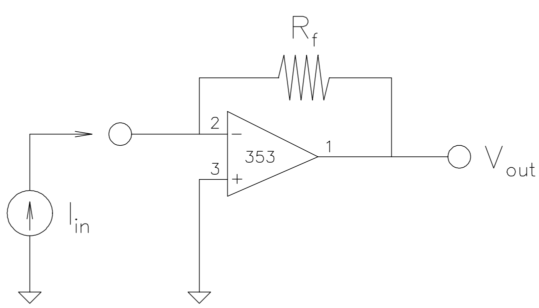
Experiment 3

Building circuits with op-amps

The purpose of this experiment is to build several realistic op-amp circuits. We learn how to use op-amps for signal conditioning in various measurements.

3.1 Current–to–voltage converter

(!)



Wire up the current-to-voltage converter circuit (note that this corresponds to simply interchanging the input and ground connections in the circuit of Section 2.3). Here we emphasize the fact that the input is explicitly a current, while the output is a voltage:

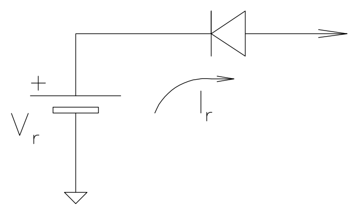
$$V_{\text{out}} = -R_f I_{\text{in}}$$

Use a feedback resistor of 10 kΩ.

Use a 10 MΩ precision resistor in series with a variable voltage supply as the current source: $I_{\text{in}} = V_{\text{in}} \times 10^{-7}$, for several (five or more) input currents in the nanoamperes-to-microamperes range. Measure V_{out} with the DMM.

I_{in}	Calculated V_{out}	Measured V_{out}	% error

[?] Will the input offset voltage affect the measurement of small currents more (a) when the current source is a small voltage and a small resistance, or (b) when it is a large voltage and a large resistance?

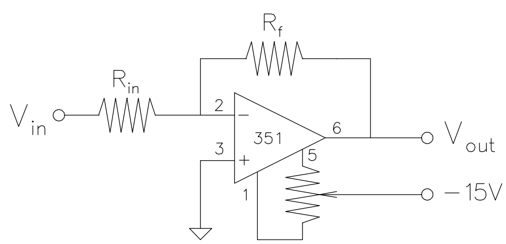


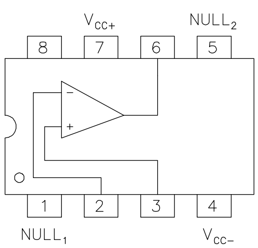
Using a signal diode 1N914, wire the following input circuit to measure the reverse bias current of the diode. Select the value of R_f necessary to give a reasonable V_{out}. Use reverse bias voltages $V_r = 1$, 2, and 5V.

V_r	V_{out}	R_f	I_r
1 V			
2 V			
5 V			

3.2 Inverting amplifier

As seen in Section 3.1, the input offset voltage of op-amps can introduce significant output errors. Many op-amps (351, 741) have additional pins for adjusting the offset to zero.





Wire the circuit shown with $R_f = 100$ kΩ and $R_{\text{in}} = 10$ kΩ (gain $\simeq 10$); connect input to common, and adjust the balance potentiometer until the op-amp output is nearly zero ($\leq$ 1mV). Set DMM to an appropriate scale.

Prior to every other experiment in this lab, check in the same manner whether the op-amp remains balanced (it should!)

Use a ±1V supply as V_{in} (disconnect the wire to common first!). Measure V_{out} for five or more values of V_{in}, in the range ±0.7V.

I_{in}	Calculated V_{out}	Measured V_{out}	% error

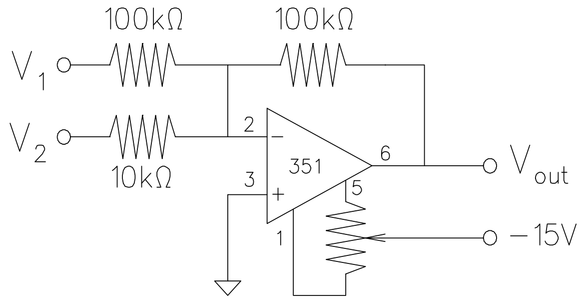
Use the FG set at 1 kHz as V_{in}. Use the two channels of the scope to monitor the inverting input of the op-amp and V_{out}. Slowly increase the amplitude of the input signal, starting near zero. Observe what happens at the inverting input as the amplifier saturates. Is the assumption of virtual ground still valid?

Keeping the amplitude of the input low and constant, vary its frequency. Can you estimate the maximum slew rate of the 351?

3.3 Summing amplifier

Inverting amplifier configuration may be used to perform several mathematical operations. The summing amplifier provides an output related to the algebraic sum of two or more signals.

(!)



Wire up a summing amplifier, as shown. Use the ±10V supply as V_1 and the ±1V supply as V_2. Measure V_{out} for six or more combinations of input voltage values. Keep one value constant for at least three values of the other and *vice versa*.

V_1	V_2	V_{out}
	. . .	

[?] Plot V_{out} *vs.* V_2 for constant V_1, and V_{out} *vs.* V_1 for constant V_2. Explain the values of the slopes and intercepts.

Disconnect the summing network from the 351; leave the balance pot and power connections in place for later use.

[?] Design a circuit whose output represents $3V_1 - 4V_2$.

[?] Design and describe an inverting amplifier with a thermistor as one resistor such that the output voltage becomes more positive as the temperature inreases. The thermistor resistance is 10.5 kΩ at 28°C and 9.5 kΩ at 23°C. Choose the component values so that V_{out} changes 10 mV per °C near room temperature. Also include an offset circuit so that $V_{out} = 250$ mV at 25°C. Assume that the thermistor resistance changes linearly with T^{-1}.

3.4 Op-amp characteristics

It is important to recognize the limitations of op-amps so that measurement errors may be avoided in instrumental applications. We will explore two important characteristics of several different common integrated circuit op-amps.

(!) To measure the input offset voltage V_{offset}, connect the op-amp as a voltage follower and connect the non-inverting input to common. The output voltage equals V_{offset}. Perform this measurement for the three different types of op-amps and include the data in the table. Repeat for both of the LF353 dual op-amps. Note that the pinout of the 741 op-amp is identical to that of the LF351.

(!) To measure the input bias current, I_{bias}, a 10 MΩ resistor should be connected between the non-inverting input of the voltage follower and common. The IR drop across the resistor results from the bias current. The output voltage V_{out} is the sum of the offset voltage, V_{offset}, and the IR drop across the resistor. $I_{bias} = (V_{out} - V_{offset})/R$. Carry out this determination for each of the op-amps under investigation, tabulate, and comment on the results.

Op–Amp	$V_{offset} = V_{out}$, for $R_{in} = 0$	V_{out}, for $R_{in} = 10\text{M}\Omega$	I_{bias}, nA
LF353-1			
LF353-2			
LF351			
μA741			