Physics 3108 Lab 2: Current Source

Background

Many electrical measurement require the use of a current source. For example, even in a simple multimeter, a current source is used in order to measure resistance. In PY3108 you are to design and build a current source, which will be used for futher experiments and measurements.

Purpose

To learn about and understand the design of current sources based on OpAmps and instrumentation amplifiers. To use this knowledge to build a current source onto a circuit board **- *which will be used in later experiments.***

Summary

During the first week, you are to design, build and characterise various current sources on the prototype board. Based on your experiments, you should propose a final design. Note that it is better to demonstrate learning and understanding than to merely make a lot of different circuits.

During the second week, you will finalise your design and provide appropriate design documentation.

During the third week, you will put together your current source using your design. You completed current source should be fully characterised.

End Requirements:

Maximum Current: at least 80mA (more is OK)
Voltage across load at Maximum Current: >3.5V
(don't forget the voltage drop across the transistor)
Control (or Input) Voltage: <10V
Supply Voltage for OpAmp 0, 9V (eventually with a single battery)
How low a supply voltage are you able to use?

Procedure:

Unlike a traditional lab, the procedure is ambiguous and open ended. Thus, the following are guidelines, not step by step instructions. For example you are told to characterise the current source. In this context, to characterise means to make measurement of the current source in order to extract parameters that are characteristic of the current source. For example:

- What current is sourced for a given applied voltage? (units: A/V)
- Is this a linear relationship?
- What is the maximum current that can be sourced into a small resistor?
- Many others possible.

Supplies and extra Notes:

- You will be supplied with OpAmps, IAmps, NPN and PNP transistors, a large selection of large resistors and a few high power small resistors (1Ω and 10 Ω).
- It is a good idea to use the 1Ω and 10 Ω resistors as load resistors when testing your circuits.

Part A – Design and Experiment - First Week

1. Using the prototype board: design, build and characterise one or more current sources. You can choose those described at the end of this document, or other designs that you find on your own.
2. Describe what you have characterised and learned (what works? what doesn't? what limitations did you see? Etc.)

Part A Submission due: Tuesday September 26, 2017

Part B – Planning – Second Week

1. Complete the final design of your circuit by following the example given in the lecture, and shown in the document: Circuit Board Design Helps. This includes:
   a. A schematic showing the various components (include the values you are proposing), voltages and currents
   b. Equations that you have used to analyse your circuit
   c. A circuit board diagram showing how you intend to put together the circuit
   d. A spreadsheet showing the predicted behaviour of your circuit as a function of input voltage.
3. Based on the **End Requirements** provided: design, build and characterise a current source that meets the requirements.
4. Propose your final current source (design including schematic, resistor values, etc.) with characterisation data.

- **NOTE**: Please recommend what you believe to be the best resistor values

Part B Submission due: Tuesday October 3, 2017

Part C – Creation – Second and Third Week

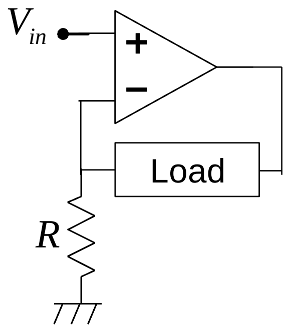
1. Build or construct your current source (based on your previous submission) using solder and circuit board material.
2. Fully characterise the current source (ideally using your LabView code)

- Hand in the actual device as well as your results.
- Ensure that each pair of wires is clearly labelled.

Part C Submission due: Tuesday October 10, 2017
Note: your circuit needs to be submitted into my office or mailbox before the end of the day.

Current Source Examples:

1) Simple Current Source A

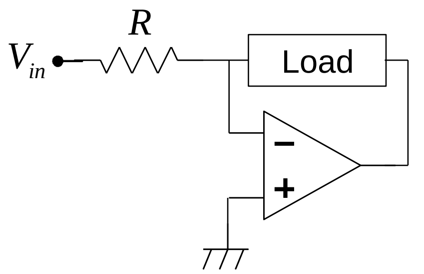


Here the current that flows is: $I = \frac{V_{in}}{R}$

The current is only supplied by the OpAmp and this is a limitation of the design.

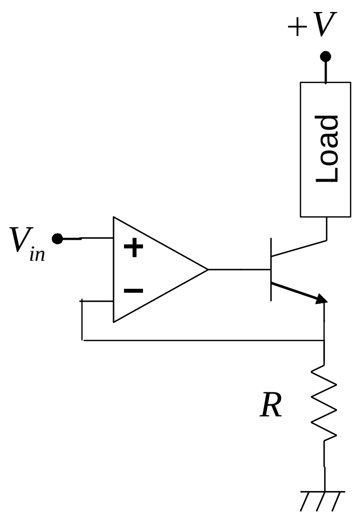
The load is floating, and this is not ideal.

2) Simple Current Source B



This current source has all the same limitations as the previous version.

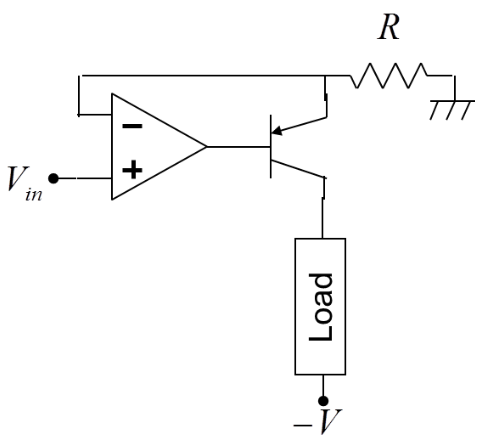
3) Current Sink



This current source overcomes the major limitation of the simple current sources. The current is no longer limited by the output of the OpAmp, since the OpAmp is used to turn on the transistor.

This design is still limited in that the load is not grounded, but rather exists between the current sink and a high voltage supply.

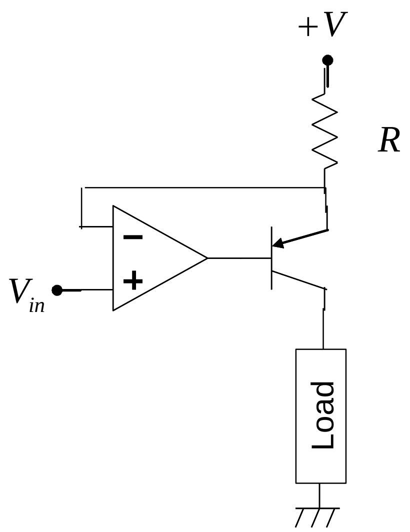
4) Current Source



This current source has all of the limitations of the previous design. Since this is a source rather than a sink, the load must exist between the source and a large negative voltage.

Note: In order for this circuit to turn on, the input voltage must be less than zero.

5) Grounded Current Source



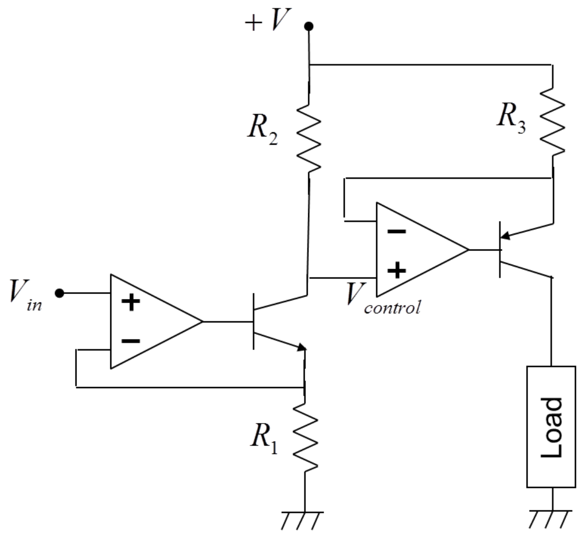
This current source is terminated into ground, which is what we would like. Unfortunately the current is not proportional to the control voltage, rather:

$$I = \frac{V - V_{in}}{R}.$$

This is awkward in practice.

NOTE: In order for this circuit to turn off (zero current) the output of the opamp must be ~ +V. This means that the input must also be ~+V. If you want to attempt this on the breadboard, connect +V to 5V, connect the 741 OpAmp to ±12V, and ensure that the input voltage can reach 5V.
While this circuit can be made to work on the breadboard, it cannot work using a 9V power supply and an input voltage between 0-5V.

6) Good Current Source (use this one for your final circuit this year)



This current source is an improvement on the previous, where an additional OpAmp circuit is used to convert from a zero based control to a +V based control. Thus the current will be proportional to the input voltage, yet the source still terminates on ground.

The current controlled by the first OpAmp circuit will be:
$I_1 = \frac{V}{R_1}$, therefore, the control voltage will be: $V_{control} = V - I_1 R_2 = V - V_{in}\frac{R_2}{R_1}$.
And the output current is therefore:

$$I = \frac{V - V_{control}}{R_3} = \frac{I_1 R_2}{R_3} = V_{in}\frac{R_2}{R_1 R_3}.$$

The choices of the resistors are therefore important in choosing the range of currents, and the compliance voltage.

Suggestion: For this circuit to work you will need to use an OpAmp that can operate near the rails (i.e. the power supply level). The LT1490A Dual OpAmp is provided for this circuit.

WARNING: A Darlington transistor has a voltage drop of ~1-1.5V.

- Examine the output of your circuit using the oscilloscope. You will likely discover that the circuit is oscillating. This is not good! To stop the oscillation, the circuit will need to be adjusted with some extra components.

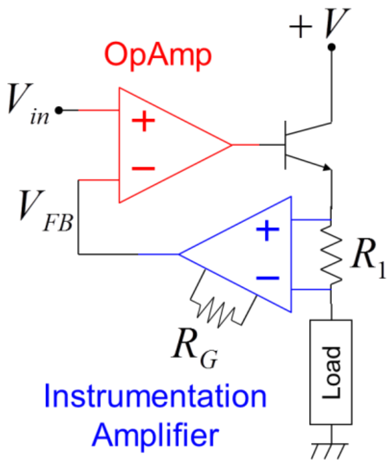
7) Good Current Source (do *not* use this one for your final circuit)

This current source is an improvement on the previous designs, where an instrumentation amplifier is now used.

As shown in class $I = \frac{V_{in}}{GR_1}$, where the gain is set using: R_G

This current source is ideal since the load is grounded, and the current is positive linearly proportional to the input voltage. It works nicely with a 0-5V input and positive supply voltage that is as low as 5V (you will be using 9V).

Note: Remember to use both positive and negative power supplies. Otherwise the circuit may not work correctly.



WARNING: Examine the output of your circuit using the oscilloscope. You will likely discover that the circuit is oscillating. This is not good! To stop the oscillation, the circuit will need to be adjusted with some extra components, as seen below. In addition, using shorter wires will help reduce oscillations.

The figure includes recommended initial values for the extra components. You will likely need to adjust the values to eliminate all oscillations.