EE413
Lab 005
the Operational Amplifier

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Instructor: TODO

Abstract

"This lab is meant to show the practical use of the operational amplifier in analog circuit design. Several common circuit configurations will be discussed."

Contents

1 Circuit prototyping setup

The circuit was build on a solderless breadboard, using through-hole parts. A classic 741 op amp was used with a +/-15V power supply.

2 Inverting DC Amplifier

2.1 Theory

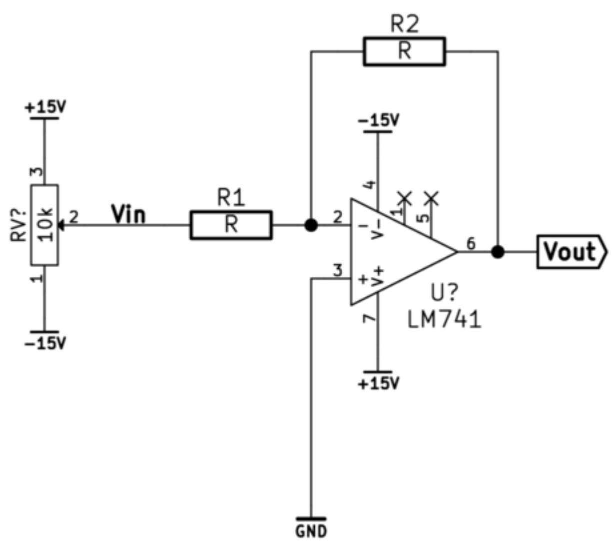

Figure 1: Inverting DC amplifier

The basic topology for an inverting amplifier is shown in Figure 1. Gain, Av, can be expressed as a ratio of the feedback impedance to the input impedance. A fraction of the output is fed back, causing the op amp to compensate and in effect amplify.

$$A_v = \frac{R_2}{R_1} \tag{1}$$

The circuit gain for ideal components is therefore;
For $R_2 = 100k\Omega$:

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{2}$$

$$= \frac{100k\Omega}{10k\Omega} = 10\times \tag{3}$$

$$= 20 \times \log \frac{10}{1} = 20dB \tag{4}$$

For $R_2 = 10k\Omega$:

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{5}$$

$$= \frac{10k\Omega}{10k\Omega} = 10\times \tag{6}$$

$$= 20 \times \log\frac{1}{1} = 0dB \tag{7}$$

In both cases, the signal phase is inverted 180°.

2.2 Measurements

Measured values for the test setup.

U_{in} (V)	U_{out} (V)	Av (×)
-0.103	+1.087	-10.35
-1.008	+10.236	-10.15
+1.004	-10.104	-10.06

Table 1: $R_2 = 100k\Omega$

U_{in} (V)	U_{out} (V)	Av (×)
-0.1003	+0.112	-1.116
-1.000	+1.038	-1.038
+1.005	-1.027	-1.022

Table 2: $R_2 = 10k\Omega$

For $R_2 = 100k\Omega$, the actual measured in circuit values of R_2 and R_1 were 119kΩ and 11.7kΩ, respectively. Calculated circuit gain for non-ideal, real components;

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{8}$$

$$= \frac{119k\Omega}{11.7k\Omega} = 10.17\times \tag{9}$$

$$= 20 \times \log\frac{\frac{119k\Omega}{11.7k\Omega}}{1} = 20.15dB \tag{10}$$

For $R_2 = 10k\Omega$, the actual measured in circuit values of R_2 and R_1 were 12.17kΩ and 11.7kΩ, respectively. Calculated circuit gain for non-ideal, real components;

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{11}$$

$$= \frac{12.17k\Omega}{11.7k\Omega} = 1.04\times \tag{12}$$

$$= 20 \times \log \frac{1}{1} = 0.34dB \tag{13}$$

3 Inverting AC Amplifier

3.1 Oscilloscope shots

3.2 Measurements

Measured amplification = — Measured phase = 180 Theoretical amplifier = Theoretical phase =

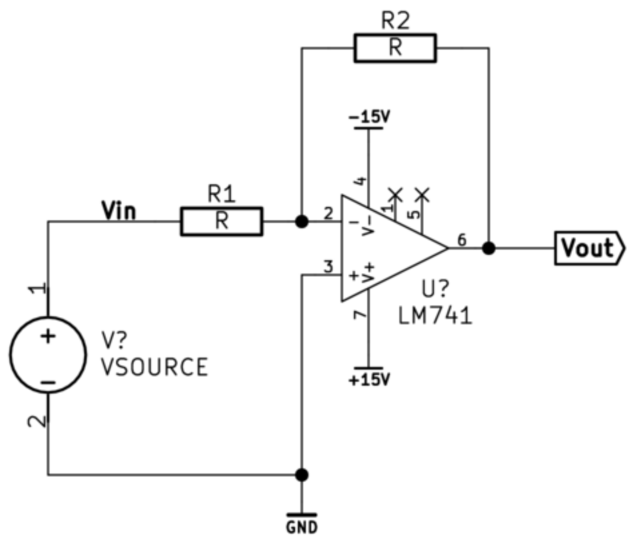

Figure 2: Inverting AC amplifier

4 Non-inverting DC Amplifier

Av = 1 + R2/R1

4.1 Measurements

U_{in} (V)	U_{out} (V)	Av ($\times$)
+0.1007	+0.2164 2	.15
+1.002	+2.048 2	.04
-1.005	-2.03 2	.019

Table 3: $R_2 = 10k\Omega$

U_{in} (V)	U_{out} (V)	Av ($\times$)
+0.1009	+1.178	11.67
+1.1013	+11.3	11.15
-1.004	-11.09	11.05

Table 4: $R_2 = 100k\Omega$

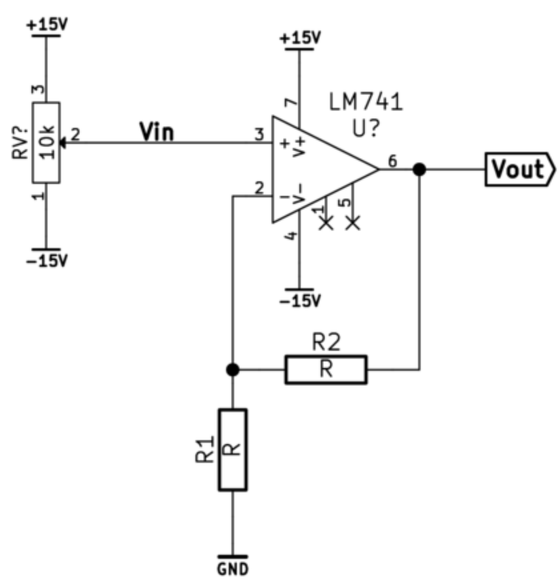

Figure 3: Non-inverting DC amplifier

5 Non-inverting AC Amplifier

5.1 Measurements

Input signal amplitude =
Output signal amplitude =
Measured amplification =
Measured phase =
Theoretical amplification = Theoretical phase =

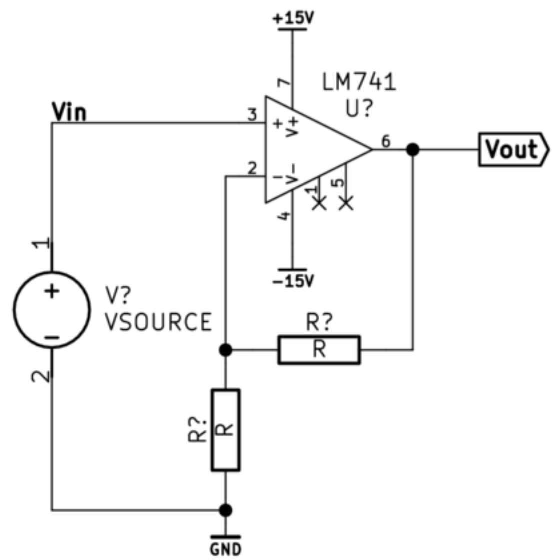

Figure 4: Non-inverting AC amplifier

6 Active full wave rectifier

Active rectifier does not suffer from the "deadzone" when the signal is too small to turn on the rectifying diode. The op amp compensates for the diode forward voltage drop. The circuit output is a full wave rectified version of the signal, with a frequency limit mostly set by the op amp bandwidth. Diode D2 prevents the op amp from hitting the rail hard when D1 is reverse biased. This makes the recovery and rise time faster when D1 biases on. This improves circuit response times.

7 Results

TODO

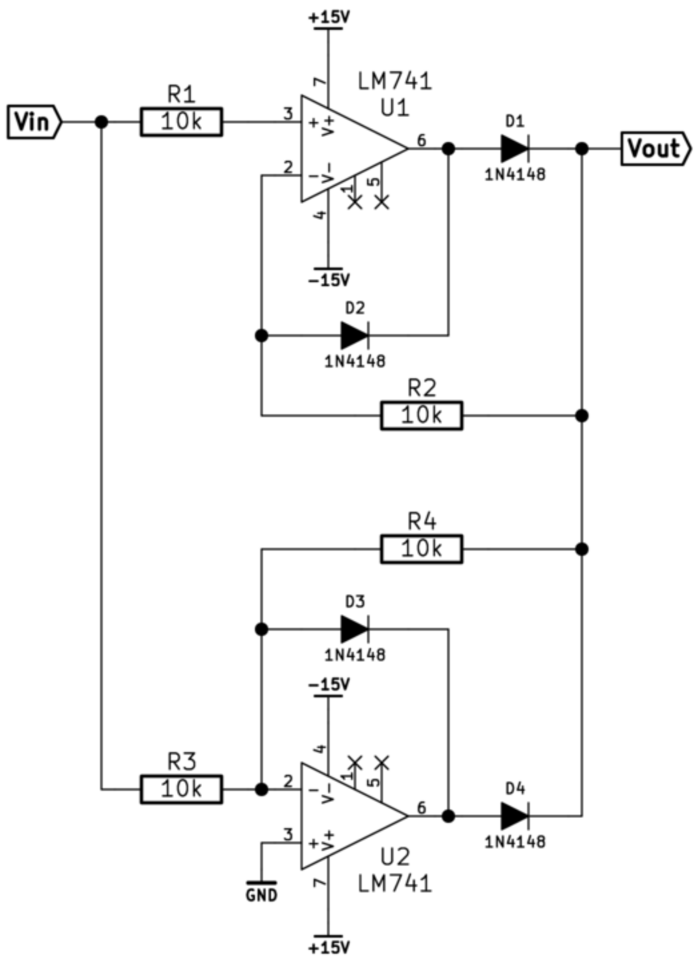

Figure 5: Active full wave rectifier