We need a different amplifier

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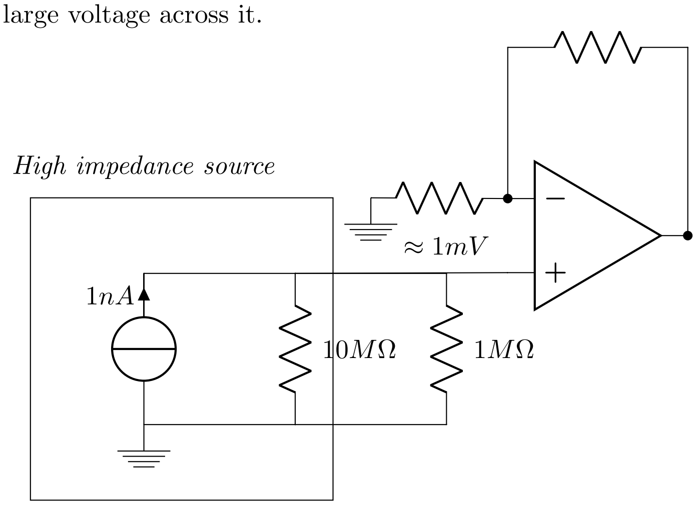
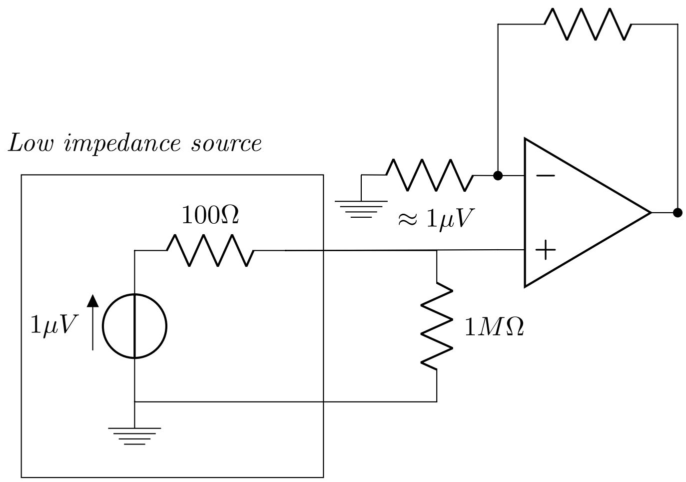
January 22, 2018

The current uCurrent style amplifier will not provide good data from the uFluidics coil because the uCurrent relies on the source having a very high output impedance, whereas the uFluidics coil has a low output impedance. Illustrated below, the high impedance source converts a $1nA$ current into $1mV$ and feeds it to the op amp to be amplified. Because the sense resistor has a significantly lower impedance than the impedance of the current source, most of the current flows through the sense resistor and generates a comparatively large voltage across it.



In contrast, in the circuit below, the sense resistor has a much higher impedance than that of the source, so the source puts almost it's full voltage across the sense resistor. However, since the source voltage is small, the voltage would require far more amplification to get to the level of the above example. The source below could be transformed to a current source in parallel with the 100Ω resistor similar to the above circuit, but since the source impedance is much lower than the sense resistor, only a very small amount of current will flow through the sense resitor, generating only a very small voltage across it.



How do we know that the coil has a low impedance? Intuitively, it makes sense because it's simply a coil of wire, and it makes sense that the impedance would be small (infinitely small, in the case of perfectly conductive wire. This agrees with faraday's law of induction, where

$$V = -N\frac{d\Phi}{dt}$$

meaning that the coil is a voltage source (low impedance). Finally, this is confirmed by experiment, when I hooked up a prototype uCurrent to the straw coil and saw very little signal (indicating that the signal was a low impedance voltage source).

Since this is the case, how much amplification do we need? The ADC on the microcontroller has 12 bits of resolution, or 4096 different values. The ADC linearly assigns these values to voltages between 0 and 3.3V, so we want the resting voltage to be around 1.5V, and a decent amount of swing when a cell passes through, say 400mV pk/pk. And from the COMSOL simulation the maximum voltage produced was around 600nV. So we need amplification of

$$\frac{400mV}{600nV} = 660,000 = 116dB$$

We'll likely need to cascade op amps to keep the feedback resistors within a reasonable value. Additionally, 600nV is low enough that it approaches the thermal noise from the op amp itself, so the op amps will need to be selected for exceptionally low noise, especially low frequency noise since the cells will be traveling fairly slowly.