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1. sensors

1.1. Thermocouples

Max of 16 possible thermocouples routed through multiplexers to a single instrumentation op-amp that feeds into a 12-bit ADC.

1.1.1. Range

-68C<->+725C RELATIVE TO BOARD TEMPERATURE

1. Calculation

   The range is affected by the gain and reference on the instrumentational amplifier.
   The system was designed with Type-K thermocouples in mind.

   Gain is defined as the multiplier of the total difference in voltage between the negetive and positive inputs of the instrumentational op-amp
   Designed gain is ideally (1 + 50k/R) with R = 500+-0.1%, resulting in a gain range of 101.1 to 100.9.

   The reference of the Op-Amp is what it defines as ground, so it will produce a voltage of [(Gain * V_{in}) + reference = V_{out}]. The designed reference voltage is a 3.3V signal put through a voltage divider where R1 = 15.6k+-0.5% and R2 = 1.3k+-0.5%. Using the voltage divider equation, this gives us a reference range of 0.256V 0.252V.

   The range of the ADC is 3.3V<->0V, so using the equation [(Gain * V_{in}) + reference = V_{out}], we can find that the range of V_{in}, assuming a reference of 0.254 and a gain of 101, is

−2.51mV <-> 30.16mV.

Using a Type-K lookup table, this gives us a temperature range of: -68C<->+725C RELATIVE TO BOARD TEMPERATURE

1.1.2. Speed

20,000 readings per second. This is split up between all active thermocouples.

1. Calculation

   Taken from page 16 of the following datasheet: https://www.ti.com/lit/ds/symlink/ina819.pdf?HQS=dis-mous-null-mousermode-dsf-pf-null-wwe&ts=1697232709484&ref_url=https%253A%252F%252Fwww.mouser.com%252F we see that the total harmonic distortion and Noise of the amplifier remain relatively constant at G=100 up to a frequency of 20kHz.

   on page 17, we see an output rise time of about 75mV per 1uS. Since we are aiming for a max of 3.3V, this would requre a worst case time of 44uS for a complete amplitude shift. Using 1S/($Rise_{time}$) = Hz, this gives us a max worst-case scenario frequency of 22kHz

   From both of these, we can see that we can expect about 20,000 accurate readings per second.

   The ADC has been discounted as it can handle a minimum of 50kHz samples per input. The multiplexer has been discounted from this calculation due to its exceedingly quick rise time making its contribution insignificant.

1.1.3. Granularity

Max of +-1C accuracy with the realistic accuracy probably nearer to +-2C or 3C.

1. Calculation

   The ADC is 12 bit, giving 4096 discrete measurement zones over the 3.3V range. Assuming a linear relationship in temperature and voltage over the temperature range, we get an ideal accuracy of +-0.2C, but this is unreasonable to assume due to noise and cold-junction heteroginity as these measurements are relative to the temperature readings of an on-board absolute-temperature sensors that have 0 +-0.5C accuracy and can only read the temperature near themselves within the cold-junctions. As such, to play it safe, we will assume a max of +-1C accuracy with the realistic accuracy probably nearer to +-2C or 3C.

1.2. Pressure Transmitter

A single presure transmitter that acts as a current source emitting between 4mA and 20mA converted to 0.66V to 3.3V by a 165 ohm resistor. This voltage is read by a 12-bit ADC.

RELATIVE TO ATMOSPHERIC PRESSURE

1.2.1. Range

The pressure Transmitter can read up to 0<->1500 PSI relative to atmospheric pressure.

1.2.2. Granularity

0.5PSI with a max error of 8PSI over range

1. Calculation

   The ADC has 3351 discrete measurement points between 0.66V and 3.3V
   Given the range of 0 <-> 1500 PSI, we get a granularity of 0.447 PSI or about 0.5 PSI. The manufacture recognizes a non-linearity in readings of about 0.5%, so the actual accuracy would be more like a max error of 8PSI

1.2.3. Speed

ADC can handle 50kHz minimum per pin, so at least 50kHz however there is the option of up to 200kHz if you only care about the pressure transmitter's readings.

1.3. Load cell

1.3.1. Range

1.5T : 0<->14715N Calculation(1500kg*9.81m/s^2 = 14715N)

1. Calculation

   1500Kg * 9.81m/s^2 = 14715N

1.3.2. Granularity

3.65N max.

1. Calculation

   The load cell can produce up to 2mV per 1V of excitation. Given 12V of excitation, this gives us an output of 24mv max. There is also a "zero balance" voltage of 1.5%, so we lose 1.5% of the total range of our ADC leaving 4034 useful discrete reading levels. Given the max range of 14715N, we get 3.65N per level.

   Given the sensor's max error of about 3N, this means that our granularity limit in in the ADC at 3.65N per level.

1.3.3. Speed

20kHz

1. Calculation

   Due to the use of the same model of Instrumentational op-amp as the thermocouples, we can conclude a max accurate reading frequency of 20kHz. The ADC can handle 50kHz minimum.