} = 1.22\, mV/step$$

While we cannot achieve the 16-bit resolution initially promised, the resolution is still acceptable for our purposes.

3. Simultaneous Sampling of 5 sensors

With thorough investigation, it is unlikely that a single microcontroller would be able to reasonably handle 5 sensors concurrently. To solve this problem, we have opted to increase the number of microcontrollers to two and have each microcontroller process data from two sensors.

According to our calculations as made in technical requirement 1, two sensors per microcontroller is much more doable.

4. Sensor power requirements

To meet the power requirements of the sensor and board, a buck converter will be used to convert the 12-24V DC supply into 5V, which will power the sensors as well as the board itself.

5. Bridge resistance sampling

The bridge resistance will be acquired using a shunt resistance of 200 ohms and sampling the voltage across the shunt resistance. This will give us the current, as per ohm's law, which will allow us to calculate the current bridge resistance. To do so I will be employing the use of the microcontroller 12-bit ADCs.

According to data sheet

$INL = \pm 3$

$ENOB = 10.5\, bits$

The voltage range after amplification is between [0.5,1]V for resistance between 5K and 9K ohms

$$\frac{[0.5,1V]}{1.8V} \times (2^{10} - 1) = 284\ steps\ available = 8\ bits\ at\ 1.75\ mV\ steps$$

$$\frac{1-0.5V}{(9000-5000)\Omega} = 0.125\ mV/\Omega$$

So a step of 1.75 mV would mean that we have 284 sections of 14 ohms.

6. Error to be less than 1%

Testing must be completed before any error measurement can be made.