EE413
Lab 005
the Operational Amplifier

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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. No decoupling caps was used and signal lines were not properly terminated.

2 Inverting DC Amplifier

2.1 Theory

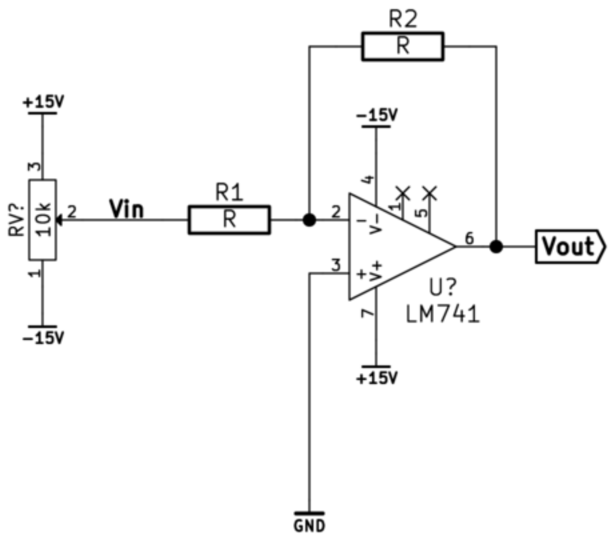

Figure 1: Inverting DC amplifier

The basic topology for an inverting amplifier is shown in Figure 1. Gain A_v, can be expressed as a ratio of the feedback impedance to the input impedance. Op amp action makes the negative input appear as a "virtual earth" summing node. The voltage drops across the resistors scale linearly with their value, and since the op amp compensates to ensure equality in the summing junction, the net effect is an amplified and inverted output.

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

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 are shown in Table 1 and Table 2.

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;

$$
\begin{aligned}
A_v &= \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} && (8)\\
&= \frac{119k\Omega}{11.7k\Omega} = 10.17\times && (9)\\
&= 20 \times \log \frac{\frac{119k\Omega}{11.7k\Omega}}{1} = 20.15dB && (10)
\end{aligned}
$$

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;

$$
\begin{aligned}
A_v &= \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} && (11)\\
&= \frac{12.17k\Omega}{11.7k\Omega} = 1.04\times && (12)\\
&= 20 \times \log \frac{\frac{12.17k\Omega}{11.7k\Omega}}{1} = 0.34dB && (13)
\end{aligned}
$$

3 Inverting AC Amplifier

3.1 Theory

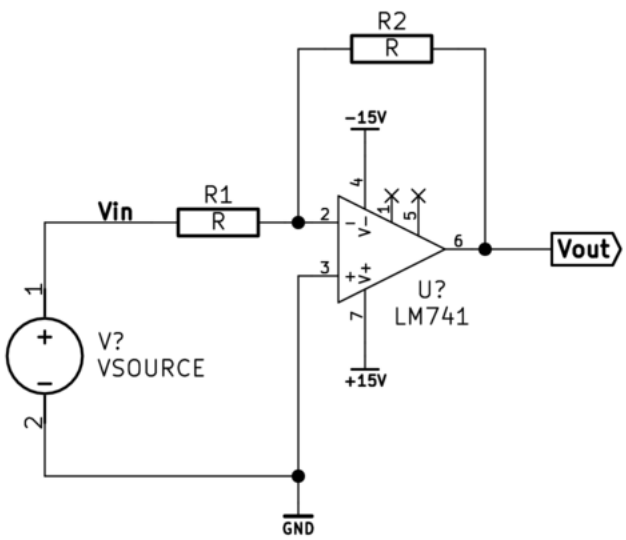

Figure 2: Inverting AC amplifier

The basic topology for an inverting AC amplifier is shown in Figure 2.

$$A_v = 1 + \frac{R_2}{R_1} \tag{14}$$

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

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{15}$$
$$= \frac{100k\Omega}{10k\Omega} = 10\times \tag{16}$$
$$= 20 \times \log\frac{10}{1} = 20dB \tag{17}$$

For $R_2 = 10k\Omega$:

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \tag{18}$$
$$= \frac{10k\Omega}{10k\Omega} = 10\times \tag{19}$$
$$= 20 \times \log\frac{1}{1} = 0dB \tag{20}$$

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

3.2 Measurements

TODO

3.3 Oscilloscope shots

Oscilloscope photos in figure 3 and figure 4 show the amplifier input on channel one the amplifier output on channel two. Channel two volts/div is set to compensate for the high impedance 10:1 probe setting.

4 Non-inverting DC Amplifier

4.1 Theory

The basic topology for an non-inverting DC amplifier is shown in Figure 5. Gain A_v, is set by the attenuation-factor of the circuit in the feedback-loop. A fraction of the output is fed back, causing the op amp to compensate and in effect amplify.

$$A_v = 1 + \frac{R_2}{R_1} \tag{21}$$

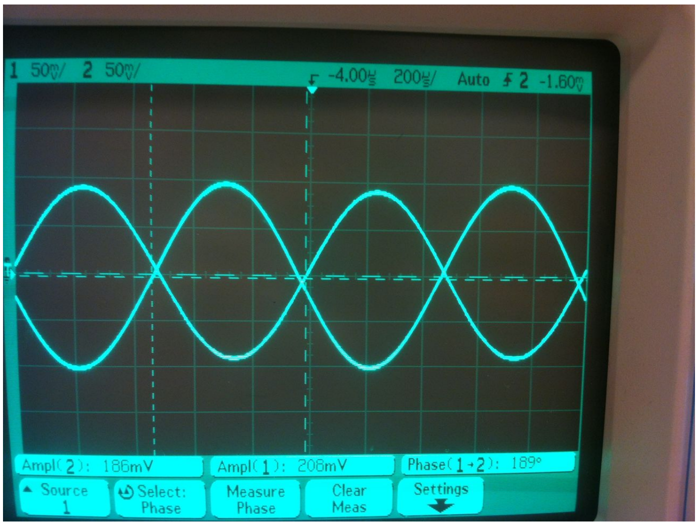

Figure 3: Inverting AC amplifier - 20dB gain

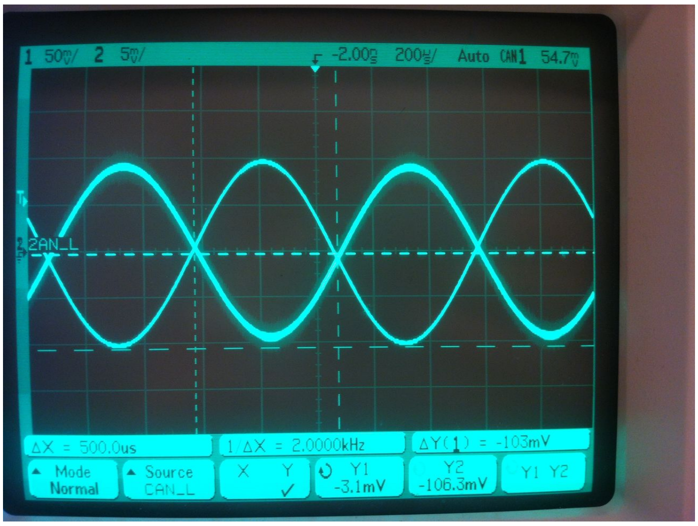

Figure 4: Inverting AC amplifier - unity gain

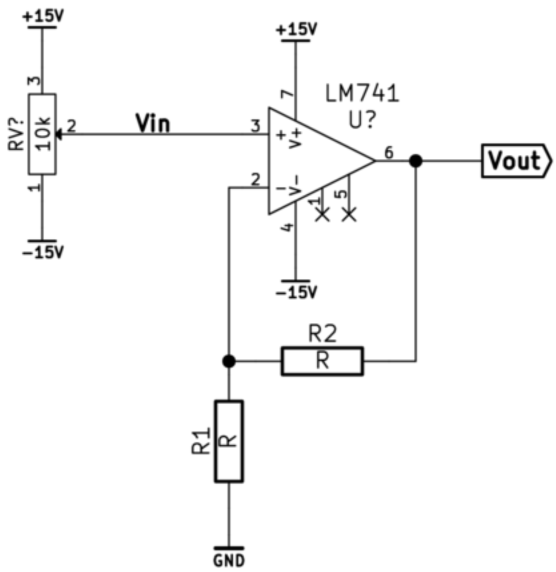

Figure 5: Non-inverting DC amplifier

4.2 Measurements

Measured values for the test setup are shown in Table 3 and Table 4.

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: $R_2 = 100k\Omega$

5 Non-inverting AC Amplifier

5.1 Theory

The lab circuit for the non-inverting AC amplifier is identical to the non-inverting DC amplifier. The basic topology is shown in figure 6.

5.2 Measurements

6 Active full wave rectifier

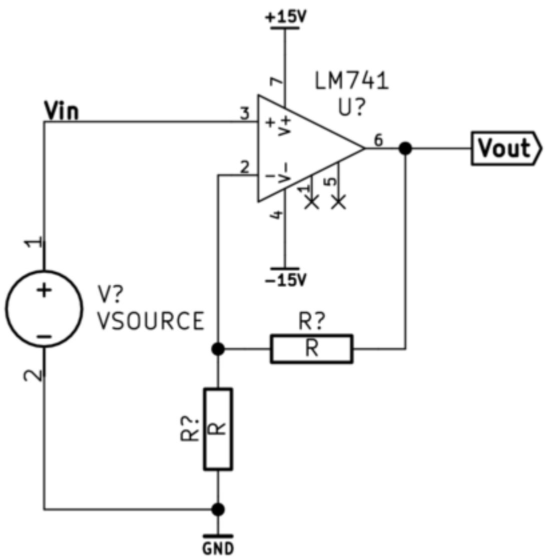

Figure 6: Non-inverting AC amplifier

7 Results

TODO

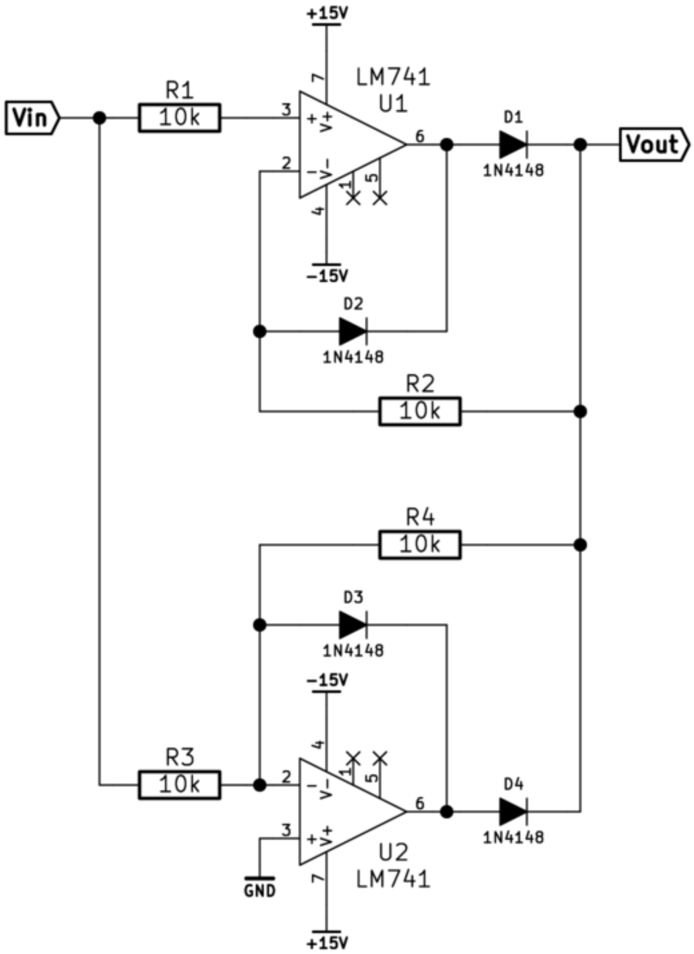

Figure 7: Active full wave rectifier