EECE 2150 - Circuits and Signals: Biomedical Applications

Lab ECG I – The Instrumentation Amplifier

Sec. 2

Introduction:

As discussed in class, **instrumentation amplifiers** are often used to reject common-mode signals and provide a stable gain with a high-impedance input over a modest range of frequencies. This is required for amplifying bio-potentials associated with electrocardiogram (ECG) signals.

In this lab, we will explore the operation of the instrumentation amplifier, and with any luck observe ECG signals on the oscilloscope.

Unlike in the previous Operational-Amplifier lab, we will use two 9V batteries to power our instrumentation amplifier circuit. This is to electrically isolate the circuit from the AC power for safe connection to students.

The circuit you build today will be used for the rest of the semester (with various filters and amplifiers added). For this reason, properly **color code** your wiring and **DO NOT** disassemble your circuit when you are finished today!!!! Also try to keep your circuit to one region of the protoboard so you will be able to add other stages (circuits) later to connect to this circuit.

Part 1 – Connecting and Powering the AD627 Amplifier.

1.1 As discussed in class, the AD627 is a high quality, instrumentation amplifier integrated circuit with adjustable gain. Like the LM741 Chip, the AD627 requires external DC power supplies for operation. It can be connected with one supply, but in this case we will use two 9V batteries. Connect the AD627 instrumentation amplifier as shown on the next page (more details are on page 15 of the spec sheet, posted on Blackboard along with this lab writeup), in **double-ended power configuration, using ground for the REF input**. Use the provided 9V battery connectors, being sure to provide a positive and negative 9V supply (i.e. the two batteries must be connected with opposite polarity but common ground). Also, be sure to use the capacitors as shown below and on the spec sheet. **Q1:** what do you think the capacitors are for?

1.2 Select the **Rg value** to give a total circuit gain of about **25**. **Q2:** what **Rg** value is needed, according to the spec sheet?

1.3. Note that it is very important that **all grounds on your breadboard be connected together** to avoid ground loops. (*Reference voltage, battery, AD627 grounds, function generator when you use it in Part 2, etc.)*

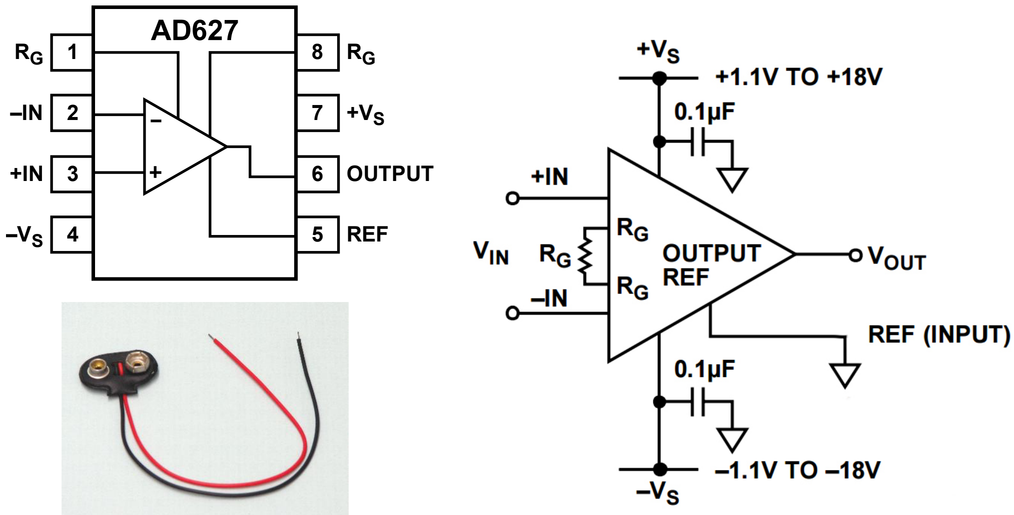

Figure 1 – The AD627 Instrumentation Amplifier pin-out and connection diagram (see AD627 spec sheet online for details). Use 9V batteries to power the circuit rather than the DC power supply using the connectors provided. Connect the REF input to ground.

Part 2 - Testing the AD627

2.1 Generate a **sinusoidal test signal** to test the operation of the AD627 chip. As discussed in class, the AD627 amplifies small differences between the two input pins. Use the function generator to give a **sine wave with a 10-50 mV peak-to-pea**k amplitude.

2.3 Use an appropriate value for the sine wave frequency that is in the middle of the expected frequency range of an ECG signal. **Q3:** Given our discussions in class, what would a reasonable frequency be to use?

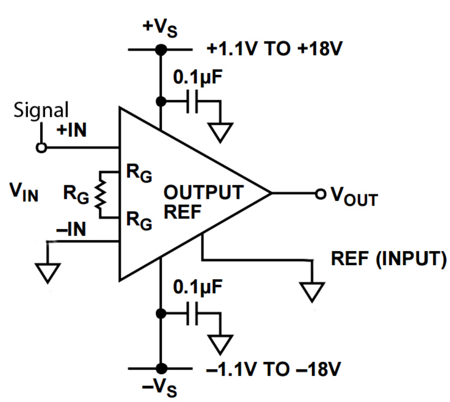

Figure 2 – Test signal circuit configuration

2.4 Connect this test signal to the input pins of the AD627 (one input should be the sine wave, the other should be ground, and the other side of the function generator, remember, also has to be connected to ground !)

2.5 Measure the output on the oscilloscope. Remember to adjust the **horizontal (time) axis** of the oscilloscope to an appropriate value given your sine wave.

2.6 What is the **gain** of the amplifier? Record this in your lab-book. Is it as you expected from the spec sheet? This is also known as the **"differential gain" G_d.**

2.7 Measure the upper "**cut-off**" frequency of the amplifier. What frequency corresponds to 0.707 of maximum gain?

2.8 Try to measure the **common mode gain Gc** of your AD627 circuit. You can do this by connecting the same lead from the signal generator to both AD627 inputs at the same time and measuring the size of the output signal. The idea here is that you are putting the same signal to both sides of the AD627 and measuring what the output signal is. The input signal will need to be larger here, but should not approach the power supply voltage. In this case, use about a 250 mV Peak-to-peak sine wave at 60 Hz. Can you see any output at 60 Hz? You may not be able to get a signal you can measure here, precisely because the AD627 is very good at "rejecting" common mode inputs like you have here. If you get a noisy signal, try to estimate its amplitude as well as you can. If you can measure a signal, the ratio of this output to the input amplitude (where the input amplitude is the amplitude of the signal coming from the function generator) is Gc.

2.9 The common mode rejection ratio CMRR is then given by $20\log_{10}(Gd / Gc)$. Note that the magnitude of the common mode gain will be much less than one. If you could measure a common mode gain, what value do you get? Does this agree with the spec sheet?

Part 3 – First attempt at measuring your ECG signal.

Making an ECG measurement is challenging and requires some patience and trial and error. **In all probability will not work well on the first try**, but this is part of developing the circuit/technique. With a little patience and adjustment, you should be able to get a very clean ECG signal.

Use the Biopac EL503 electrodes provided. The Electrode placements below are suggested for the optimum signal, but simply using the right and left forearm may be more convenient for testing, and is also fine as far as acquiring an ECG.

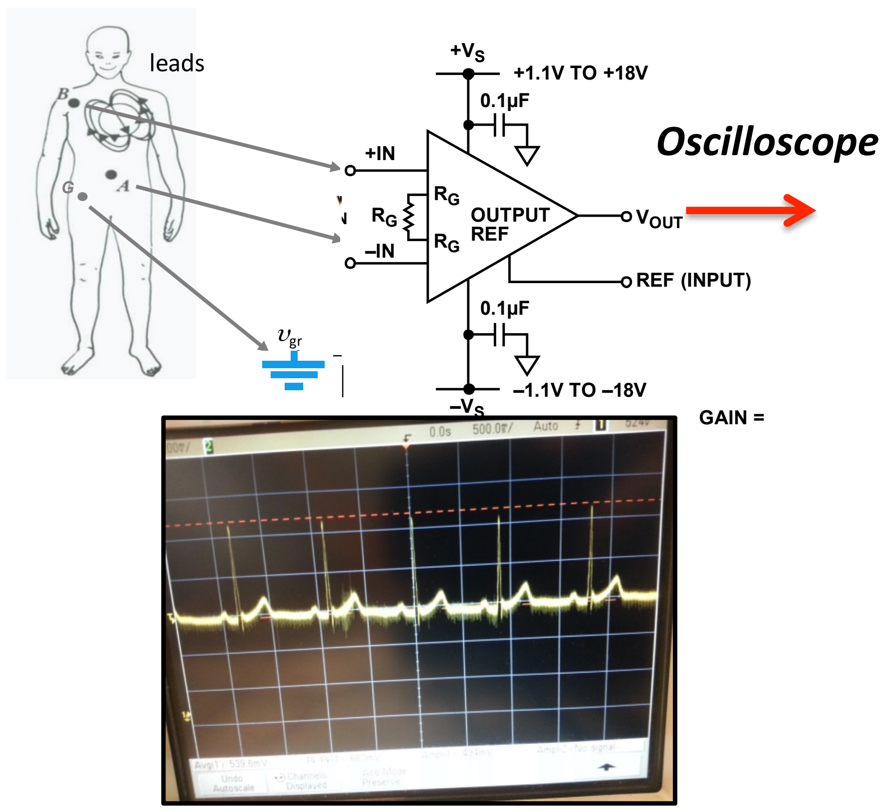

Figure 3 – ECG Measurement Configuration

Some considerations - Read before attempting!

3.1 **Electrode placement:** electrodes can be placed across your chest (upper right and lower left as shown above) or on your forearms. Be sure to attach a **third electrode to your body connected to ground.** This is very important. **Q4:** Why do you think this is important to do? If you are not sure, discuss this with the instructor or TAs.

3.2 **Connectors:** You may use the specialized electrode connectors provided. Somewhat surprisingly, many students have better results by making lead wires and attach them to the conductor by stripping a ~1" length from the end and wrapping it around the conductor tightly a few times and crimping with pliers. Do not solder since this will damage the electrode.

3.3 Try to keep your muscles still when you are acquiring your data (**Q5:** Why?). We suggest that **one student wear the electrodes and hold still**, while the other student adjusts the equipment.

3.4 Observe the EKG signal on the oscilloscope. If it looks perfect, you are very lucky!! However, you will probably have some noise or a lot of noise or a small signal. Describe the signal that you get.

3.5 This is one occasion where the "**auto scale**" button on the oscilloscope **will probably not work**. Set an appropriate **horizontal (time) axi**s, such as **500 ms/division**. Also set an appropriate **vertical axis** based on your anticipated ECG signal amplitude. You may want to use "AC coupling" at first to find your ECG wave if there is a substantial DC offset. We will remove this DC offset in the next lab.

3.6 One source of noise is your body acting as an antenna and picking up low frequency signals, largely from the 60Hz power lines. We try to eliminate this as much as possible by using the difference amplifier feature of the instrumentation amplifier, assuming that the potential of your entire body is changing at the same time due to external influences. Another potential source of noise is that any loop of wire acts as a transformer as the magnetic field changes inside it. You may have seen this in your physics course and you will see it in the future in your electromagnetics course. One way we can eliminate loops of wire is by twisting the wires together. This is used in ethernet cables – they contain "twisted pairs." Here, you may be able to do the same thing by twisting the three wires going to the body together. Try this and describe the results.

3.7 In future labs, we will filter out the dc potentials that are superimposed on the time-varying cardiac signal (one method is shown on page 19 of the spec sheet (Figure 46)), and we will build filters to eliminate high-frequency noise before analog to digital conversion.

3.8 You may want to adjust the **R_g resistor** value to get a more useful value of the gain.

Observe the ECG signal on the oscilloscope. Describe your signal in your report.

You can also take a snapshot of your oscilloscope screen for your report.

What to hand in: For this lab you do not have to hand in anything, not even the Lab Reflection responses! Just be sure to document your work and answer all questions (not just the numbered ones) in your course notebook and have the TAs sign off when you are done.

Also <u>remember NOT to disassemble your circuit</u>, you will use it again in the next lab!

IMPORTANT: BEFORE YOU LEAVE THE LAB:

(a) Place all of the components that your removed from the red tool box back in that box and return it to the cabinet that houses them
(b) Collect all used components and wires from your bench and place them in your group's reusable plastic container. If you are not going to use these components or wires again please discard them in the trash bin located in your lab room.
(c) Turn off all of the equipment you have used on your workbench.

(d) Make sure you return your protoboard, the equipment wires and your reusable container to the front window.

(e) **Make sure to have your notebook signed by an instructor before you leave the lab.**

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