Design of a Microelectrode Array Amplifier
ECE 6410 Advanced Electronic Instrumentation
Fall 2015
version 7 January 2016

A microelectrode array (see http://www.multichannelsystems.com/) is essentially a Petri dish with an array of microelectrodes plated onto the bottom of the dish. Neurons, grown on top of these electrodes, connect to one another to form biological neural networks. These electrodes are used to measure and stimulate the electrical activity of these neural networks to study the effects of pharmacological agents, network formation, learning mechanisms, etc. [1].

Neurons (and electrodes) are bathed in a solution necessary for neuron growth and function. A reference electrode placed in the solution is considered to be the signal ground. Electrodes enable measurement of extracellular voltages with respect to the reference node.

Assume that the electrode voltages have an amplitude $\leq 100\ \mu V$, with a frequency spectrum ranging from 30 Hz to 3 kHz, and that electrodes can have a DC offset ranging from -100mV to 100mV. Also assume that the electrode can be modeled as a voltage source with an output resistance of 100 kΩ (see [2] for a more complete discussion of these values). Your electrode amplifier must provide a voltage gain of 1000 V/V while blocking any DC component. In addition, the output of your amplifier will be input into an A/D converter, so an anti-aliasing filter is needed, with a roll-off of at least -80dB/decade. The design must utilize a Linear Technology® (www.linear.com) LT1167 instrumentation amplifier in the first stage; note that additional amplifier stages may be required.

1. Based on the above description, develop a list of quantitative specifications for your amplifier. What is your recommendation for an acceptable CMRR? Justify.
2. Design your preamplifier around the LT1167 instrumentation amplifier (you will need to read the LT1167 datasheet).
3. Provide a recommendation for the number of A/D converter bits and sampling frequency; take into account the noise of the amplifier output referred to the input. Reference [5] might be useful here.
4. Use only standard value components. You must use Digi-Key (digikey.com) as the parts provider. Provide a spreadsheet that lists all parts (description and Digi-Key part number), cost per part, and total cost for your design.
5. Use LTspice® (www.linear.com) to test your design to insure that all specifications are met; for example, evaluate the CMRR performance of your preamplifier using LTspice®.
6. Prepare a report that summarizes your design and includes all requested information. Provide a table that shows your specifications and compares the performance of your design to the specifications.

This project was inspired by previous work [3, 4].

Reminders

1. Projects are to be completed on an individual basis.

2. You may NOT use any references other than your text, references cited in this project description, or references cited in the syllabus to complete this project. If you use one of these sources, CITE the source!

References

[1] S. Marom and G. Shahaf, “Development, learning, and memory in large random networks of cortical neurons: lessons beyond anatomy,” *Quarterly Review of Biophysics*, vol. 35, pp. 63-87, 2002.

[2] R. A. Blum, J. D. Ross, E. A. Brown, and S. P. DeWeerth, “An integrated system for simultaneous, multichannel neuron stimulation and recording,” *IEEE Transactions on Circuits and Systems—I*, vol. 54, pp. 2608-2618, 2007.

[3] Y. Jimbo, N. Kasai, K. Torimitsu, T. Tateno, and H. P. C. Robinson, “A system for MEA-based multisite stimulation,” *IEEE Transactions on Biomedical Engineering*, vol. 50, pp. 241-248, 2003.

[4] J. Stahl, *Dual Channel Low Noise Amplifier for Experiments in Neurophysiology*, Western Michigan University Master of Science in Electrical Engineering thesis, June 2009.

[5] M. Thoren, *Delta Sigma ADC Bridge Measurement Techniques*, Application Note 96, Linear Technology, January 2005, available at http://cds.linear.com/docs/en/application-note/an96fa.pdf