

ELECTRONICS LABORATORY

PART 6

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OPERATIONAL AMPLIFIERS

6.1 ANALYZING DC OPERATION OF OPERATIONAL AMPLIFIERS

Inverting operation of operational amplifier is given in Figure 6.1. Operational amplifiers are good at DC amplification. Input is applied to the negative pin of the inverting amplifier. There is a 180 degree phase difference between the input and the output. If positive signal is applied to the input, a negative signal is taken from the output with amplitude as much as the gain. Similarly, if negative signal is applied to the input, a positive signal is taken from the output with amplitude as much as the gain.

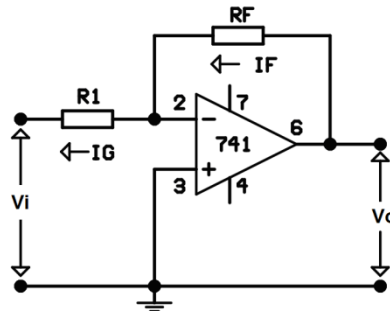


Figure 6.1

The resistance R_1 is the input resistance and the resistance R_F is the feedback resistance in the circuit. The voltage between the negative input (2nd pin) of the operational amplifier and the chassis is zero volts. For that case;

$$V_i = I_i R_1$$

For the output $I_i = I_F$, so,

$$V_o = I_i R_F = I_F R_F$$

In electronic circuits gain always equals to the ratio of the output to the input.

$$A = \frac{V_o}{V_i} = \frac{I_i R_F}{I_i R_1} = \frac{R_F}{R_1} \quad (\mathbf{I_i \text{ is cancelled out}})$$

It must always be remembered that there is a 180 degree phase difference between the inputs and the outputs of the inverting amplifier. For example, if the input voltage is $V_i = 0,5$ and the gain is $A = 20$;

$$V_o = -(V_i A) = -(0,5 \cdot 20) = -10 \text{ Volts.}$$

As another example, if $V_i = -0,2$ Volts;

$$V_o = -(V_i A) = -(-0,2 \cdot 20) = -(-4) = 4 \text{ Volts.}$$

Operational amplifiers operate with both negative input signal and positive input signal. So they are used for AC amplification. If the input and the output signals are visualized by using an oscilloscope with two channels, phase relation is easily observed.

In our experiment set, in the operational amplifier experiments, we have chosen 10K, 50K, and 100K for resistance R_F for simplicity in calculations. 50K resistance is obtained by parallel combination of two 100K resistances since 50K is not a standard value.

6.2 OUTPUT OFFSET VOLTAGE OF OPERATIONAL AMPLIFIERS

When no signal is applied to the inputs of the operational amplifier, the voltage between the input pins must be zero. But practically, due to the difference in the characteristics of the transistors connected to the input pins, there may be a small voltage difference. That difference is multiplied by the gain of the operational amplifier and transferred to the output. That unbalanced situation is undesired in most of the applications. That undesired voltage at the output is called output offset voltage (V_{oo}). The output offset voltage is generally prevented by connecting an adjustable resistor between the negative supply voltage and the offset pins of the operational amplifier (generally the middle pins).

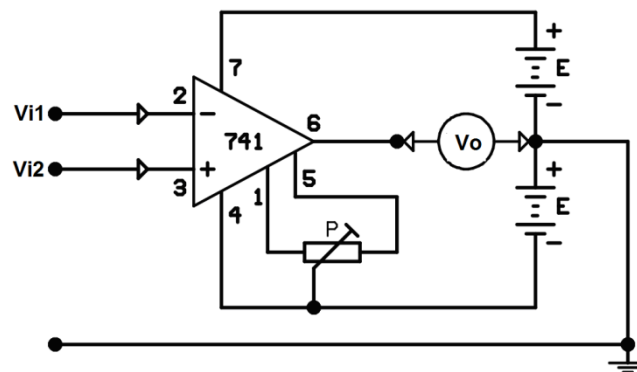


Figure 6.2

The circuit used to adjust the offset voltage is given in Figure 6.2. The potentiometer P is adjusted until zero voltage is obtained at the output while there is not any signal at the input.

The output offset voltage is formed by three parameters.

- 1- Input bias current (**IB**)
- 2- Input offset current (**IOC**)
- 3- Input offset voltage (**ViO**)

Operational amplifiers are fabricated by using transistor technology. So, the input offset voltage is increased by the increasing temperature and the operation of the circuit. That increase is approximately $5\mu\text{Volt}$ for 1°C increase in the temperature.

6.3 THE INPUT BIAS CURRENT OF OPERATIONAL AMPLIFIERS

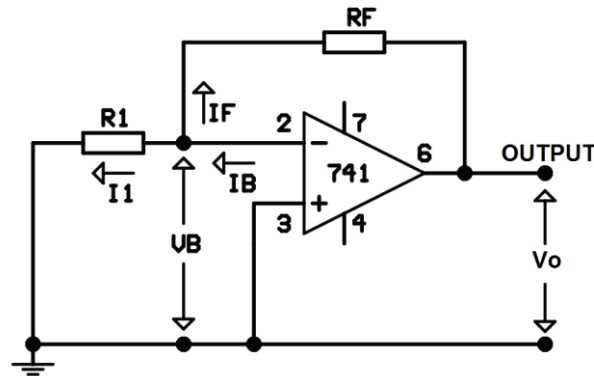


Figure 6.3

The input currents of the operational amplifier are seen in Figure 6.3. The input bias current is the average of the input currents. As we know, input bias current is one of the reasons for output offset voltage (V_{oO}).

Input Bias Current is $I_B = I_1 + I_F$.

$$I_1 = \frac{V_B}{R_1} \quad I_F = \frac{V_B - V_o}{R_F} \quad I_B = \frac{V_B}{R_1} + \frac{V_B - V_o}{R_F}.$$

The current I_1 is assumed to be zero since the voltage V_B is too small. Then the effect of the input bias current to the output offset voltage is calculated by $V_{oO} = I_B \cdot R_F$. The methods given in Figure 6.4 and 6.5 are used to minimize the effect of the input bias current to the output offset voltage.

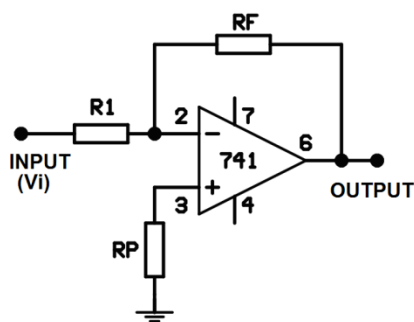


Figure 6.4

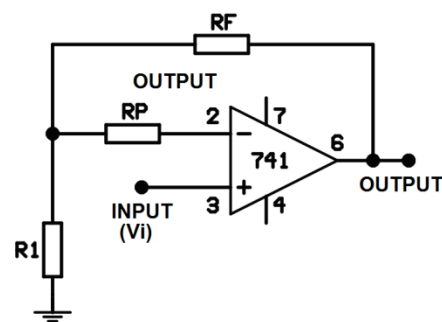


Figure 6.5

The resistance R_1 is the input resistance and the resistance R_F is the feedback resistance in the figure. R_P is the resistance used to minimize the effect of the input bias current to the output offset voltage.

The value of the resistance R_P is;

$$R_P = \frac{R_1 \cdot R_F}{R_1 + R_F}$$

6.4 INPUT OFFSET VOLTAGE OF OPERATIONAL AMPLIFIERS

The input offset current is the difference between the currents when the inputs are grounded and the output offset voltage is set to zero.

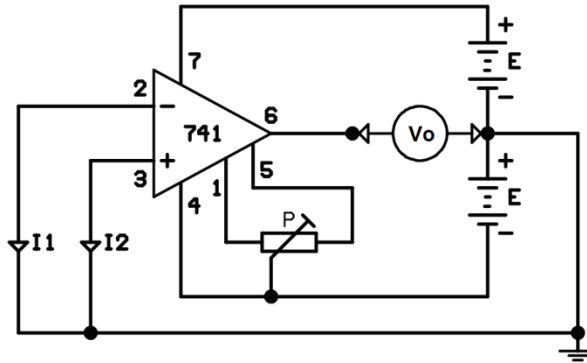


Figure 6.6

Input offset current is:

$$I_{iO} = I_1 - I_2 \text{ or } I_{iO} = I_2 - I_1$$

The input offset current causes the output offset voltage to increase $V_{oO} = R_f \cdot I_{iO}$ times when a signal is applied to the inputs of the operational amplifier.

As we know, input offset voltage is the voltage between the inputs when no signal is applied to the inputs.

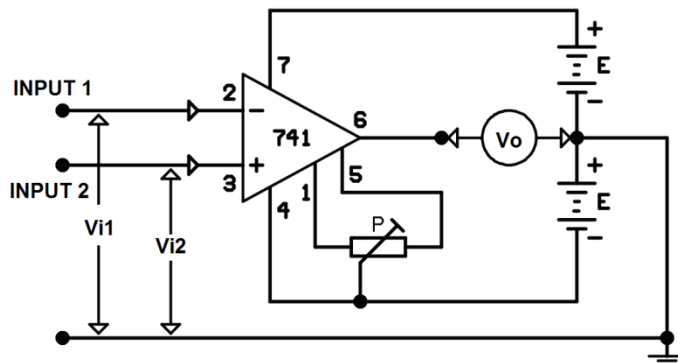


Figure 6.7

Input offset voltage is;

$$V_{iO} = V_{i1} - V_{i2} \text{ or } V_{iO} = V_{i2} - V_{i1}$$

Input offset voltage causes the output offset voltage to increase $V_{oO} = V_{iO} \cdot A$ times. (**A**) is the gain of the operational amplifier.