Unit 41 Negative feedback

- If a fraction, β, of the output of an amplifier is fed back and subtracted from the input to the amplifier and if the open loop gain of the amplifier is large, the closed loop gain of the amplifier is given by:

$$A_V = \frac{1}{\beta} = \frac{1}{\text{Feedback fraction}}$$

The general configuration of a negative feedback amplifier is shown in Figure 41.1.

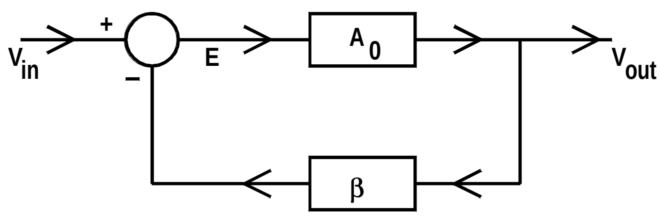

Figure 41.1: Block diagram of negative feedback loop.

The input signal is fed to the +input of a comparator, represented by the circle in the diagram, and the feedback signal is fed to the −input of the comparator. The output of the comparator is the difference of these two signals and is called the error signal, E. (This comparator is part of the op-amp but may be a separate block in other control loops.)

The high gain amplifier, the op-amp in our circuit, amplifies this error signal by an amount A_0 where A_0 is the open loop gain of the amplifier or op-amp. This gives an output:

$$V_{out} = E \times A_0$$

We then take a fraction of this output voltage, β, for instance by using a potential divider, and we feed back a signal $\beta \times V_{out}$ which is subtracted at the −input to the comparator. This then gives the fundamental equation for the negative feedback amplifier:

$$V_{out} = E \times A_0 = (V_{in} - \beta V_{out}) \times A_0$$

which simplifies to give:

$$A_V = \frac{V_{out}}{V_{in}} = \frac{A_0}{1 + A_0\beta} = \frac{1}{\frac{1}{A_0} + \beta}$$

where A_V is the closed loop voltage gain. If the open loop gain is large ($A_0 = 10^5$ for an op-amp) then $\frac{1}{A_0}$ is very small compared to β and the gain of the negative feed back amplifier is given by:

$$A_V \approx \frac{1}{\beta} = \frac{1}{\text{Feedback fraction}}$$

This allows the gain of the amplifier, A_V, to be determined to a high degree of accuracy by passive components such as resistors.

Negative feedback systems are used in many areas of modern industry as well as in electronic circuits. The applications may in general be divided into two groups:

Control systems. A typical example of a control system is a chemical process where a uniform product is to be delivered even though the load or process throughput may vary. Figure 41.2 shows the general configuration of such a control system.

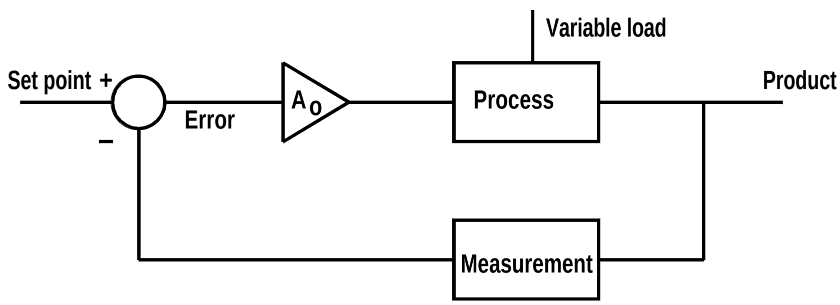

Figure 41.2: Generalized control loop.

The characteristic feature of a control loop is that the set point is fixed but that the load or throughput may vary. The loop maintains the product operating point (temperature, pressure etc.) constant. The table shows, on each horizontal row, some typical applications of negative feedback control systems and some of the associated variables within the control loop.

Application	Set point	Measurement	Control method	Load
DC power supply	Voltage	Voltmeter	Transistor	Current drawn
Hot water heater	Temperature	Thermometer	Heater	Water flow
Traffic	Speed limit	Speedometer	Accelerator	Road incline
Economy	Growth	Inflation	Interest rates	Rest of world

In general, negative feedback control systems act in such a way as to minimize the error, in spite of external factors, so as to obtain a uniform product and a stable system.

In contrast, a good example of the instabilities associated with a positive feedback system are the Black Mondays associated with the effects of the computerized share dealing programs used by dealers on the stock exchange. These programs introduce positive feedback by selling on a falling market and buying on a rising market.

Servo systems comprise the second main group of negative feedback applications. These systems are illustrated in Figure 41.3.

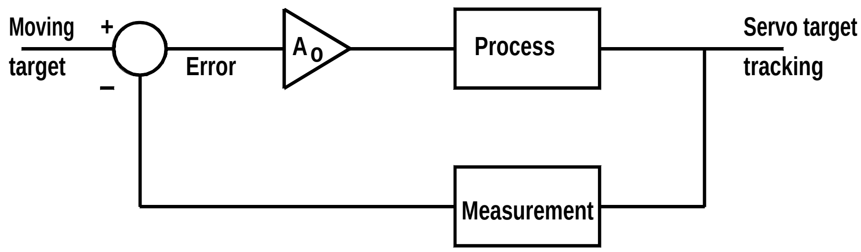

Figure 41.3: Generalized servo loop.

In this group the target or set point varies and the servo loop acts to force the process to follow the varying target. The load in general is constant or nearly so.

A good example of a servo system would be an automatic guided vehicle which follows a white, painted track around a factory floor as it delivers parts to the various machines.

Another example would be a national economy, viewed from the point of view of a government coming up for re-election, in which the apparent growth rate is manipulated by controlling interest rates at the expense of inflation.

41.1 Example

41.1 Analyze the noninverting amplifier shown in Figure 41.4 in terms of a negative feedback system.

In this case the fraction of the output that is fed back is determined by the potential divider on the output voltage.

$$\text{The feedback fraction} \quad \beta = \frac{R_2}{R_1 + R_2}$$

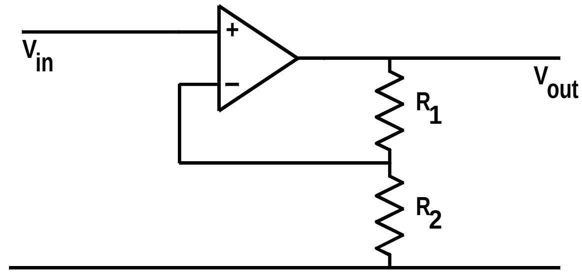

Figure 41.4: Example 41.1.

Therefore the gain of the amplifier is:

$$\begin{aligned} A_V &= \frac{1}{\beta} \\ &= \frac{1}{\frac{R_2}{R_1+R_2}} \\ &= \frac{R_1+R_2}{R_2} \\ &= 1+\frac{R_1}{R_2} \end{aligned}$$

which is the same result which we obtained in Unit 40 using a different method.

41.2 Problems

41.1 List four different negative feedback systems with which you are familiar. In each example, identify the controlled variable, the measuring element and the control element.

41.2 The op-amp used in the amplifier shown in Figure 41.5 has an open loop gain, $A_0 = 10^5$. Use the basic feedback equation:

$$V_{out} = A_0 \left(V_{in} - \beta V_{out}\right)$$

to determine the exact voltages at each of the three signal terminals of the op-amp when the input signal, $V_{in} = 0.10\,\text{V}$.

What is the output voltage calculated, using the formula for the gain, $A_V = 1 + \frac{R_1}{R_2}$, derived in Unit 40? Is there any significant difference between the two answers?

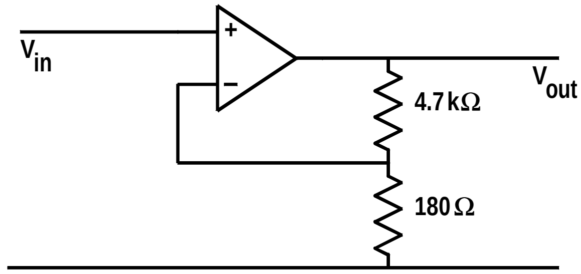

Figure 41.5: Problem 41.2.

41.3 If the op-amp used in Problem 41.2 is replaced by a low specification op-amp having an open loop gain, $A_0 = 5 \times 10^3$, calculate the new output voltage for the same input voltage of 0.10 V. Does the use of a low gain op-amp cause a significant change in the output voltage?

41.4 Design a noninverting amplifier which has a gain of + 75. Calculate suitable component values and draw the full circuit including the power supply connections to the op-amp. What is the value of the feedback fraction for the amplifier?

41.5 A negative feedback controller has a response curve as shown in Figure 41.6 where the output of the controller is plotted against the measurement expressed as a percentage of the range. If the error is zero when the system is operating at 50% of load, calculate the error for 10% of load and for 60% of load.

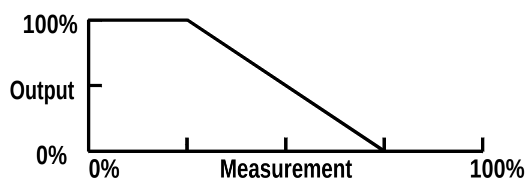

Figure 41.6: Problem 41.5.