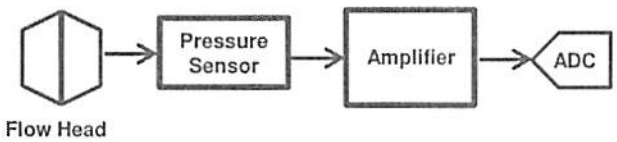
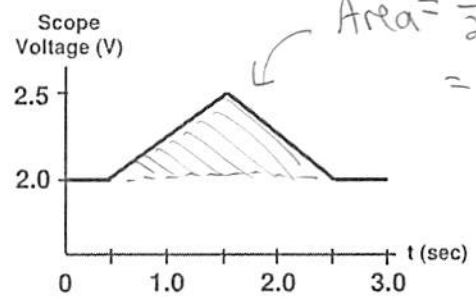
BME/ECE 386 QUIZ (W20) NAME: Solutions

1 problem for 20 pts

Spirometer

You are asked to design a flow spirometer system to measure a maximum flow of F_{MAX} = 20 L/s with a sensitivity of ΔF_{MIN} = 0.03 L/s. You know the instrumentation amplifier has A_d = 1200 and V_N = 8 mV. It is powered by 10V and GND, so you can assume the amplifier output is limited to +9V (max) and 1V (min). The ADC operates from 0 to 10V with 12 bits and V_N = 2 mV. The system is calibrated by injecting 1.6 liters of air into the spirometer. The measured voltage is shown below.



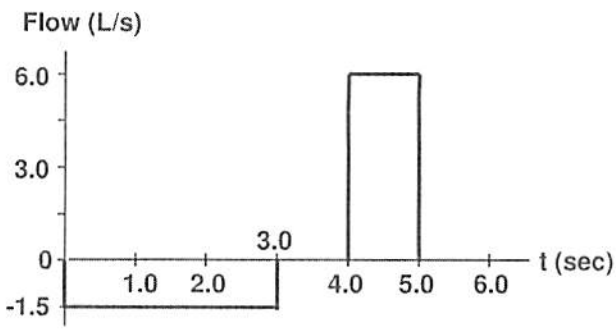


Area = $\frac{1}{2}(.5V)(2s)$ = 0.5 V·s

(a) Does the current system satisfy one, both, or none of the design specifications? Show all work!

NOTE: The total noise from two components is computed by: $V_{N,TOTAL} = \sqrt{V_{N1}{}^2 + V_{N2}{}^2}$

(b) Suppose we measure a patient taking a deep breath and forcefully exhaling into the spirometer. The resulting flow plot is shown on the right. Sketch the resulting curve for volume vs time. Make sure to label your axes and include the value of the patient's FVC!



(a) $V_{Meas} = V_{Ref} + A_d SRF$

$\frac{\int (V_{Meas} - V_{Ref})\,dt}{0.5\ Vs} = A_d SR \frac{\int F\,dt}{1.6L}$ → $S.R = \frac{.5\ Vs}{1200\,(1.6L)} = 2.6\times10^{-4}\ V\cdot\frac{s}{L}$

OK if we don't know separate values.

Max V_{Meas} = 9V ← Limited by amplifier

• When F = 20 L/s

• $F_{max} = \frac{9-2\,V}{1200(2.6\times10^{-4})\ V\cdot s/L}$

OR = 22.4 L/s ✓

→ $V_{Meas} = 2 + 1200(2.6\times10^{-4})\times 20$

= 8.24V ✓ > 20 L/s

(extra sheet for work)

$\Delta F_{MIN} = \frac{\Delta V_{MIN}}{\frac{\partial V_{Meas}}{\partial F}}$ ← $\Delta V_{ADC} = \frac{10-0V}{2^{12}-1} = 2.44\,mV$

$V_{N_T} = \sqrt{8^2 + 2^2} = 8.25\,mV$ ✱

- Sensitivity?

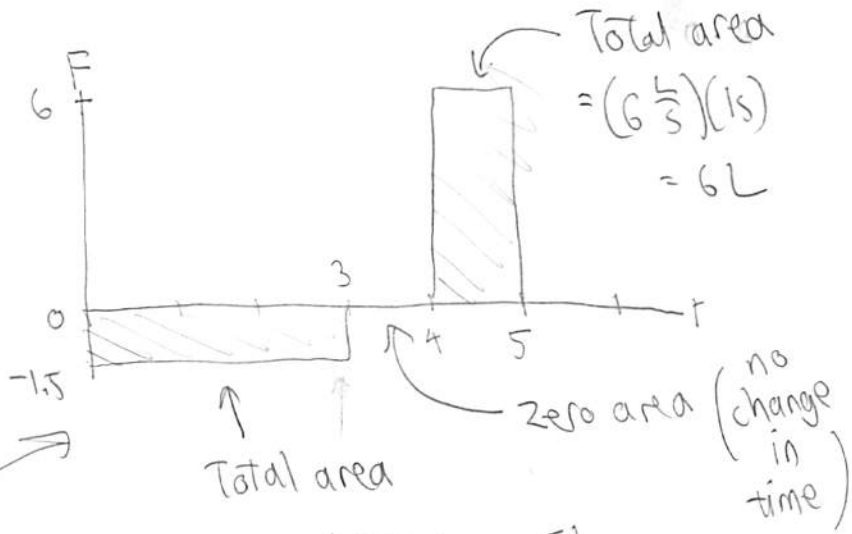
$= \frac{V_{N\,TOT}}{A_d\,SR} = \frac{8.25 \times 10^{-3}\,V}{1200 \times 2.6 \times 10^{-4}\,V \cdot s/L} = \boxed{.0264\,L/s}$

+12

$< .03\,L/s$ ✓

Satisfies BOTH! ☺

(b) Volume $= \int F\,dT$



+8