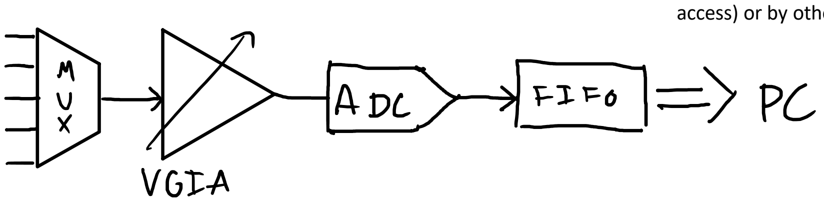
DAQ exercise

1) Draw the schematic of a DAQ and describe it.

Mux - Mutiplexer - Allows to adquire several channels
VGIA - Variable Gain Instrumentation Amplifier - Allows to use the complete dynamic of the ADC by amplifying the signal.
ADC - Analog to Digital Converter - Samples and discretizes the signal
FIFO - First in First out Memory - Place to store the samples before sending them to the computer. The sending can be done by DMA (direct memory access) or other means, like by interrupt in the motherboard



2) With the DAQ we want to acquire the following signals:

V_1: Analog signal with 50 kHz bandwith maximum amplitude 4 V peak to peak in alternate coupling, to be acquired with a resolution better than 10 mV

V_2: Digital signal with levels 0-3 V and a clock frequency of 100 kHz

V_3: Termocouple temperature signals with sensibility 40 μV/K, used to measure a temperature around 1000 °C with an uncertainty of 100 mK

a) Describe the number of analog channels and the configuration to use to acquire these 3 signals.

b) What is the minimum frequency of the ADC to correctly acquire these signals?

a) V_3 is a thermocouple, so it requires differential mode.

3 signals, differential mode => 6 channels

b) V_1: $Bw = 50\,kHz \Rightarrow f_{s1} = 2Bw = 100\,kHz$

V_2: Digital: 1 point per period $\Rightarrow f_{s2} = f_2 = 100\,kHz$

V_3: No freq. requirements

$$f_{s_{ADC}} = n_{ch} \cdot Max\{f_s\} = 3 \cdot 100\,kHz = 300\,kHz$$

c) If the DAQ have a set of gains equal to G = 0.1 / 1 / 10 / 100 / 1000, chose the correct gain for every signal. With ADC = ±1V

d) What is the minimum number of bit to correctly acquire these signals?

$S = 40\,\mu V/K$

c) $G_{DAQ} = \{0.1\,;\,1\,;\,10\,;\,100\,;\,1000\}$

$D_{ADC} = \pm 1V$

$D_{DAQ} = \{\pm 10V\,;\,\pm 1V\,;\,\pm 0.1V\,;\,\pm 0.01V\,;\,\pm 0.001V\}$

$D_1 = \pm 2V \Rightarrow G_1 = 0.1$

$D_2 = 3V \Rightarrow G_2 = 0.1$

$D_3 = (1000-25)\cdot S = 39\,mV \Rightarrow G_3 = 10$

d) $\Delta V_1 = 10\,mV \Rightarrow m_1 = \log_2\left(\frac{D_1}{\Delta V_1}\right) = 10.9 \Rightarrow 11\,bit$

$$\Delta V_3 = \sqrt{12}\cdot U(3) = \sqrt{12}\cdot 100\cdot 10^{-3}\cdot 40\cdot 10^{-6} = 13.8\,\mu V$$

$$m_3 = \log_2\left(\frac{D_3}{\Delta V_3}\right) = 13.8 \Rightarrow 14\,bit \Rightarrow m_{DAQ} = Max\{m\} = 14\,bit$$

$$\Delta V = \frac{D}{2^m} \Leftrightarrow m = \log_2\left(\frac{D}{\Delta V}\right)$$

You have to write in the next blocks how many counts are displayed by a counter in frequency measurement with 100 ms of opening time if I have to measure a frequency of 10 kHz

$T_{op} = 100\,ms$

$n_{count} = \frac{T_{op}}{1/f} = 1000$

0	0	0	1	0	0	0

× 10 Hz

What is displayed if I measure the same frequency (10 kHz) with the counter set as period measurement with a clock of 5 MHz

$T_{op} = 1/f = 1/10kHz$

$n_{count} = \frac{T_{op}}{T_{clk}} = \frac{f_{clk}}{f} = 500$

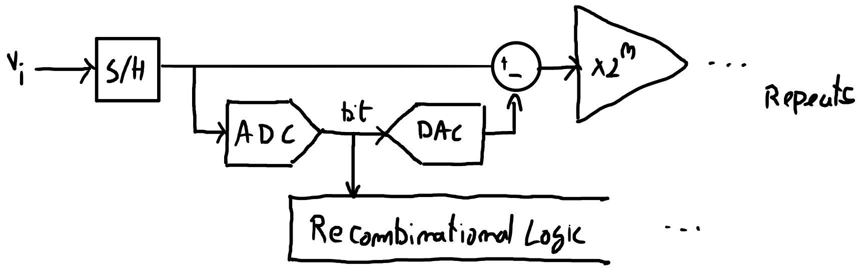
0	0	0	0	5	0	0

× 0.2 µs

ADC exercise

a) You have to briefly describe how a pipelined converter without recursion works.

Firstly it samples the signal then converts it to bits. These bits are then reconverted to an analogic signal. This reconverted signal is subtracted to the sampled voltage. Their diference (ie. The conversion error is then amplified and sent to the next stage which does the same.



I have a converter with 12 bit and working at 2 MSa/s without any other non-idealities than an internal noise with a variance $\sigma_N^2 = 3\times10^{-7}\,V^2$, with a dynamic of 0–2 V. Calculate the equivalent number of bits of the converter

$$n_e = n - \frac{1}{2}\log_2\left(1 + \frac{\sigma_N^2 + \sigma_{Ext}^2}{\sigma_Q^2}\right) = 12 - \frac{1}{2}\log_2\left(1 + \frac{3\times10^{-7}}{19.86\times10^{-9}}\right) = 9.99$$

$$\sigma_Q^2 = \frac{\Delta V^2}{12} = \frac{\left(D/2^m\right)^2}{12} = \left(\frac{2}{2^{12}}\right)^2 \cdot \frac{1}{12} = 19.86\,nV^2$$