Lab: 12 Date: April 4th, 2024

Instructions:

- Write down all your observations in your notebook.

Objectives:

- To understand the working and design of an ECG Amplifier
- Design the readout IC for recoding ECG Signal

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1. **ECG Amplifier**

An ECG (Electrocardiogram) amplifier is an electronic device designed to accurately capture and amplify the electrical signals generated by the heart. The ECG signal is typically very small in amplitude, on the order of milli-volts, and may be subject to noise and interference from various sources, such as muscle activity or power line noise. The ECG waveform itself contains frequencies primarily in the range of 0.5 Hz to 150 Hz but can be contaminated with high-frequency noise. Therefore, the amplifier includes low-pass filtering to remove high-frequency noise and using 50 Hz notch filter for reducing the supply noise interference while preserving the integrity of the ECG signal. In this experiment you have to readout the ECG signal using ECG Amplifier.
The lab aims to build an ECG front-end amplifier and capture the ECG signal using provided probes. The experiment consists of three primary sections:

(a) **Instrumentation Amplifier (INA)**
(b) **Right Leg Drive**
(c) **Filter Section**

(a) **Instrumentation Amplifier (INA)**

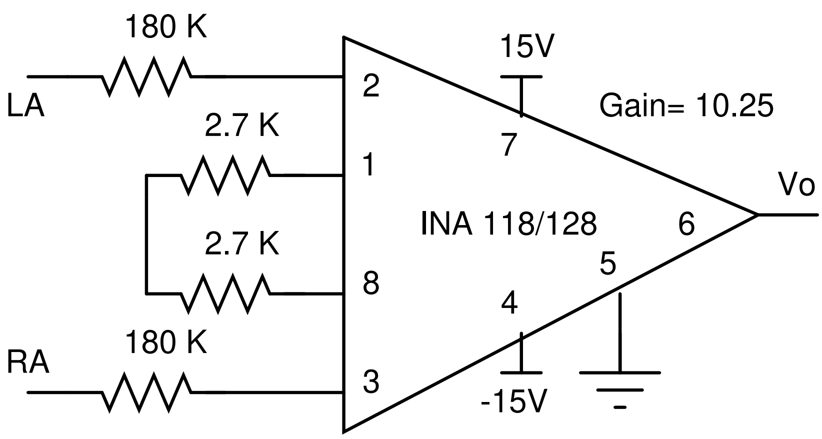

Figure 1: INA Amplifier

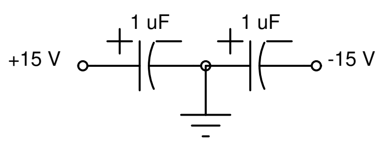

Figure 2: Cap. connection with Supply nodes

i. **Theory**
The instrumentation amplifier (INA) is a crucial component in ECG (electrocardiogram) system, designed to amplify the small voltage differentials produced by the heart's electrical activity. Before implementing the circuit, it's essential to conduct preliminary testing on the instrumentation amplifier (INA) to ensure its functionality and performance meet the required specifications.

ii. **Verification of the INA**

Construct the circuit on a breadboard shown in Figure [1]. Use ±15V DC power supply voltage for all INA 118/128 and op-amp ICs. Connect a 1µF capacitance from supply to ground as shown in figure [2]. Positive/Negative terminal are also shown in each capacitor. So connect properly otherwise the capacitor will blow off if you do not connect it properly. **Do not dismentle the circuit because you will need it later to design the complete ECG Amplifier.**

A. **Differential gain:** Connect a sinusoidal signal of $V_{pp} = 100mV$, 100 Hz at input at RA node of the figure[1] above. Connect LA node to ground. Measure the INA output voltage V_o and verify its gain. **[1 Marks]**

B. **Common mode gain:** Now, Verifying the common mode gain of the INA by applying $V_{pp} = 100mV$, 100 Hz on both LA & RA node. Common mode input to INA should give zero output. What is the noise level you measure at the output V_o ? **[1 Marks]**

(b) **Right Leg Drive Seciton**

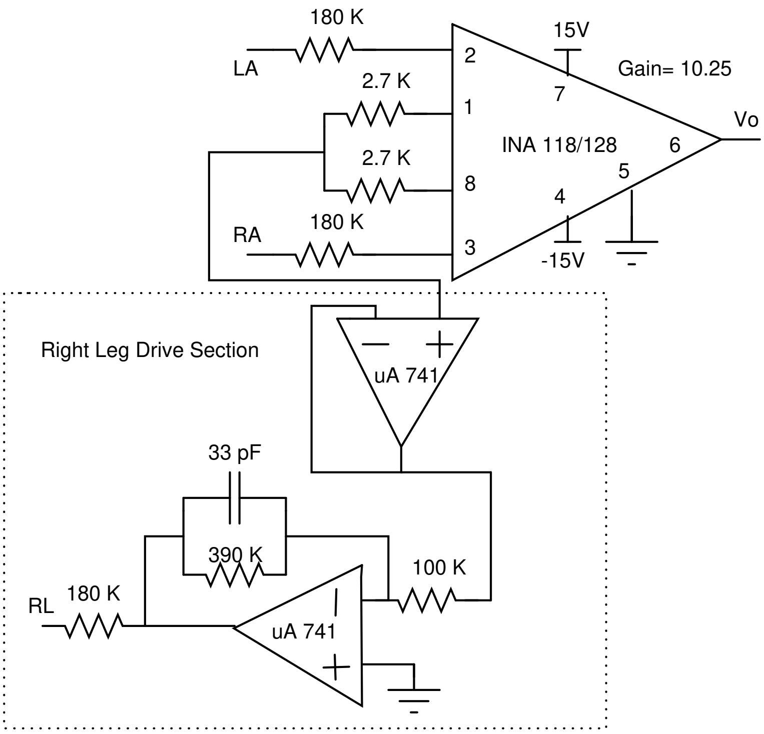

Figure 3: Right Leg Drive

i. **Theory**

The Right Leg Drive section enclosed in dotted line shwon in [3]. It is basically used to minimize the common mode interference. Do the derivation yourself for better understanding.

ii. **Verification Step**

A. Before implementing the circuit first you have to test the opamp uA_741 IC via connecting it in the unity gain Buffer. **[1 Marks]**

B. Implement the circuit shown in figure.[3] Apply $V_{pp} = 100mV$, 100 Hz on both LA & RA node. Connect a wire between the 2.7kΩ resistors and input of the buffer in RLD section as shown in the figure[3]. Measure the output at RL node and report the gain of the right leg drive section. **[2 Marks]**

C. **Again do not dismentle the circuit because you will need it later to design the complete ECG Amplifier.**

(c) **Filter Section**

i. **Theroy:**

If you have completed the Lab-12 homework then you will be very fimiliar with the Filtering design. We are using Low pass filter whose cut-off frequency is 150 Hz because our frequency of interest is 0.5 to 150 Hz and we also want to reduce high frquency noise effect. We are using 50

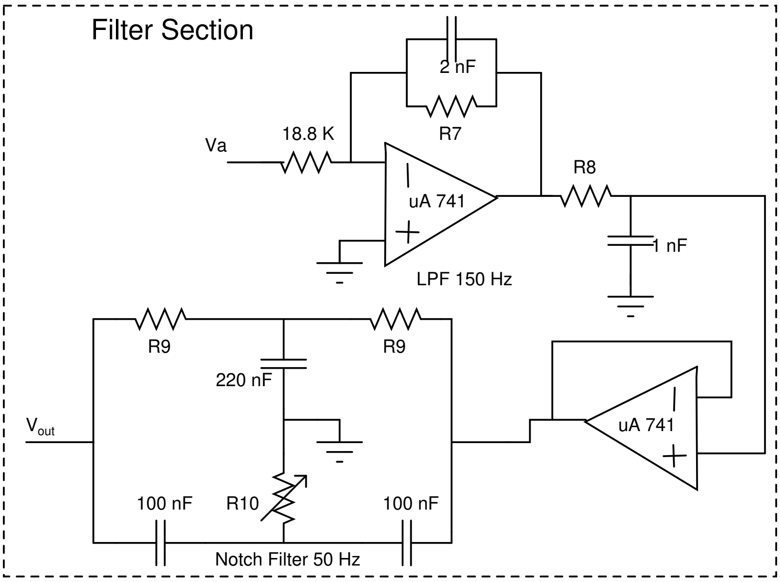

Figure 4: Filter Section Circuit

Hz Notch filter for reducing supply interference whose frequency is around 50 Hz. You can see the filter section enclosed in dashed line box shown in figure [4].

ii. **Verification:**

A. Take similar values of resistors R7, R8, R9 that you got in Lab-12 homework and take R10 as a variable + fixed resistor. For example ,if you want R10 as 30kΩ then you can take 25kΩ fixed resistor in series with 10kΩ potentiometer. **[1 Marks]**

B. Implement the Filteting section and connect it with the INA as shown in the figure [4]. Don't dismantle the circuit. Apply input signal V_a as $V_{pp} = 1V$ with 50 Hz frequency and adjust the R10 pot. such that attenuation factor should be greater than 3 between V_a and V_{out} nodes. **[2 Marks]**

C. Apply input signal V_a as $V_{pp} = 100mV$ with frequency 10, 50, 100 and 2K Hz. Mearsure the V_{pp} of the V_{out} at the given frequencies and write down in a tabulated form. **[2 Marks]**

2. **ECG Signal Recording using ECG Amplifier:**
Connect INA, RLD and Filter Circuit as shown in figure [5] for implementing the ECG Amplifier. **Make sure all sections share the same ground terminal**. Make sure the decoupling capacitor is connected correctly.

(a) **Experiment:** **[5 Marks]**

i. Switch off the DC power supply. Connect ECG probe and electrodes on Right arm's (RA) wrist, Left arm's (LA) wrist. Connect Right leg (RL) electrode near the ankle to your respective partner and ask him/her to remain stable while taking measurement.

ii. Each electrode has two wires in which one is for ECG signal and other is for ground. So connect all three electrodes ground to the common ground of the circuit.

iii. The other end of the ECG probes have to be connected to the ECG Amplifier at RA, LA and RL node as shown in figure [5].

iv. Switch on the DC power Supply. Connect the output terminal V_{out} to the DSO and set the x-axis scaling to 200 ms on the DSO. Adjust the voltage scale on the DSO for proper waveform. Show the result to your respective TA. Draw the output waveform that is displayed on DSO.

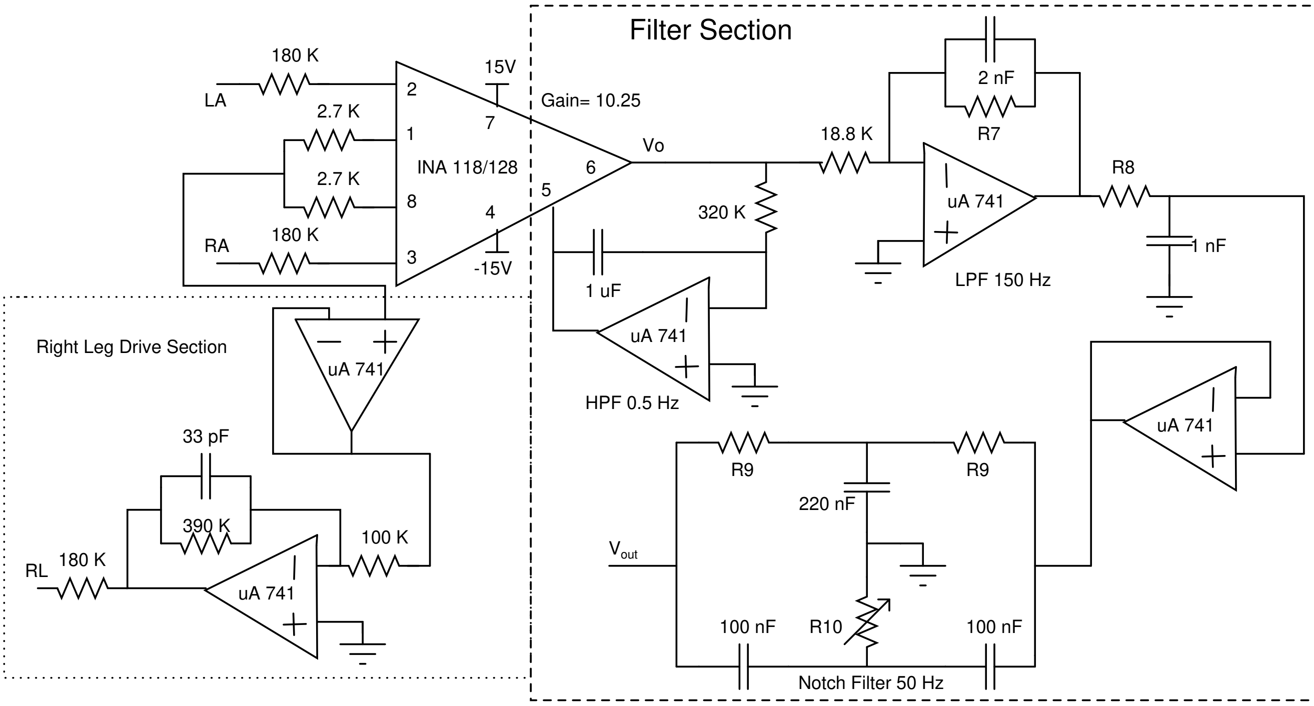

Figure 5: Filter Section Circuit