Design and Schematic Review - Look up Table

1. **ADC References and Supply**
   I realize I neglected to list any voltage supplying components
   a. 16-bit
      i. REF5025AIDR - Voltage reference IC
         1. Supplies the desired 2.5 V Vref to the ADC
   b. 12-bit
      i. MCP1725-1802E/SN - LDO regulator
         1. Supplies 1.8 V Vref externally to the internal MCU ADC, among other components on my circuit
   c. TPS7B8633QDDARQ1 - LDO regulator
      i. Supplies 3.3V to MCU and others from 12-24V supply
   d. L78L05CD13TR - LDO regulator
      i. Supplies 5V to peripherals from 12-24V supply
   e. According to my estimates, these should all be able to handle the power requirements of the full (4 sensor) board without any issue.

2. **Amplifier Gain Adjustment**
   a. 16-bit
      i. You mentioned that a gain of 25 would be excessive, after consulting the data sheet more thoroughly, the only tested data offered is that of a gain of 10, which I will be reducing to. In all likelihood a larger gain would be possible, but I am not convinced due to any negative effects it could have.
      ii.
   b. 12-bit
      i. With the signal being extremely tiny, with ranges from ~[0.5,0.8] mV I found it necessary to drastically increase the gain in order for the signal to be read by the 12-bit ADC on the MCU. The signal is rounded to [0.5,1] mV to make room for sensor variations, which makes our bridge resistance range [5000,9000] ohms.
      ii. My reasoning ultimately led me to a gain of 1000x by adding 2 additional op amps (TL3472IDR) for a total of 3 amplifiers before the ADC (10x10x10).
      iii. This yields a [0.5,1] V signal, which will reduce the 12-bit resolution, but with Vref = 1.8V (minimum Vref) can give us an effective resolution of:
      $\frac{1V}{1.8V} \times (2^{12} - 1) = 2275\ steps\ available = 11\ bits\ at\ 0.44\ mV\ steps$

However, when considering ENOB:

With increased resistance range

$\frac{[0,1V]}{1.8V} \times (2^{10} - 1) = 568\ steps\ available = 9\ bits\ at\ 1.75\ mV\ steps$

With only interested range

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

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

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

iv. Of course, this method has some apparent issues among others:
   1. Buffered signal from extra amplifiers cascaded
   2. Loss of resolution due to ADC constraints
   3. Other unknown issues that I have yet to identify

v. However, sticking to the MCU ADC frees up SPI lines that could be used elsewhere. Considering we will still have 284 sections to use when looking at bridge resistance it may still be useful, though not nearly as graceful as I had hoped with the ideal 12-bits.

3. **Resolution Loss**
   a. 16-bit
      i. According to the data sheet

         $INL_{Max} = \pm 6$

         $INL_{typical} = \pm 2$

         $EOB = 16 - log_2(\frac{INL}{0.5})$

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

         $INL = \pm 3$

         $ENOB = 10.5\ bits$
   c.
4. **RC filtering**
   a. I have placed a number of RC filters meant to filter to 80 kHz.
   b. They are located before amplification and before the ADCs

5. **Findings**
   a. Upon review of my design I realized a grave oversight regarding amplification. Since my design attempted to maintain the differential signal from the sensor up to the ADC, I had overlooked the magnitude of the signals coming out of the sensor. My design required an amplification of the differential signal in order for

the difference to be detected to an acceptable resolution by the ADCs. However, such amplification can't be done without something like an instrumentation amplifier, which would convert the differential signal into a single ended one. If I were to amplify with my current design I would have lines of 25 V going into the ADC.

b. It is entirely possible that I am mistaken in this observation, and my fully differential amplifier operates as originally intended. I read somewhere that differential amplifiers remove common mode voltage. Any clarification on my confusion is greatly appreciated.

6. Questions

a. Regarding my glaring amplification issue, is there a way I can amplify a differential signal without creating a single ended signal before the ADC?
    i. If not, would there be a purpose to using a differential ADC at that point? My understanding is that common mode noise is avoided with differential ADC, could converting the single ended signal (after instrumentation amp) to another differential signal to keep that advantage and still use differential ADC?

b. Would it be possible to print boards to house a single module (1 MCU and its peripherals), and then connect a second board when we know the first one is functioning acceptably (I plan on having them share the same power components)? I know that when we order from JLCPCB they require that we order something like 5 boards minimum for each order.
    i. This could help save on board costs and keep things modular.

c. I have a pin on the MCU that has a programming input and Vref for the internal ADC together. Neither are reprogrammable, but occupy the same location. Currently my idea is to have some kind of 2:1 MUX setup to switch between them based off of a programming mode button of some kind (button puts everything on standby so that switching Vref off has no effect).
    i. Is this overkill? I understand that having a regular single pole switch would also work, but I am worried about any damage switching Vref abruptly would cause. Please let me know your thoughts.

d. One of my regulators has a “power good” signal that I can use. How beneficial would it be to implement this? I notice none of my others have it.

Current Final Main Parts List

Supply
LDO Regulator 12-5V
L78L05CD13TR

LDO REgulator 12-3.3V
TPS7B8633QDDARQ1

Reference Voltage IC 2.5V
REF5025AIDR

LDO Regulator 3.3-1.8V
MCP1725-1802E/SN

MCU
PIC32MZ2048EFG064-I/PT

ADC
MCP33131D-10T-I/MS

DAC
DAC8830ICD

Signal Conditioning and Amplification
ADC Differential Driver
MCP6D11T-E/MS

Input Conditioning Dual OpAmp
TL3472IDR

DAC Output OpAmp
OPA704UA