Control System Circuits with Opamps 27.04.2009

Purpose

- To introduce opamps, transistors and their usage
- To apply a control system with analog circuit elements.

Difference Amplifier

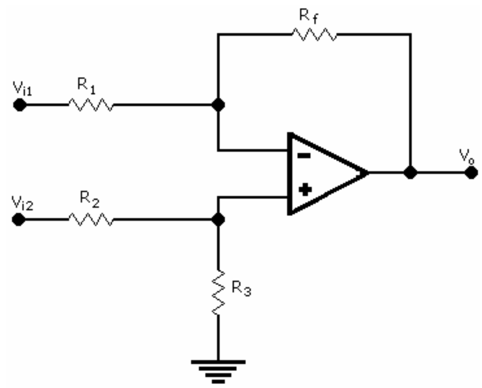


Figure 1 Basic Difference Amplifier Circuit

The difference amplifier shown in the Figure 1 is the complement of the summing amplifier and allows the subtraction of two voltages or, as a special case, the cancellation of a signal common to the two inputs. If

$$R2/R1 = R4/R3 = a \qquad \text{then} \qquad Vout = a\,(V2 - V1)$$

Difference Amplifier Experiment

Components

Qty.	Item
4	10kΩ resistor
2	20k Ω resistor
1	LM 741

Procedure

Build up the circuit shown in the Figure 2, V1 and V2 are the input voltages; adjust V1 as 3V and V2 as 2V, then measure the Vout voltage.

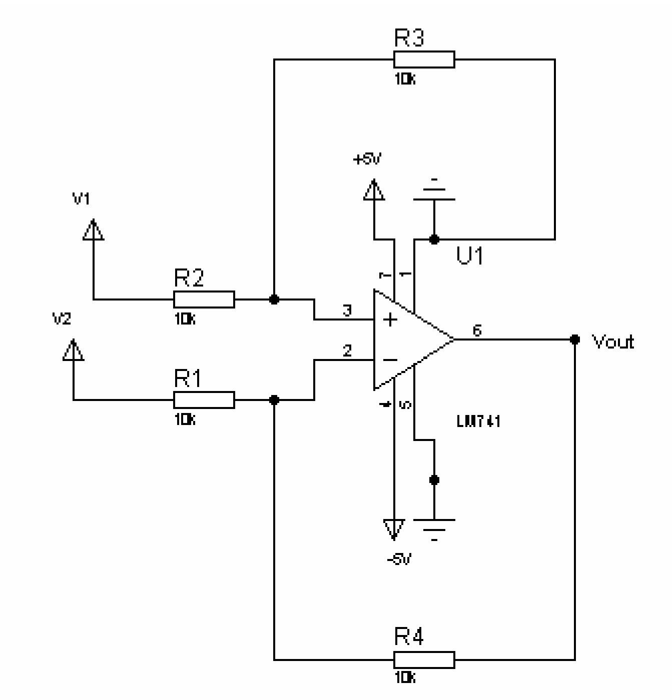


Figure 2 Difference Amplifier Circuit

Now, adjust V1 as 2V and V2 as 3V then measure the output voltage, finally change R4 and R3 with 20K Ohm resistors, then measure the output voltage.

Opamp Integrator

The basic integral action is carried out with using opamp as it is shown in the figure 3.

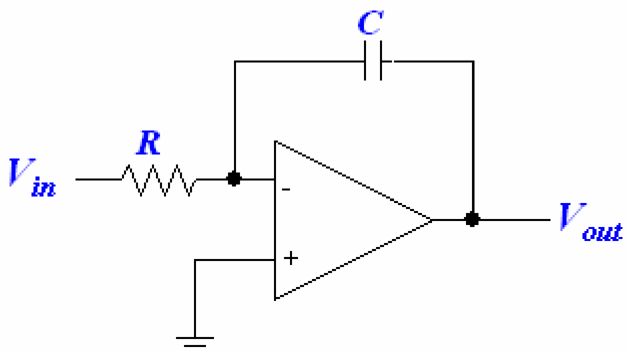


Figure 3 Basic Opamp Integrator

The output signal is a scaled and inverted integral of the input signal:

$$V_{out} = -\frac{1}{RC}\int_0^t V_{in}(\tau)\,d\tau$$

Opamp Integrator Experiment

Components

Qty.	Item
4	5kΩ resistor
2	100uF Capacitor
1	LM 741

Procedure

Build up the circuit shown in the Figure 4, The signal generator shown in the left side is the input voltage, and the oscilloscope shown in the right side is the integral of the input signal. At this circuit R is selected as 5k Ohms and C is selected as 100 micro Farads, so from the formula given in below;

$$V_{out} = -\frac{1}{RC}\int_0^t V_{in}(\tau)d\tau$$

Vout is the integration of the Vin multiplied by 2. If this integration circuit is used in a PID circuit, the Ki gain will be 2.

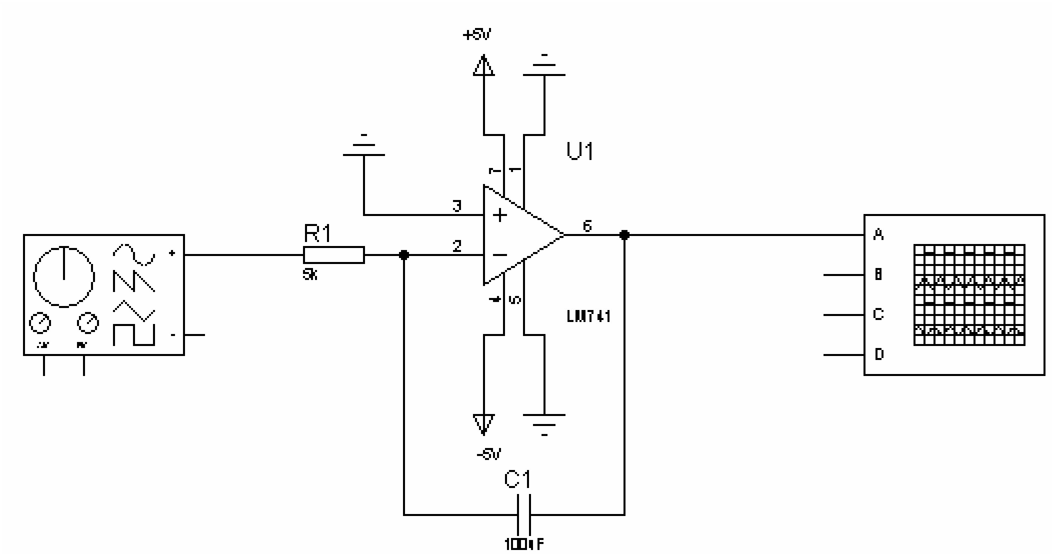


Figure 4 Opamp Integrator Circuit

Now, change R with 10k Ohms and 100k Ohms, compare the outputs of three resistor values with the help of the oscilloscope.

Opamp Differentiator

The basic differential action is carried out with using opamp as it is shown in the figure 5.

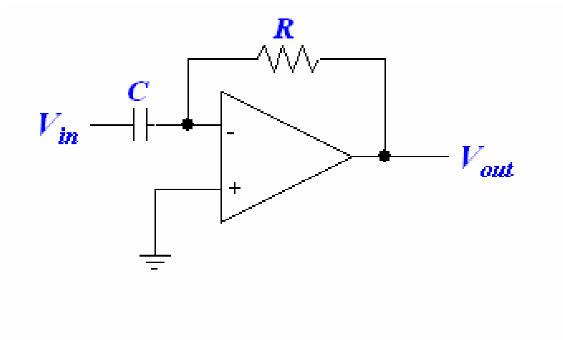


Figure 5 Basic Opamp Differentiator

The differentiator will scale and invert the derivative of the input signal:

$$V_{out} = -RC\frac{dV_{in}}{dt}$$

Opamp Differentiator Experiment

Components

Qty.	Item
4	10kΩ resistor
2	100uF Capacitor
1	LM 741

Procedure

Build up the circuit shown in the Figure 6, The signal generator shown in the left side is the input voltage, and the oscilloscope shown in the right side is the integral of the input signal. At this circuit R is selected as 10k Ohms and C is selected as 100 micro Farads, so from the formula given in below;

$$V_{out} = -RC\frac{dV_{in}}{dt}$$

Vout is the derivative of the Vin multiplied by -1. If this integration circuit is used in a PID circuit, an inverting amplifier should be applied, this amplifier will adjust the Kd gain.

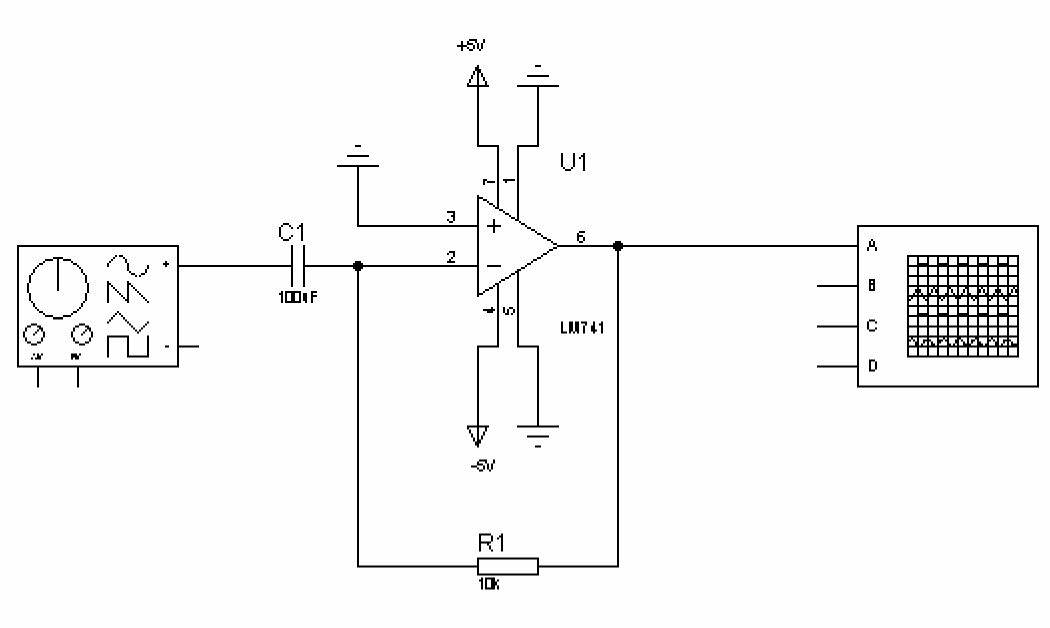


Figure 6 Opamp Differentiator Circuit

Now, change R with 5k Ohms and 100k Ohms, compare the outputs of three resistor values with the help of the oscilloscope.

Opamp Summer

Summer With Gain

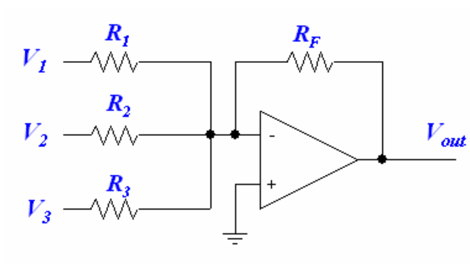


Figure 7 Summer with Gain

The summer circuit shown in Figure 7 will output the inverted sum of the input voltages, after applying gains to the inputs.

$$V_{out} = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

Summer Without Gain

If we do not want the summer to apply any gain to the inputs, simply choose all the resistor values to be the same.

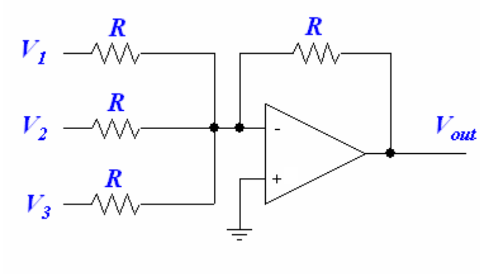


Figure 8 Summer without Gain

This summer circuit shown in the Figure 8 will output the inverted sum of the input voltages.

$$V_{out} = -(V_1 + V_2 + V_3)$$

Summer Without Gain Experiment

Components

Qty.	Item
4	10kΩ resistor
1	LM 741

Procedure

Build up the circuit shown in the Figure 9, The voltages connected to R2, R3 and R4 are the input voltages V1, V2 and V3. The DC voltmeter shown in the right side of the figure is the output voltage. V1, V2 and V3 voltages are adjusted as; 1V, 2V and -1V. The output of the circuit is calculated from the formula;

$$V_{out} = -(V_1 + V_2 + V_3)$$

Vout is the summation of three inputs multiplied by -1, an inverting amplifier should be applied in here. At this circuit, Vout should be -2 Volts.

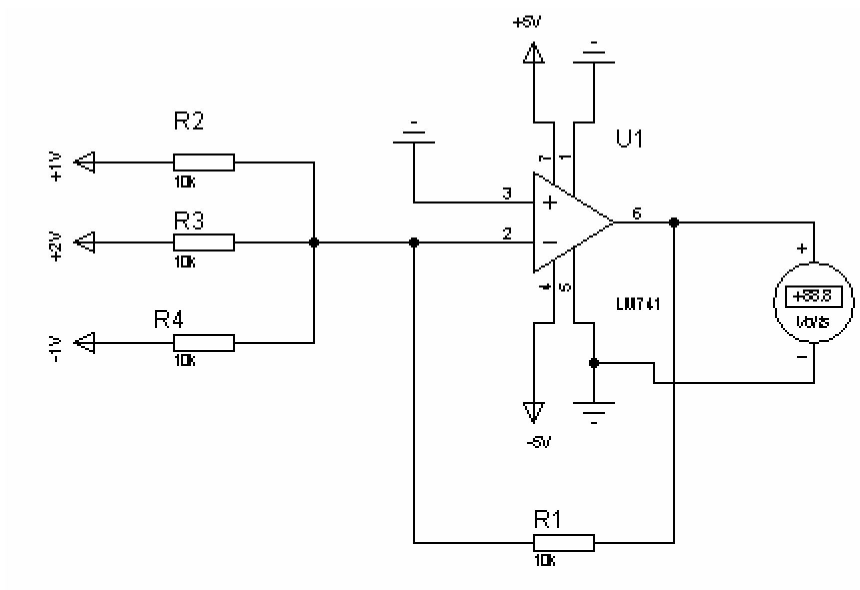


Figure 9 Opamp Differentiator Circuit

Now, change V1, V2 and V3 values with several values and check the circuit. This circuit can be used in summing the proportional, integral and derivative actions of a PID controller. And the Kp, Kd and Ki gains can be also set in this operation.

Inverting Amplifier Experiment

Components

Qty.	Item
2	10kΩ resistor
1	LM 741

Procedure

Build up the circuit shown in the Figure 10, The voltage connected to is the input voltage Vin and the DC voltmeter shown in the right side of the figure is the output voltage. Vin is adjusted as 2V, this is an inverting amplifier, so the output voltage will be -2V.

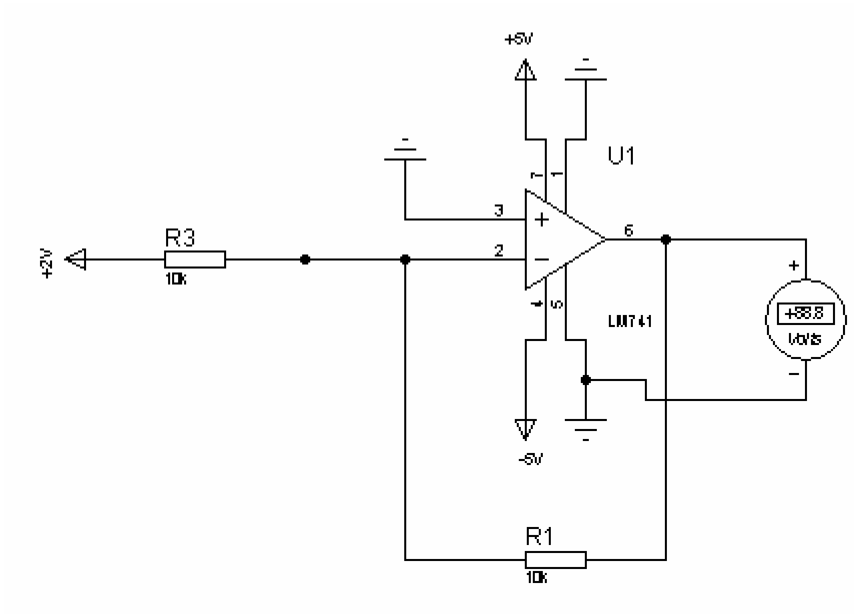


Figure 10 Inverting Amplifier Circuit

Now, change Vin and measure Vout. This circuit should be used in inverting the output signal of summing, differentiator and integrating amplifier circuits.

Analog Motor Drive

In order to drive motors, 2 transistors is needed, one NPN and one PNP transistor. In the circuit shown in the Figure 7, NPN transistor drives motor in the voltages between 0 to 12V and the PNP transistor drives motor in the voltages between -12V to 0.

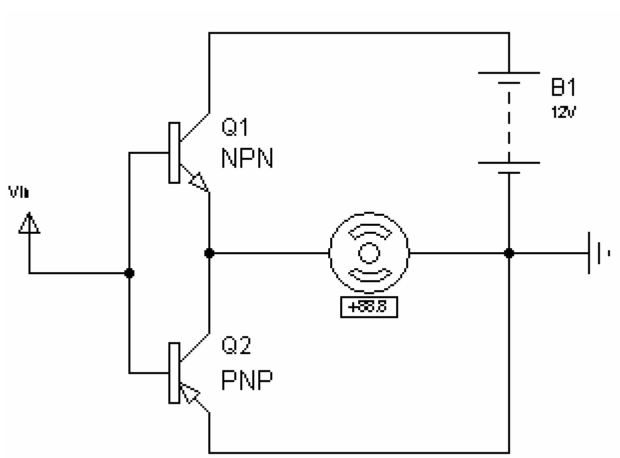


Figure 11 Analog Motor Drive Circuit

The key point in analog motor drive with transistors is the selection of the transistors; the transistors must be power transistors. The figure 11 shows the analog drive of two DC motors.

Bipolar Power Supply

In the PID controller, a bipolar power supply is needed. Two batteries in series are used to make a bipolar power supply. This connection is shown in the figure 12.

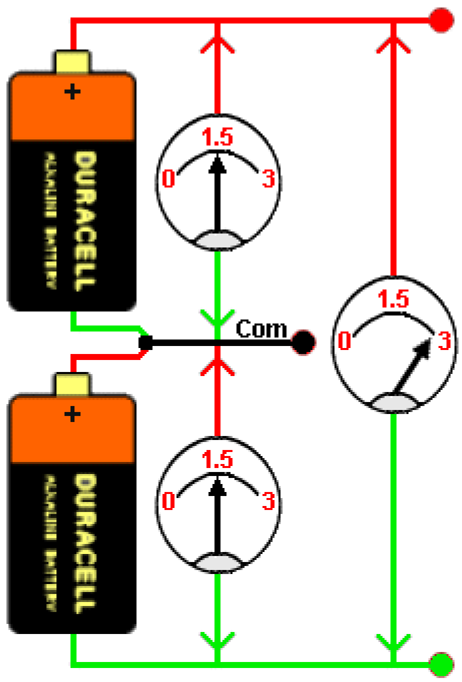


Figure 12 Bipolar Power Supply with Batteries

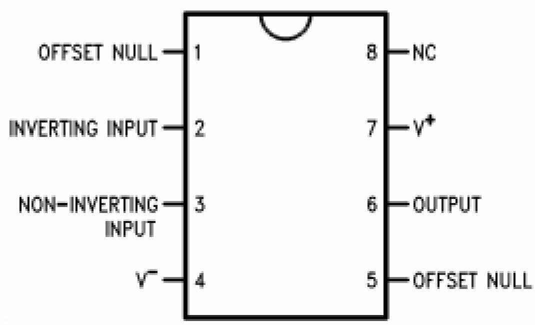
By making the center node the ground reference, we now have +1.5 volts and -1.5 volts. The red part in figure 12 is the +1.5 volts, black part is ground and the green part is the -1.5 volts.

Appendix

National Semiconductor

LM741
Operational Amplifier

Dual-In-Line or S.O. Package



	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous