# Electrophysiology using IOLab

IOLab Tech-note 2018-01
Mats Selen, Jan/13/2018

While we have developed an IOLab expansion module to do a 9-lead ECG (further described in Appendix B), there is a much simpler solution for creating a high-quality "1-lead" measurement using a pair of short wires, two small clips, two inexpensive and easily available ECG electrodes, and the high gain inputs (labeled G+ and G-) on the IOLab expansion header.

The IOLab's high gain inputs feed a DC coupled differential amplifier, described further in Appendix A. While the design of this amplifier is not optimized for electrophysiology due to its relatively low input impedance, it can still be used for this purpose by trading some excess bandwidth for finer resolution. In other words, by zooming and then smoothing the tiny ECG signal using the IOLab software, we can get great results like those shown at the right.
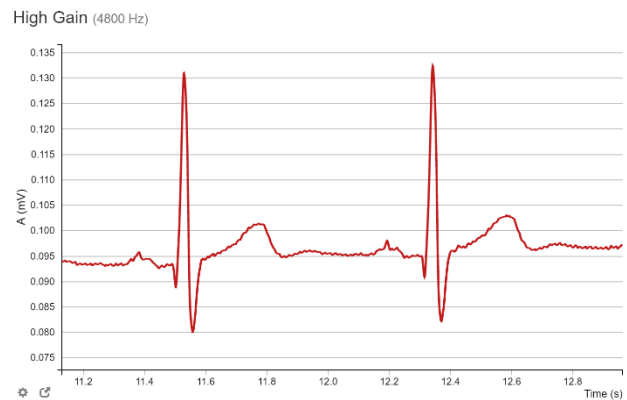
The rest of this brief note will describe how to reproduce these results for yourself.

Equipment Required (in addition to your IOLab):

1) Two wires, each about a foot long, each with a clip soldered to one end. If the wires are composed of a single solid strand you can push this directly into the holes of the expansion connector. If the wire is multi-stranded (like mine were) you can solder a pin to the other end as shown in the picture below.
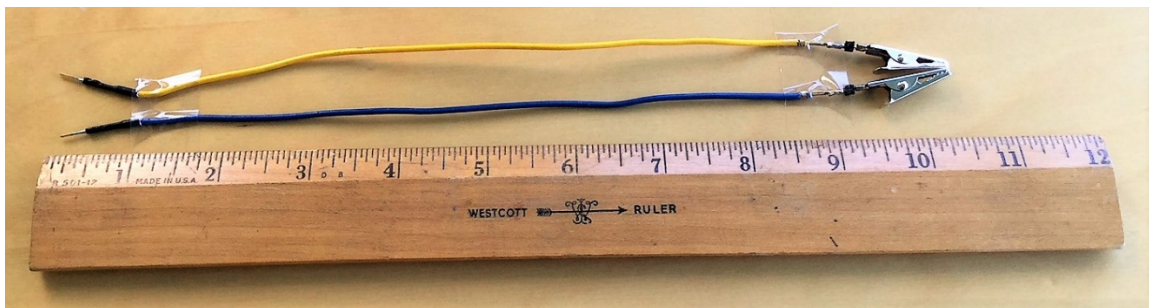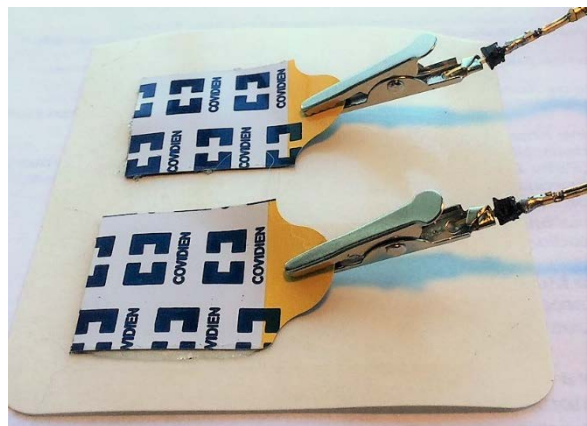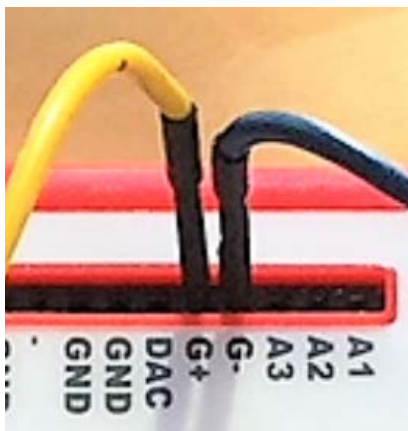
2) ECG electrodes. The ones shown in the picture can be bought on Amazon for about $10 for 100. I get great results with these but I'm sure there are many other kinds that will work just as well.
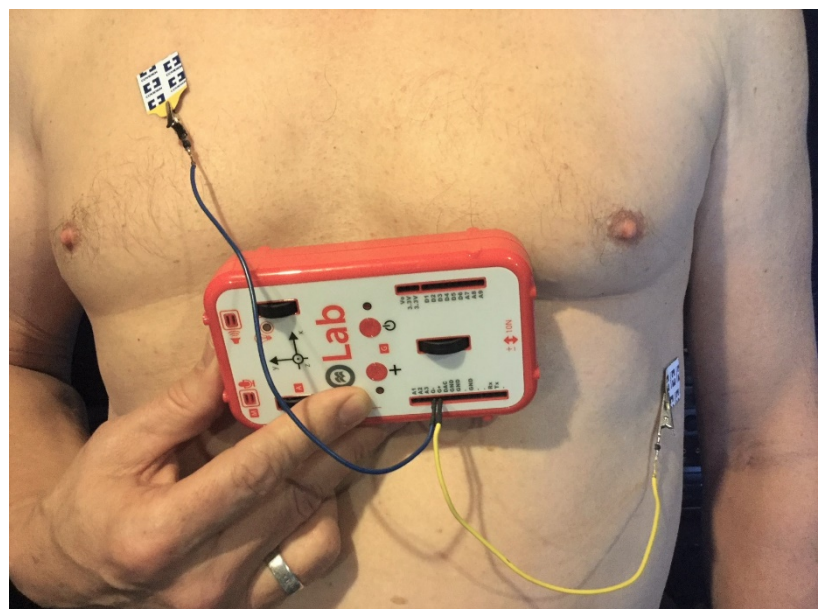

Procedure:

Plug the wires into the G+/G- holes on the IOLab expansion connector and clip the electrodes to the other ends of the wires.

Attach the electrodes to your test subject. The data shown here was acquired with the pads in the locations shown in the picture to the right, but you can project the cardiac signal onto other axes by moving the electrodes around.

Acquire data using the High Gain sensor sampling at 4800 Hz – the signal will be very small:
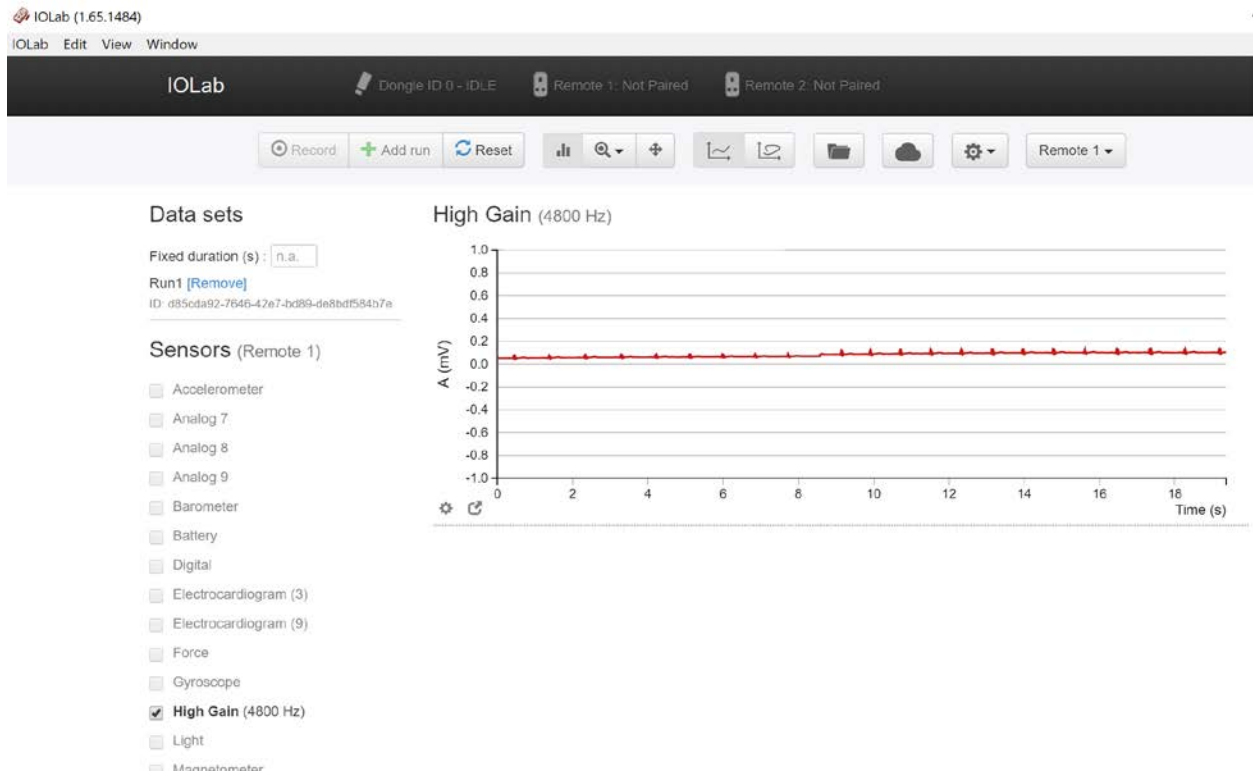
Zoom in on the signal and set the smoothing to 25 using the toolbar menu:

When I follow these steps I get the results shown below. Note that the scale is in mV and that the standard deviation of the selected data is 0.17 µV, which is pretty respectable.

Some problems to avoid:

The above results are certainly good enough for students to explore the concepts of electrophysiology, but there are a few things that can make the data look worse if you aren't careful. Here are some do's & don'ts:

1) Make sure the electrodes are making good contact with the skin. This is sometimes not as easy as it sounds. If the electrodes shown above are not doing the job there are slightly fancier ones with metal snaps to clip onto (example to the right) that may work better for you. These are also available on Amazon.


2) Related to the above comment and based on my own experience, different people (and even the same people on different days) will have ECG signals of different size. I suspect this has to do with the fact that that the input impedance of the IOLab amplifier is not that high, which makes the system more susceptible to differences in the effective "output impedance" of the body plus the electrodes. The latter presumably depends on body and skin chemistry, body shape, exact electrode placement, etc. and it seems like this can vary quite a bit.

3) Keep the wires as short as possible (mine are just 11"), and avoid acquiring data near sources of 60Hz noise (like computer power supplies, etc.) If you see 60 Hz noise in your ECG trace then try moving to another location or rearranging the wires a bit. Running on a laptop can help. **FYI** - It is quite easy to check if you are experiencing 60Hz noise - just use the FFT tool built into the IOLab software to look for peaks at 60/120/180 Hz. (You should set the smoothing to 1 while you are using the FFT tool to hunt down and minimize noise, then set it back to 25 when you are finished.)

   Fun Fact: One thing that makes the IOLab particularly good at recording ECG's (or other very small signals) is the fact that it runs on batteries. This avoids the problem of ground loops, which are a major source of 60Hz noise for most traditional ECG machines and the reason that these machines typically require fancy hardware & software filters.

4) Make sure your subject sits quietly (or better yet lies down) and does not move during the acquisition of the ECG data. Electrical signals from other muscles can overwhelm the tiny ECG signal and can cause large DC swings in the baseline, making the ECG signal more difficult to understand.

## Appendix A: The IOLab High Gain Amplifier.

The IOLab device has a simple op-amp based DC-coupled differential high-gain amplifier with a gain of 1400. The design is pictured below:


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Faraday/Seebeck Preamp
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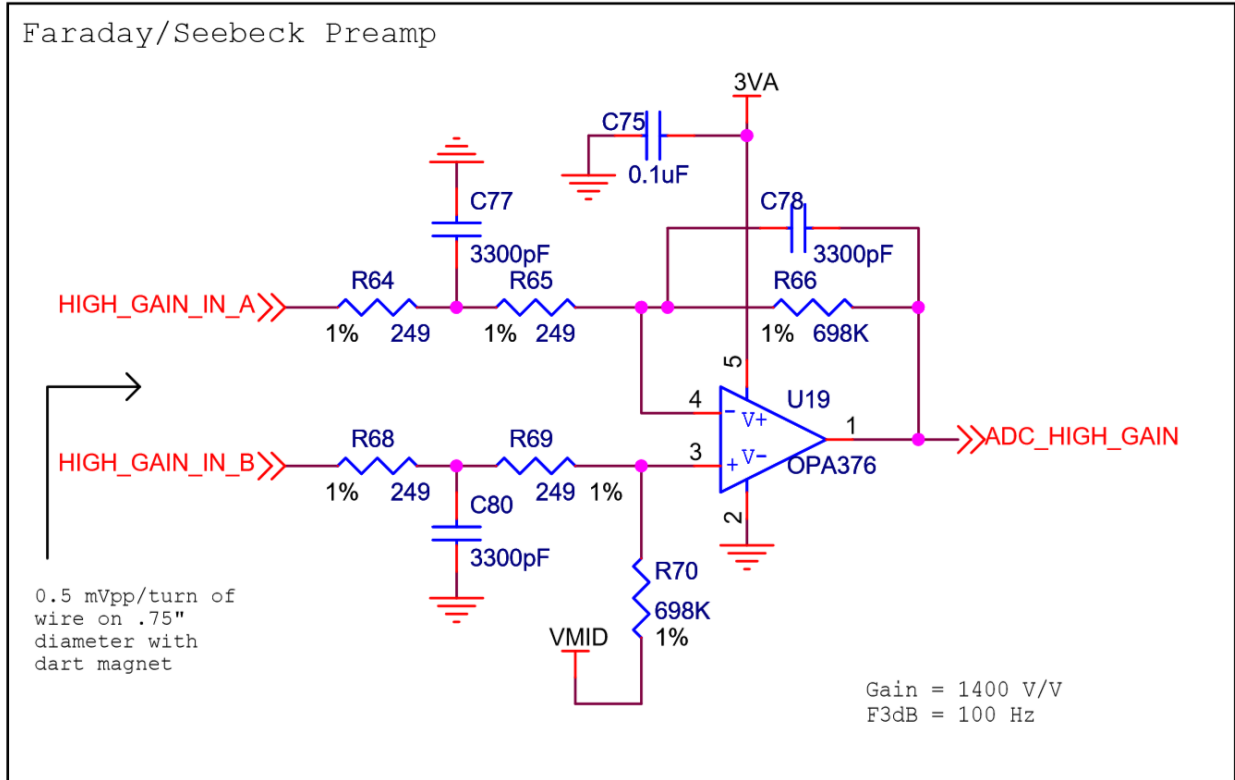
The HIGH_GAIN_IN_A (HIGH_GAIN_IN_B) inputs are connected to the G− (G+) inputs on the IOLab expansion connector. U19 is a Texas Instruments OPA376 op-amp.

Appendix B: The IOLab ECG Expansion Board.

We have designed an expansion board that plugs into the IOLab device and provides the impedance and gain features necessary to acquire high-quality 9-lead ECG data. The common design of each channel is shown below, along with some images of the devices and the data. More information, along with plans for building your own, can be found on at http://www.iolab.science/expert_documents.html
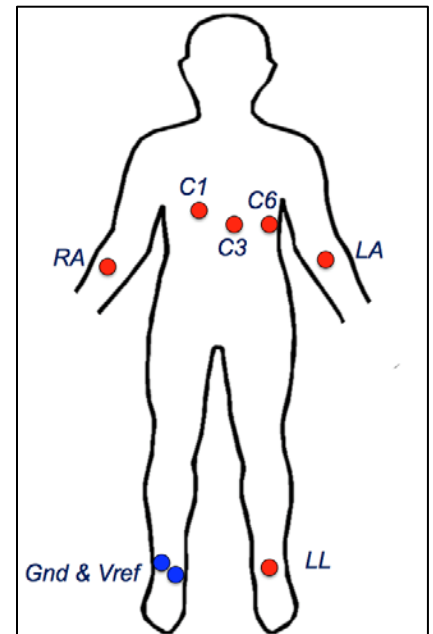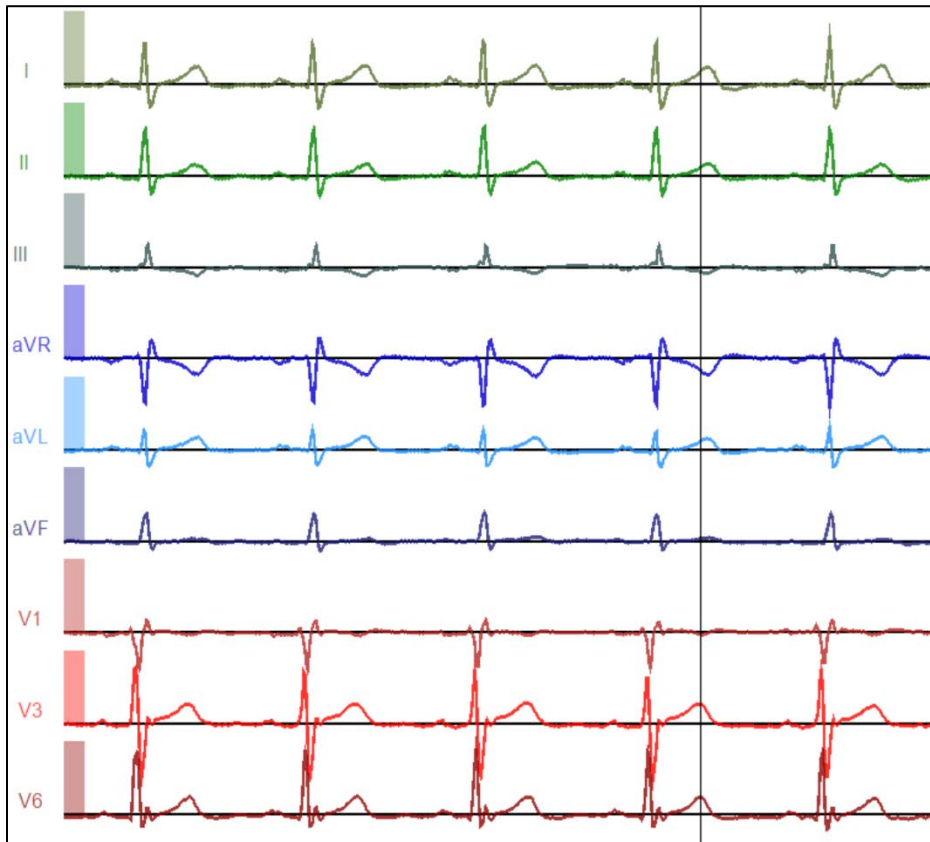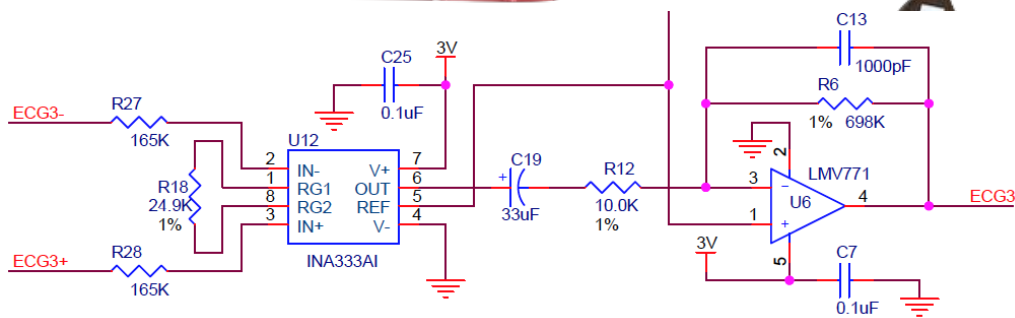
Lead	Calculation
I	$V_{LA} - V_{RA}$
II	$V_{LL} - V_{RA}$
III	$V_{LL} - V_{LA}$
aVR	$V_{RA} - (V_{LA} + V_{LL})/2$
aVL	$V_{LA} - (V_{RA} + V_{LL})/2$
aVF	$V_{LL} - (V_{RA} + V_{LA})/2$
V1	$V_{C1} - (V_{RA} + V_{LA} + V_{LL})/3$
V3	$V_{C3} - (V_{RA} + V_{LA} + V_{LL})/3$
V6	$V_{C6} - (V_{RA} + V_{LA} + V_{LL})/3$