MECH 421: Mechatronics System Instrumentation
2020/2021 Winter Session – Term 2

# Homework 2

Assigned: Jan 22, 2021
Due: Jan 29, 2021

Let us consider a non-inverting amplifier shown in Fig. 1. We assume that the op-amp input impedance $R_i$ is **infinite**, the output impedance $R_o$ is **non-zero**, and the open-loop gain $A$ is a **finite constant**. There is a disturbance current $I_o$ injected into the amplifier output terminal.

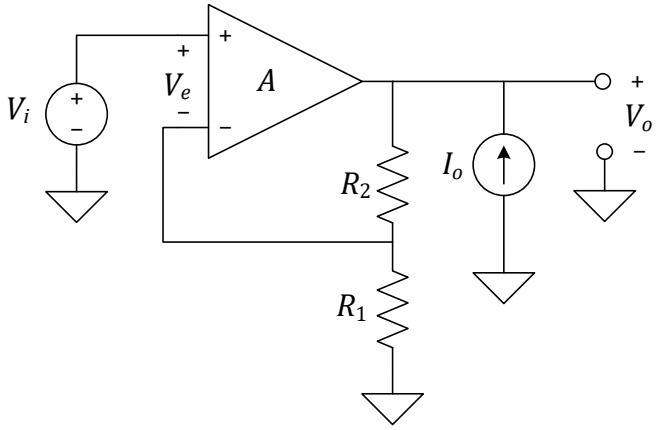


Figure 1: Schematic of a non-inverting amplifier.

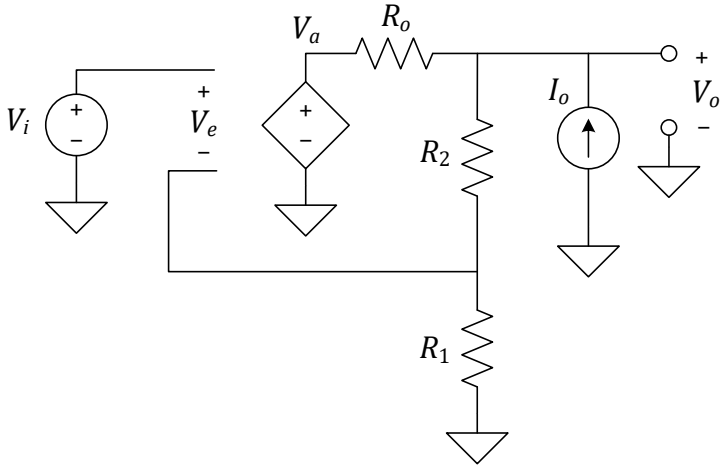


Figure 2: Equivalent circuit model.

Fig. 2 shows the equivalent circuit model. Here, the output stage of the op-amp is modeled as a dependent voltage source with a series output impedance $R_o$. The output from

the dependent voltage source is $V_a = AV_e$, where $V_e$ is the differential voltage applied to the op-amp input signal port. Note that the amplifier output voltage $V_o$ is not equal to $V_a$ because $R_o \neq 0$.

**Problem 1**

(a) Find an expression for $V_o$ in terms of $V_a$ and $I_o$ as the input variables.

(b) Find an expression for $V_e$ in terms of $V_i$ and $V_o$ as the input variables.

(c) Complete the block diagram in Fig. 3.

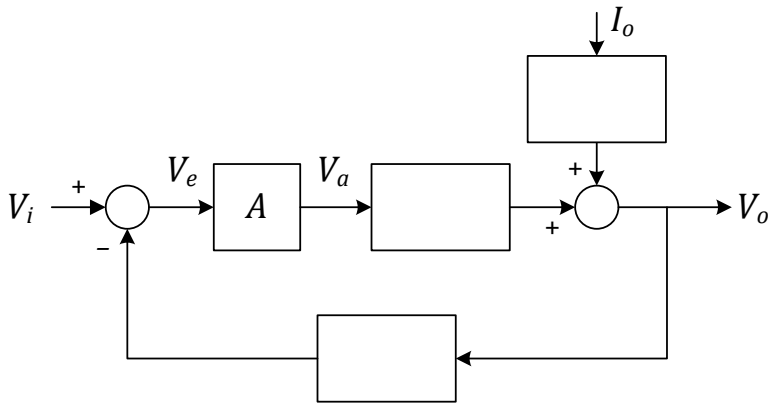


Figure 3: Block diagram.

**Problem 2**

For $R_o = 50\,\Omega$, $R_1 = 1\,\text{k}\Omega$, and $R_2 = 9\,\text{k}\Omega$, find the amplifier gain $V_o/V_i$ when

(a) $A = 10^5$

(b) $A \to \infty$

**Problem 3**

For $R_o = 50\,\Omega$, $R_1 = 1\,\text{k}\Omega$, and $R_2 = 9\,\text{k}\Omega$, find the amplifier output impedance $V_o/I_o$ when

(a) $A = 10^5$

(b) $A \to \infty$

**Problem 4**

Let us consider an op-amp circuit shown in Figure 4. We assume that the op-amp is **ideal**, i.e., the input impedance $R_i$ is infinite, the output impedance $R_o$ is zero, and the open-loop gain $A$ is infinite.

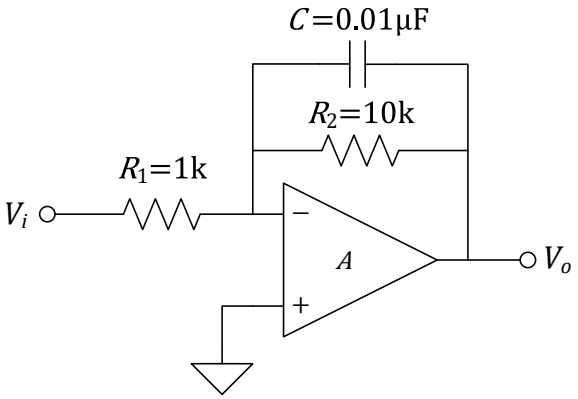


Figure 4: Schematic of a non-inverting amplifier.

(a) Derive the transfer function $V_o(s)/V_i(s)$

(b) Plot the Bode plot and the step response.