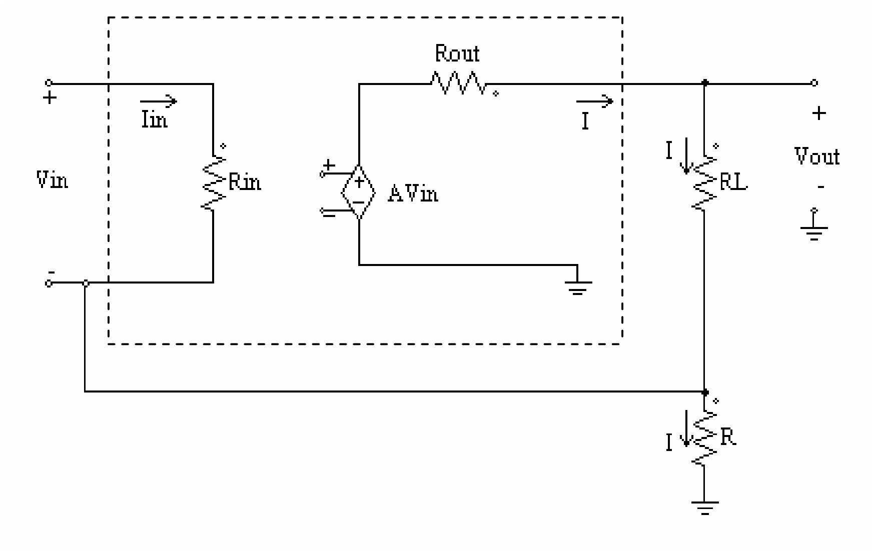
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

22.071/6.071 Introduction to Electronics, Signals and Measurement

Spring 2006

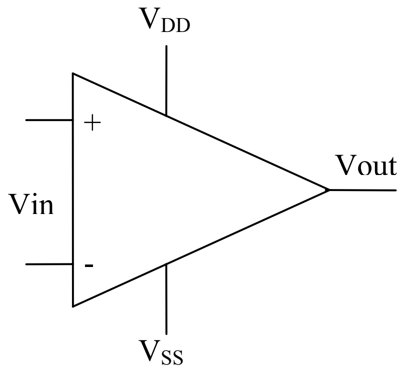
Laboratory 9: Dependent sources, Op-Amps, Current Source.

We have been introduced to dependent sources and have analyzed the following circuit.



The dependent source in the above circuit is a voltage controlled voltage source whose output is proportional to Vin with a constant of proportionality A>>1.
Additionally we know that resistance Rin is large (MΩ in practical devices) and resistance Rout is small (10s Ω).
The large value of the resistance Rin implies that the amount of current flowing through Rin is very small (zero in the ideal case). If we assume that the input voltage Vin corresponds to an output of a transducer then we see that this circuit does not demand the delivery of power from the sensor circuit. In other words our transducer device, whose goal is to just give an electrical signal that is related to some physical quantity, is buffered (protected, isolated) from the demands of the measuring circuit.

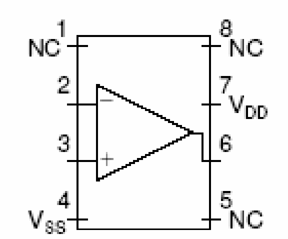
The part of the circuit enclosed by the dashed lines is a device called the Operational Amplifier (op-amp). The schematic of an op-amp is:



The terminals labeled VDD and VSS are the positive and negative power supply connections for the device.

In this class we will use the LF356 op amp. The 356 is a good, cheap, easy to work with op amp well suited to most basic circuits. More expensive op amps tend to sacrifice op-amp ideality (finite input current, stability, power supply reject, etc.) for specific purposes (high speed, low noise etc.) and can be much more difficult to work with. The data sheet for the 356 is available in the class web site.

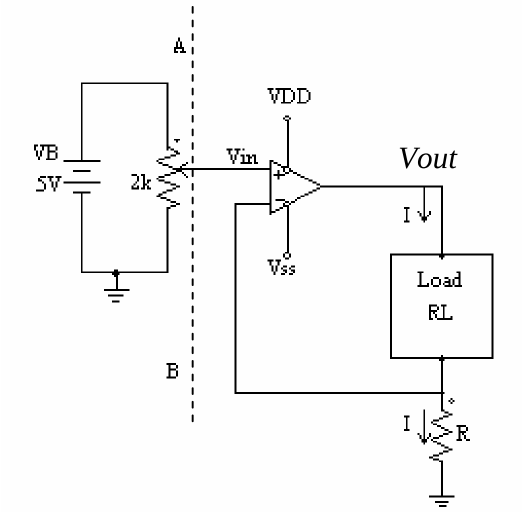
The pinout of the 356 is the same as that of another widely used op amp, the 741, and is shown below.



We will use this op-amp to construct and characterize a **current source**.

Current Source and Power Transfer.

Let's investigate the following circuit.



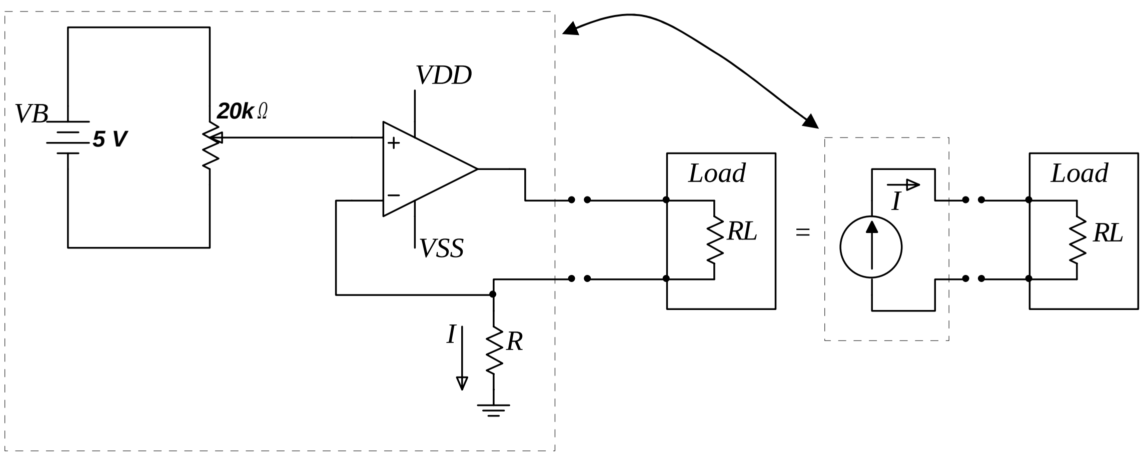
As you recall from the class notes, $Vout = Vin\frac{R+RL}{R}$ and the current through resistor RL is

$$I = \frac{Vin}{R}$$

Notice that the current I provided by this circuit does not depend on the value of the resistor RL, the load resistor. The amount of current flowing through the load is determined by the value of resistor R and the input voltage Vin.

Build the circuit shown above. The circuit to the left of the vertical line AB provides the input voltage Vin for your current source. For the voltages VDD and VSS use +15V and -15V respectively.

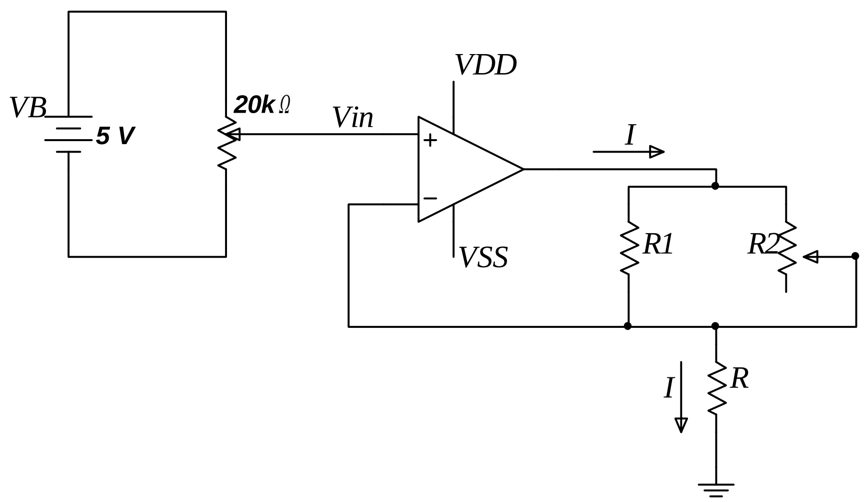
You have just built a fundamental current source as indicated below.



Perform the appropriate measurements/calculations and complete the table below.

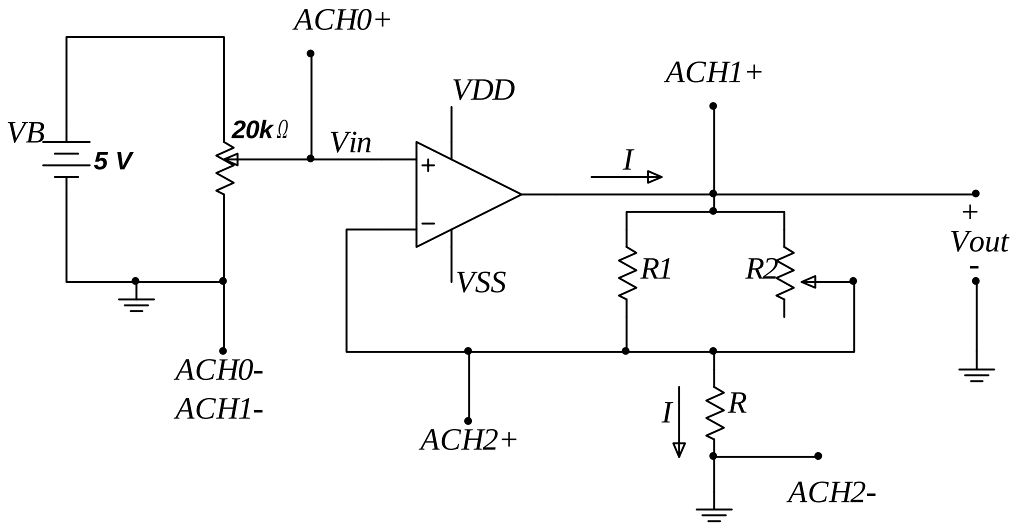
Vin	RL	R	Vout (measured)	I (calculated)	I (measured)
1	1k	1k			
1	10k	1k			
5	1k	1k			
5	1k	10k			
5	10k	1k			

Now that we have constructed a current source let's use it to investigate the simple current divider and related power transfer issues.
We will simply replace the load resistor RL with two resistors connected in parallel as shown on the circuit below. One of these resistors (*R2*) is the variable 20kΩ resistor. For *R1* use a resistor in the range 1kΩ to 10kΩ.



Select appropriate values for all relevant circuit parameters in order to generate a current of 10mA. List the parameters and their values.

Next, let's make the connections indicated in the schematic shown below.



The channel ACH2 measures the current I, while ACH0 and ACH1 measure the voltage Vin and Vout respectively.

From the class web site download and open the virtual instrument **Current_Divider_01**.

Vary the value of resistance R2 by trimming the potentiometer. Plot and comment on the power dissipation characteristics of the current divider.

Answer the following:

1. Give expressions for the current through resistors R1 and R2

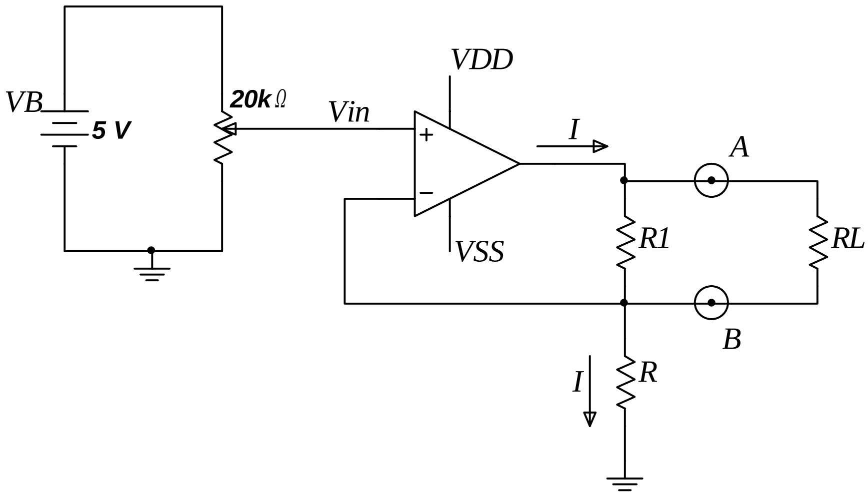
2. Give expressions for the power dissipated in resistors R1 and R2

3. From your experimental results you should observe that as $R2 \rightarrow 0$, the power dissipated in R1 (P_{R1}) and the power dissipated in R2 (P_{R2}), $\rightarrow 0$. Explain this result.

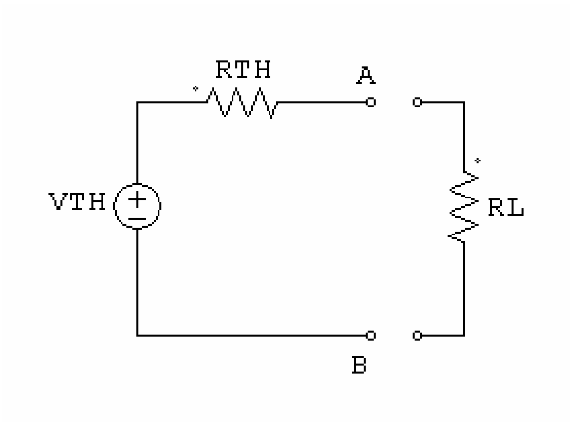
4. Why is there a maximum in P_{R2} but not in P_{R1}?

Equivalent Circuit. – for extra credit -

We will next perform a set a simple measurements in order to determine the Thevenin equivalent circuit seen by resistor RL.



In order to determine the Thevenin equivalent circuit we must calculate/measure the equivalent resistance RTH and the equivalent voltage VTH. The resulting equivalent circuit across terminals *A* and *B* will have the form:

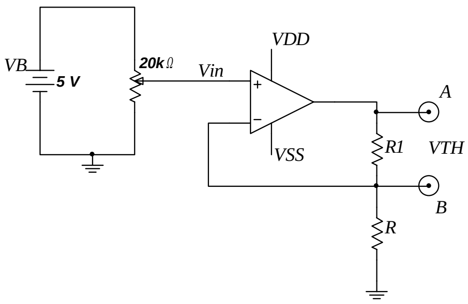


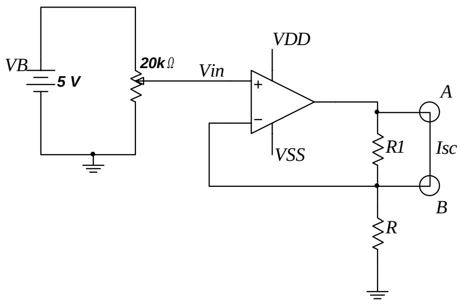
VTH is the open circuit voltage across terminals AB and RTH, the equivalent resistance, is the ratio of VTH to the short circuit current, I_{SC} , through AB (the Norton current).

$$R_{TH} = \frac{V_{TH}}{I_{SC}}$$

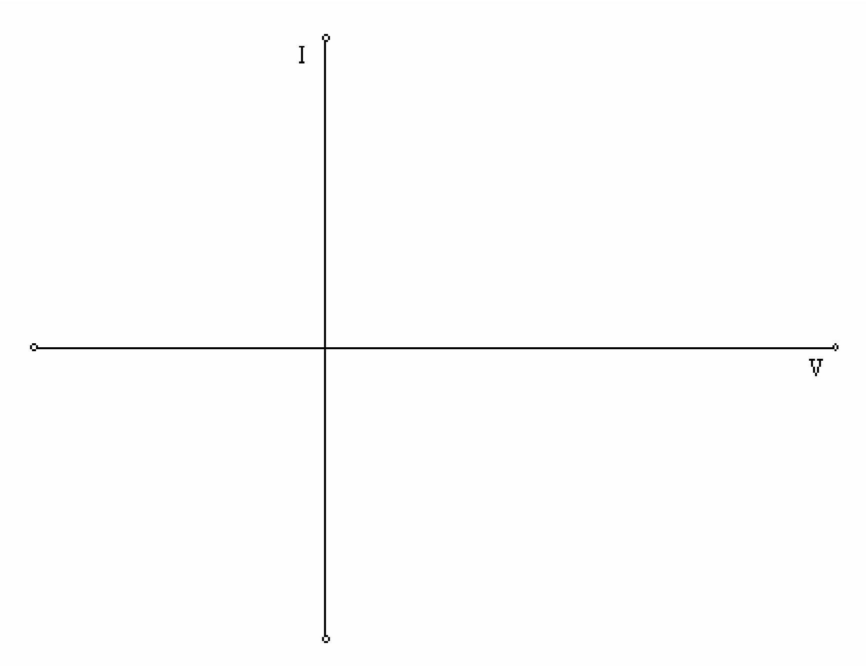
You are free to use any values for the resistors R1 and R provided that you do not violate the specifications of the operational amplifier.

Schematically, the measurements are performed as indicated below.





Draw a graph of the IV characteristic curve of your equivalent circuit.



Indicate the values of ISC and VTH on the above graph.
Determine the operating point for

RL=1kΩ.

RL=10kΩ.