Potentiostat Hardware for USB-Style Sensors

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A portable measurement system was assembled using a commercial potentiostat, a custom circuit board, and a 3D-printed enclosure. The system will help demonstrate the portability and simplicity the electrochemical sensors being developed in BioMicroSystems Lab.

1 Introduction

BioMicroSystems (BMS) Lab is developing point-of-care electrochemical sensors for measuring heavy metal concentrations in environmental samples, such as manganese in lake water [Kang et al., 2014].

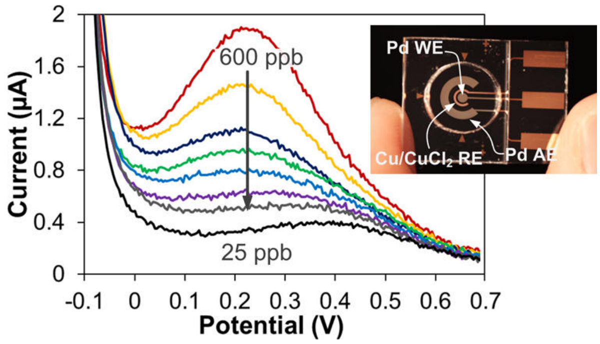


Figure 1: *Measuring Manganese [Kang et al., 2014]*

Three electrodes are inundated in a sample and a potential is applied between two of the electrodes, while a different pair of two electrodes is used to measure current. At some applied voltage, an oxidation-reduction reaction occurs between the metal of interest and the working electrode surface. Charge is emitted as the metal changes oxidation state; so measuring and integrating the current gives the quantity of metal reagent in the sample.

In a three electrode system, one electrode must be common to both the voltage pair and the current pair, and this is termed the working electrode. For the other two electrodes (reference and counter) to accurately separate voltage and current, they must be virtually grounded by amplifier electronics. A device which drives the virtual ground, sets a potential, and measures the resulting current is called a potentiostat.

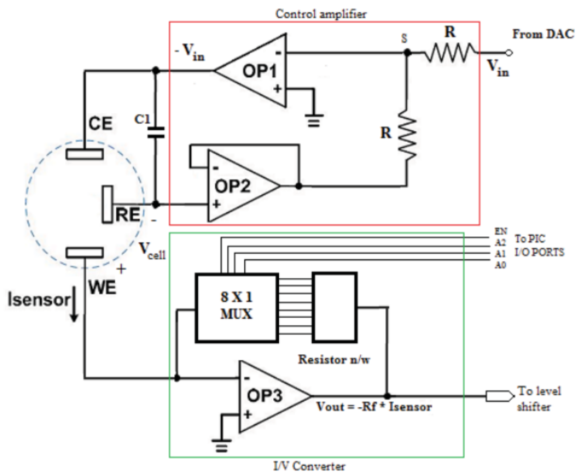
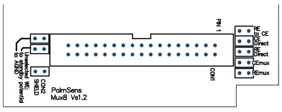


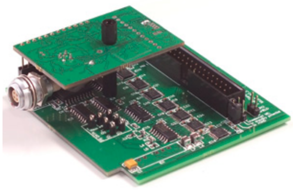
Figure 2: *Op-Amp Potentiostat [Sukhavasi, S., 2011]*

The possible advantages of the point-of-care electrodes being developed by BMS Lab include low cost, portability, measurement speed, and simplicity for non-technical operators. To realize these advantages, a small, portable potentiostat is needed with a simple user interface.

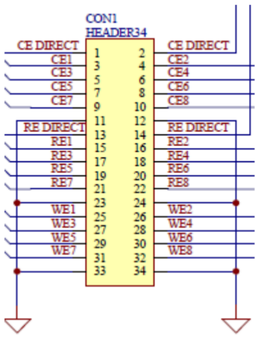
(a) *EmStat Potentiostat*



(b) *Pinout Diagram*



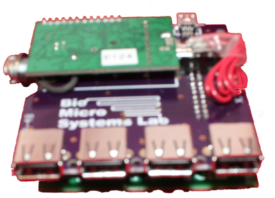
(c) *EmStat with Multiplexer*



(d) *Pinout Schematic*

Figure 3: *EmStat and Multiplexer [PalmSens, 2014]*

(a) *Breakout Board*



(b) *PCB Sandwich...tasty*

Figure 4: *Breakout Board fits between EmStat and MUX*

2 Method

2.1 Commercial Potentiostat

An OEM potentiostat board measuring only 2" x 1.35" was purchased from PalmSens, called EmStat. Also from PalmSens, a Multiplexer was purchased that allows EmStat to switch between multiple sensors. The EmStat–Multiplexer connection and the external interface towards the sensors are shown in figure 3.

The external interface from the Multiplexer is a standard 0.1" header but the sensors are made to be inserted into a USB receptacle. To make this simple for the end user, a custom breakout board was needed.

2.2 Breakout Board

The breakout board was designed to fit between the EmStat and Multiplexer for compactness; the close fit is shown in figure 4.

The breakout board was designed in CadSoft Eagle and the file `breakout-board-v3.brd` was sent to OSH Park LLC for manufacture. The Eagle board file, total project, and parts library can be found in the directory `PCB_Boards/`. In addition to the manufactured board, the components listed in table 3 are need for assembly.

Table 1: *Breakout Board Components (Digi-Key)*

Qty.	Component	Man. Part #
4	USB type-A receptacle	292303-1
1	USB mini receptacle	0548190519
1	USB mini plug kit	1734205-1
1	34-pin, 0.1" header	SFH11-PBPC-D17-ST-BK
	hookup wire and heat shrink for USB plug kit	

The dimensions of the board and part locations were designed to align with the EmStat and Multiplexer. The x-y coordinates used can be found in appendix 2. For convenience, the schematic diagram for the breakout board and a transparent view from Eagle are incluced in appendices 3 and 4.

2.3 Enclosure

An enclosure for the PCB stackup in figure 4 was designed with SolidWorks, to be 3D-printed in two parts: a base and a lid. In addition to the base and lid, six size #3-48, 1.25" long machine screws and #3-48 tapping equipment are needed for assembly. Instructions for tapping can be found in appendix 1.

Table 2: *Assembly Components*

Qty.	Component	McMaster Part #
6	3-48, 1.25" socket head cap screws	90044A243
	3-48 tap, tap driver, and spring loaded tap guide	appendix 1

The design of the packaging was tested and iterated in house using a Makerobt Replicator 2X with ABS filament. Mechanical drawings of the base and lid and a list of revisions are included in appendix 5.

For printing with MakerBot or an outside printing house, the files `Enclosure_Base.STL` and `Enclosure_Lid.STL` are needed from the `Packaging/` directory. For editing the parts, the SolidWorks files are located in the `Packaging/SolidWorks_Files` subdirectory.

2.4 Interface Boards

In addition to the potentiostat system, three small sensor interface boards were built. One allows a USB-style sensor to be extended away from the potentiostat system by a USB male-A-to-male-Mini cable. Another allows USB-style sensors to be easily connected to the WaveNow potentiostat. The third allows USB-style sensors to be connected to aligator clips for electroplating, etc.

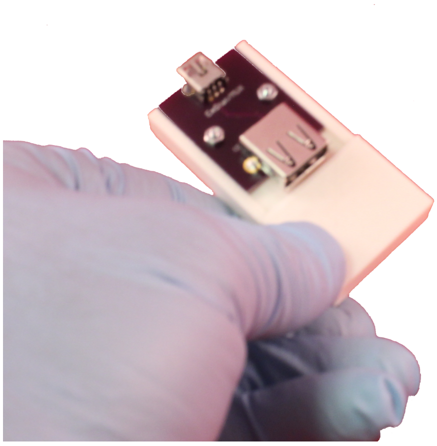


Figure 5: *1 of 3 Sensor Interface Boards*

The three Eagle `.brd` files for the interface boards are located in the `PCB_Boards/Sensor_Breakout_Boards/` directory. For the 3D-Printed platform, the `Sensor_Interface.STL` file is located in `Packaging/`. Use M2 machine screws and nuts for assembly.

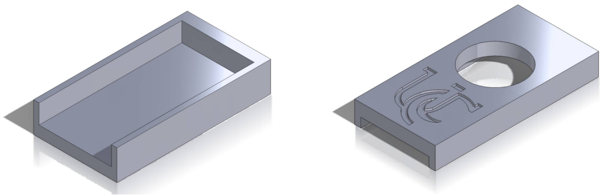
Table 3: *Interface Board Components*

Qty.	Component	Digi-Key Part #
3	USB type-A receptacle	292303-1
2	USB mini receptacle	0548190519
6	M2 machine screws	H739-ND
6	M2 nuts	H761-ND

2.5 Sensor Well

The sensors are fabricated on flat glass, but walls are helpful to form a well for the sample solution. A plastic enclosure with a well for solution was designed with the UC logo on the top. There are two parts: a bottom piece and top piece.

The files for printing are `Sensor_Enclosure_Bottom.STL` and `Sensor_Enclosure_Top.STL`, located in the directory `Packaging/SolidWorks_Files/`.



(a) *Bottom Piece* **(b)** *Top Piece*

Figure 6: *Sensor Enclosure Pieces with Sample Well*

3 Results

The enclosure base and lid were printed several times in house on the MakerBot and once outside by Shapeways. Printing with Shapeways cost $60 and had a lead time of three weeks. However, the result was a much nicer product, as shown in figure 7.

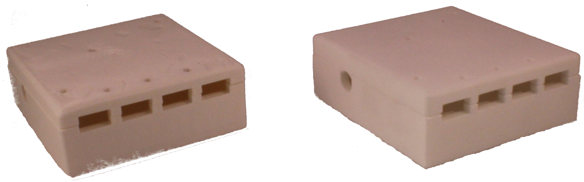


Figure 7: *Packaging Printed on MakerBot (left) and by Shapeways (right)*

The parts printed by Shapeways had much more precision than the MakerBot, to the extent that no hand filing or drilling had to be done just to get the parts to fit together. The surface finish was also better.

Furthermore, tapping is significantly improved with the Shapeways' base because the tolerance for the through hole is much tighter and the enclosure is not hollow beyond the cylindrical face.

4 Conclusions

The goals of the hardware were able to be met by assembling the breakout board and 3D-printed enclosure with the EmStat and Multiplexer boards from PalmSens. For a higher quality product, it is recommended that the enclosure be reprinted by an outside printing service such as Shapeways.

References

[Kang et al., 2014] Wenjing Kang, Xing Pei, Adam Bange, Erin Haynes, William Heineman, and Ian Papautsky. Copper-Based Electrochemical Sensor with Palladium Electrode for Cathodic Stripping Voltammetry of Manganese *Analytical Chemistry*, 2014, 86, 12070–12077.

[Sukhavasi, S., 2011] Sowmya Sukhavasi. Zinc Chip Reader for Point-Of-Care Quantification of Zinc in Blood Serum *University of Cincinnati*, Master's Thesis, 2011.

[PalmSens, 2014] PalmSens Compact Electrochemical Interfaces. EmStat^3 Connecting to MUX8 *PalmSens Compact Electrochemical Interfaces*, Product Documentation, Revision: July 2014.

5 Appendices

The following are attached:

1. Tapping Instructions – page 4
2. X-Y Alignment of the EmStat, Multiplexer, and Breakout Boards – page 5
3. Breakout Board Schematic Diagram – page 6
4. Breakout Board Top View – page 7
5. Enclosure Drawings and Revisions – pages 8–12
6. Interface Boards Mounting Block – page 13

5.1 Tapping Instructions

The base part of the enclosure needs to be tapped six times–once for each assembly screw. The screws have 3-48 threading, which means they have an outermost diameter of 0.099" with 48 threads per inch.

The machine shop in 407 Rhodes has all of the tapping equipment needed. Ron Hudepohl is very helpful and can show you where all the equipment is.

It is much better to go to the machine shop than to purchase the tapping equipment because tapping is easier if you can mount the enclosure and keep the tap vertically aligned.

If you mount the base part on mill with a digital x-y readout, figure 9 will help.

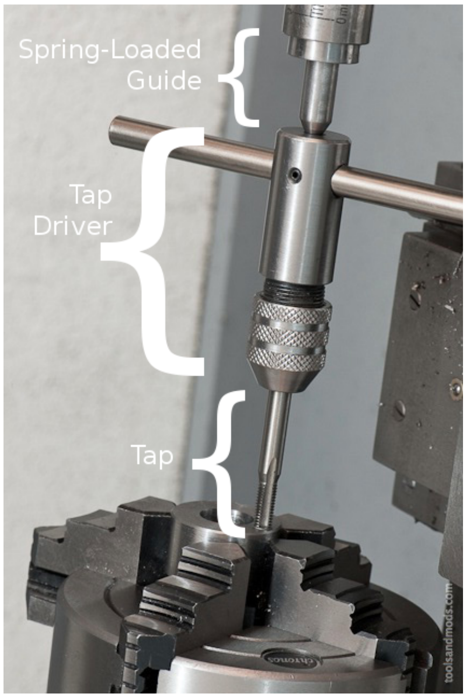


Figure 8: *Equipment for Tapping*

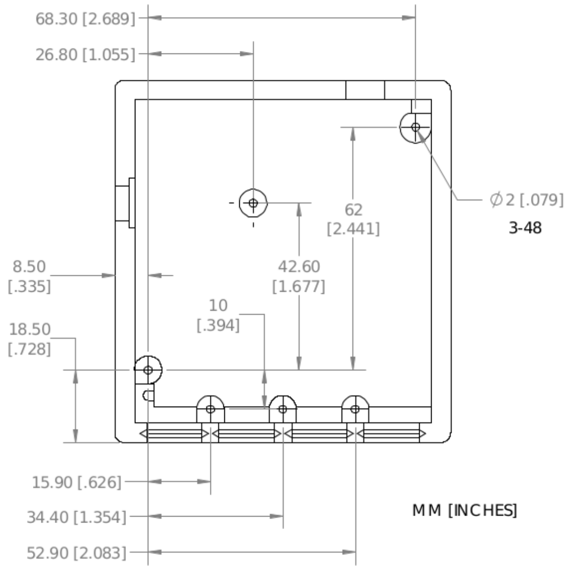


Figure 9: *Coordinates for Tapping*