

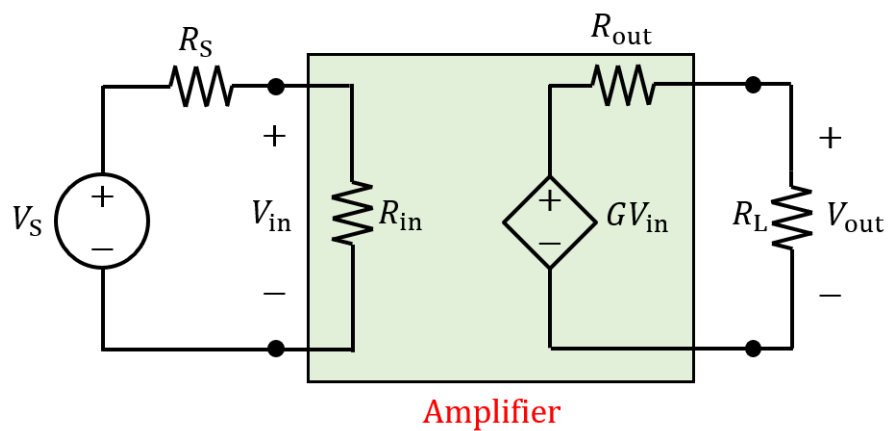
CG1111A Engineering Principles & Practice I

Tutorial 4 (12 & 13 Oct 2022)

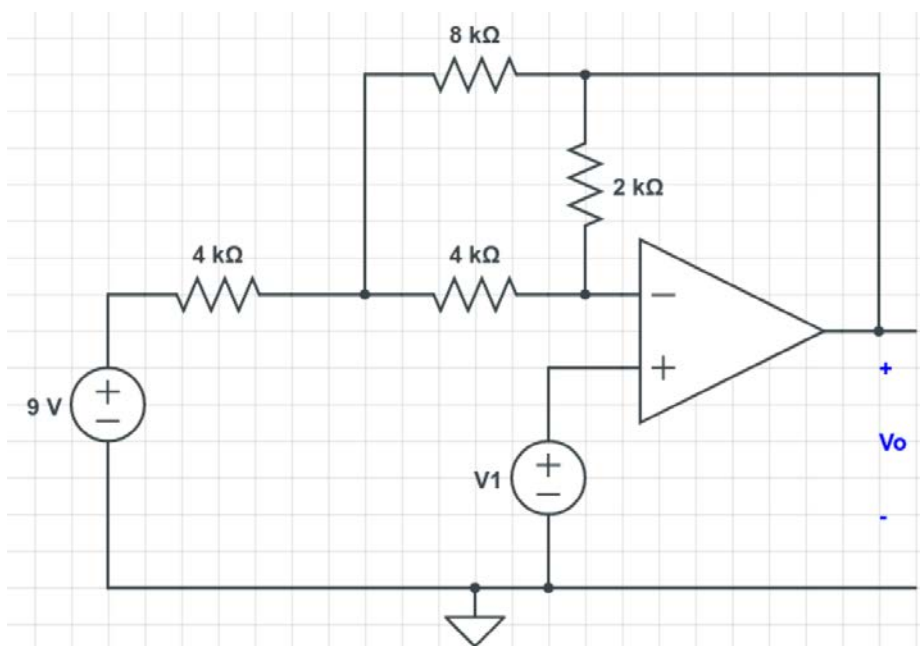
Op-amps, Filters and Sensors

1. Show that if $R_{in} = R_L$, then the power gain in dB for an amplifier circuit is given by

$$\text{Power gain (dB)} = 20 \log_{10} \left| \frac{V_{out}}{V_{in}} \right| \text{ dB}$$

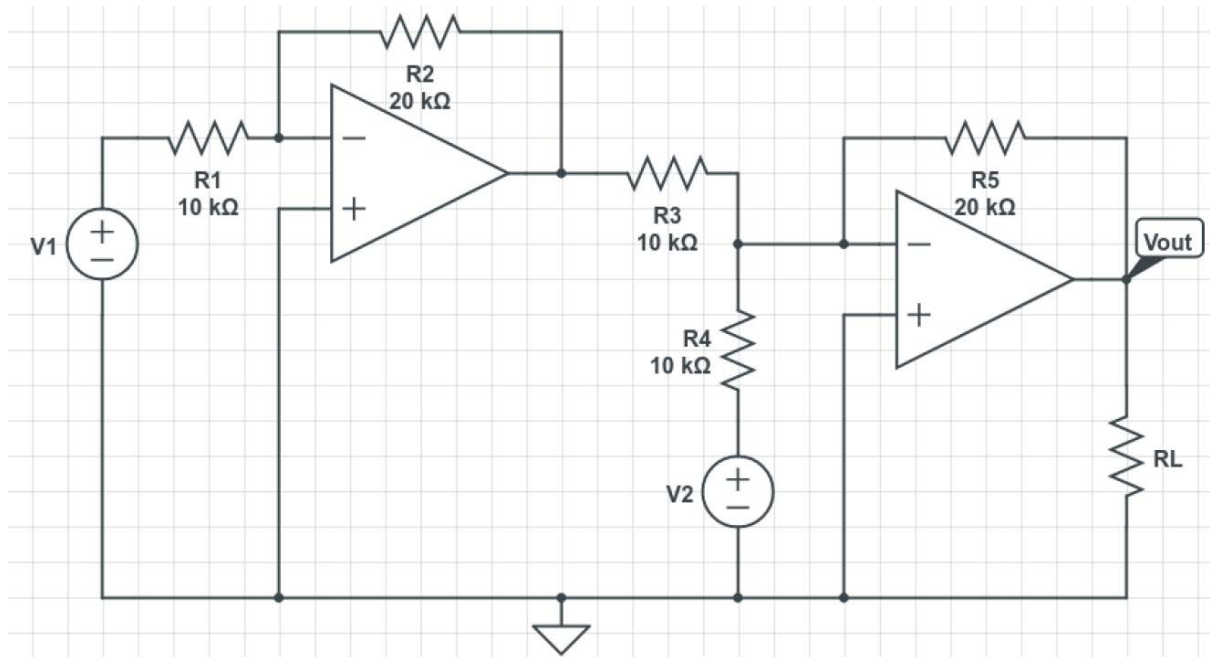


2. Calculate V_o in the given circuit if $V_1 = 0$.
(Hint: You may need to use node voltage analysis.)



Ans: $V_o = -1.64 \text{ V}$

3. Find an expression for the output voltage, V_{out} (in terms of V_1 and V_2), in the given circuit.



Ans: $V_{out} = 4V_1 - 2V_2$

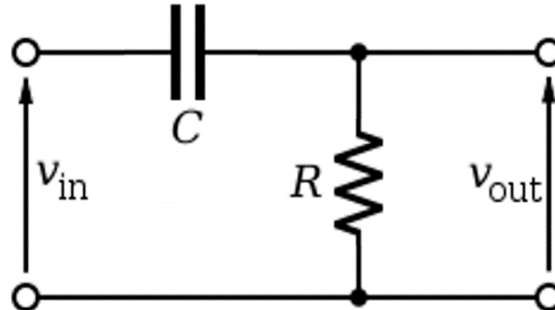
4. LM35 is a commonly used temperature sensor IC chip. It can be powered by 4-30 V power supply, and the output of the sensor varies by 10 mV/°C. For example, if the output of the sensor is 250 mV, then the temperature is 25°C. Design a temperature sensing circuit using LM35, operational amplifier, appropriate resistor values, and LEDs (red and green) as follows:
- When the temperature is below 35°C, the green LED is ON and the red LED is off.
 - When the temperature is above 35°C, the red LED is ON and the green LED is off.
5. Suppose an audio clip recorded using a microphone has frequencies in the range of 100-3000 Hz, but is corrupted by a high frequency noise of 10 kHz. The audio signal's voltages also happen to be low and it is desirable to amplify it. Design an active low-pass filter with a passband gain of 6 dB that also suppresses the 10 kHz noise by 20 dB relative to the passband gain. What should be the cut-off frequency of this low-pass filter?

Ans: $f_c = 1 \text{ kHz}$

6. Suppose an audio clip recorded using a microphone has been corrupted by a 12 kHz noise. Design a passive low-pass filter to suppress the 12 kHz noise by at least 15 dB.

7. For the following passive first-order high-pass filter, show that its cutoff frequency is given by

$$f_H = \frac{1}{2\pi CR}.$$



8. George is a frequent flyer with Singapore Airlines. He loves music, but is annoyed by the low frequency humming (30 – 60 Hz) from the airplane engine when he is flying. He decided to design a high pass filter to tackle this problem. He primarily listens to electronic dance music (generally in the frequency range of 800 to 3000 Hz). Help him design a filter to suppress the humming by at least 21 dB. What is the cutoff frequency of the filter?

Ans: 670.5 Hz

9. The REV Robotics Analog Pressure Sensor is a 5 V (V_{cc}) sensor that can measure pressures up to 200 PSI. It outputs an analog voltage that is proportional to the measured pressure. Given the output voltage (V_{out}), the pressure (p) can be calculated as follows:

$$p = 250 (V_{out}/V_{cc}) - 25$$

Suppose this sensor is connected to a setup with a maximum pressure of 10 PSI. How would you amplify the sensor output signal before sampling it with an Arduino Uno to make good use of the Arduino's ADC range of 0 – 5 V?

10. HIH-4030 is a commonly used humidity sensor IC chip. It operates at 5 V and the output of the sensor varies as 30.68 mV/Relative Humidity percentage. V_{out} at 0% Relative Humidity is 0.958 V. Design a humidity sensing circuit using HIH-4030 and Arduino Uno to obtain the relative humidity percentage. Provide details of your design such as resistors, operational amplifier configuration, if any.