

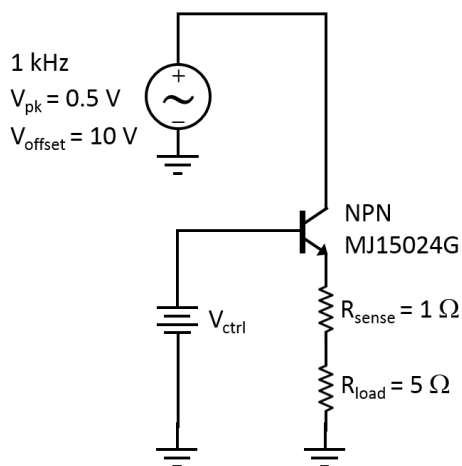
Lab 11: PI Feedback Control

This week's lab focuses on the use of PI feedback control to produce a constant current source using a noisy voltage source. The lab is the simulation version of problem #2 on the homework.

Important: The free version of Multisim will only allow you to use 25 components (DC/AC voltage sources, op-amps, resistors, capacitors, transistors, etc). Grounds are not considered to be components. Section 4 requires about 25 components, so you will have to be careful to minimize component use so as to not go over the limit. You will only use the 3-terminal ideal op-amp in this lab (use ± 15 V to power it).

Hint (for getting started): If you need a resistor, then use a $10\text{ k}\Omega$ one. If you need a capacitor, then use a 10 nF one. If you need an amplifier, then choose $\text{gain}=1$ (at least initially).

1. Basic constant current source (30 minutes)



This circuit is a basic constant current source. The current comes from the AC source, which we are using as a constant voltage source (with voltage V_{offset}) with some sinusoidal “noise” at 1 kHz and amplitude V_{pk} .

a) Construct the circuit adjust V_{ctrl} so that the current through R_{load} is $I_{\text{load}} = 1\text{ A}$.

b) Measure the amplitude ΔI_{pk} of the 1 kHz oscillations on the main current I_{load} (for 1 A). What is the fractional size of the noise?

c) Derive a formula for I_{load} in terms of R_{load} , R_{sense} , V_{ctrl} , and β . Is this a good current source? Determine β from measurements in the simulation (for $I_{\text{load}} = 1\text{ A}$). How closely does your formula match the simulation?

2. Sense resistor: Op-Amp current-to-voltage converter (15 minutes)

Attach an op-amp (3-terminal, ideal) circuit to the above constant current source to convert the current running through the sense resistor R_{sense} into a voltage in a 1-to-1 manner, such that $V_{\text{out}} = 1\text{ V}$ for $I_{\text{load}} = 1\text{ A}$.

Verify that V_{out} has the 1 kHz oscillations present in I_{load} , and that they are the expected amplitude.

3. Error signal circuit (15 minutes)

Since your objective is to make a 1 A constant current source, you need to construct an op-amp circuit (single op-amp, 3-terminal, ideal) that will generate an error signal V_{error} that is centered at zero when $I_{load} = 1$ A. You should use a 1 V DC source (i.e. battery) as the source for V_d , the desired target voltage that your feedback circuit will use as reference to produce $I_{load} = 1$ A.

How can you easily modify your circuit to flip the polarity of V_{error} ? (polarity flip: $V_{error} \rightarrow -V_{error}$) You may have to flip it in section 4. If it is complicated to flip the polarity of V_{error} , then redesign your circuit.

Verify that for $I_{load} = 1$ A, the 1 kHz oscillations on V_{error} are roughly centered around zero.

4. PI feedback constant current source (2 hrs ... infinite, if not prepared)

This section is the main part of the lab. You will use proportional and integral feedback (PI) to stabilize the current in the sense resistor R_{sense} , and thus in the load resistor R_{load} as well.

a) Construction

Construct a circuit based on 3 op-amps (3-terminal, ideal) that takes the V_{error} and implements equation 11.1 without the derivative term (i.e. the last term). Your circuit must include sub-circuits or components for each item in the equation: the LHS, the RHS terms, the “+” sign, and the “=” sign. *The hint at the start of the lab instructions will save you some trouble.*

If your circuit works, then you should have $I_{load} = 1$ A, which you can now adjust by changing V_d .

- Verify that $V_d = 0.5$ V, yields $I_{load} = 0.5$ A, and that $V_d = 0.1$ V, yields $I_{load} = 0.1$ A.

- Verify that you can change the load resistor to $R_{load} = 2 \Omega$ or $R_{load} = 7 \Omega$ without changing I_{load} (use 1 A)

Note 2: If you find that V_d controls I_{load} , but the current is only approximately correct, then you should go to part b and make the suggested adjustments to improve the performance of your circuit.

Note 2: If your circuit does not work, e.g. $I_{load} = 0$ A, then it may be incorrectly wired, or the sign of the feedback is incorrect. Try changing the sign of the feedback by flipping the polarity of V_{error} .

b) DC performance

- Change the gain of the integral feedback via the capacitor and see how it affects the accuracy I_{load} .

How close can you get to $I_{load} = 1$ A (use $R_{load} = 5 \Omega$).

- Zoom in to the current plot and measure the size of 1 kHz oscillations on I_{load} (at 1 A). How small can you make the oscillations by adjusting the proportional feedback and the integral feedback.

- Adjust the proportional and integral feedback to minimize the current oscillations, while remaining close to the target desired current of 1 A. Determine the fractional accuracy of your current source (in %), i.e. how close the actual current is to your desired current. Determine the fractional noise on your current source, i.e. the size of the 1 kHz current oscillations with respect to the full 1 A current (in %).

c) Dynamic performance

Replace the DC power source (battery) for V_d with a “clock voltage” source (square wave) at 10 Hz with a 1 V amplitude (Vp) [50 % duty cycle, and rise/fall time = 1 ns]. Measure the response of the actual current to an abrupt change in the target current (by changing V_d) for both an increase and a decrease.