Unit 46 Functional amplifiers

If the I–V characteristic for a device is described by $I = f(V)$ then:

- putting the device in place of the input resistor of an inverting amplifier gives the forward function:

$$V_{out} = -R \times f\left(V_{in}\right)$$

- putting the device in place of the feedback resistor of an inverting amplifier gives the inverse function:

$$V_{out} = -f^{-1}\left(\frac{V_{in}}{R}\right)$$

Suppose we have a two terminal device or component which has an I–V characteristic which is described by a monotonic function $I = f(V)$.

The device can be used in place of the input resistor in an inverting amplifier as shown in Figure 46.1.

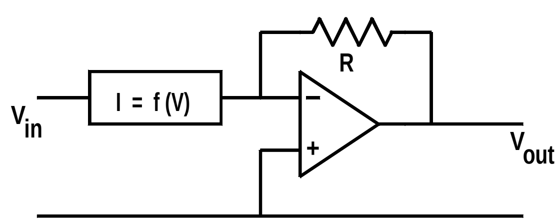

Figure 46.1: The forward function.

Then, from Unit 39, we have the relationship that the current in the input device is equal to the current in the feedback device, $I_{in} = I_f$, and therefore:

$$V_{out} = -R \times I_f = -R \times I_{in} = -R \times f(V_{in})$$

so that we can now generate an arbitrary function of an input voltage if we have available a device with the appropriate current-voltage characteristic.

If the device is used in the feedback path, then the inverse function is generated. This circuit is shown in Figure 46.2.

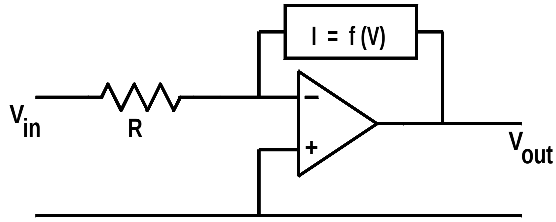

Figure 46.2: The inverse function.

Again the currents in the input and feedback paths are equal so:

$$\frac{V_{in}}{R} = I_{in} = I_f = f\left(-V_{out}\right)$$

which, if f^{-1} represents the inverse function of f, immediately gives:

$$V_{out} = -f^{-1}\left(\frac{V_{in}}{R}\right)$$

46.1 Example

46.1 Derive an expression for the output voltage from the circuit shown in Figure 46.3.

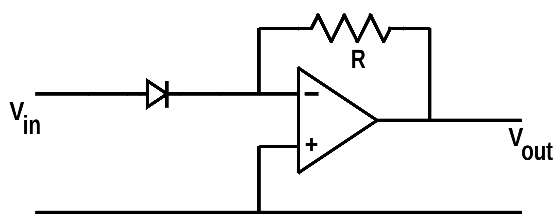

Figure 46.3: Example 46.1. Antilog function amplifier.

In this case we have a diode for which the approximate I–V characteristic in forward bias is:

$$I = I_0 \exp\left(\frac{V}{25\,\mathrm{mV}}\right)$$

Since the device is in the input path we use:

$$V_{out} = -R \times f(V_{in}) = -R \times I_0 \exp\left(\frac{V_{in}}{25\,\mathrm{mV}}\right)$$

which, if we combine the constants into k, gives:

$$V_{out} = -k\log^{-1}\left(V_{in}\right) \quad \text{or} \quad -k\ \mathrm{antilog}(V_{in})$$

The accuracy of this antilog function depends on the accuracy of the exponential function for the diode. Special diodes, called logging diodes, are available which obey the exponential function over about seven decades but it is found that a diode connected transistor in which the base is connected to the collector gives a very good log response.

46.2 Problems

46.1 Describe the behaviour of a functional amplifier which uses a device having a nonmonotonic function characteristic in the input side of the functional amplifier.

46.2 Give an approximately scaled sketch of the output voltage from the circuit in Figure 46.4 as a function of the input voltage for the range $-1\,\mathrm{V} \leq V_{in} \leq +1\,\mathrm{V}$. Suggest a reason for including the $470\,\Omega$ resistor in series with the input.

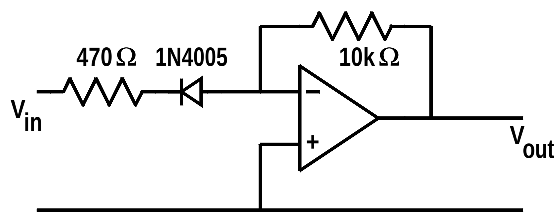

Figure 46.4: Problem 46.2. Antilog function amplifier.

46.3 Give an approximately scaled sketch of the output voltage from the circuit in Figure 46.5 as a function of the input voltage for the range $0\,\mathrm{V} \geq V_{in} \geq +5\,\mathrm{V}$.

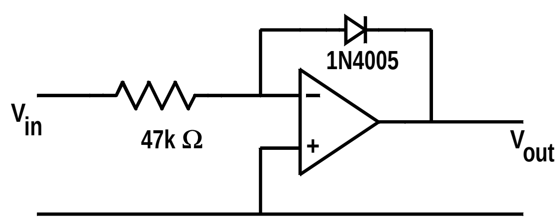

Figure 46.5: Problem 46.3. Log function amplifier.

46.4 Calculate the output as a function of the input for the circuit shown in Figure 46.6. The transistor in this circuit is connected as a transdiode and acts as a high accuracy log response diode. Show that the range of the input voltage is compressed to a small range of output voltage.

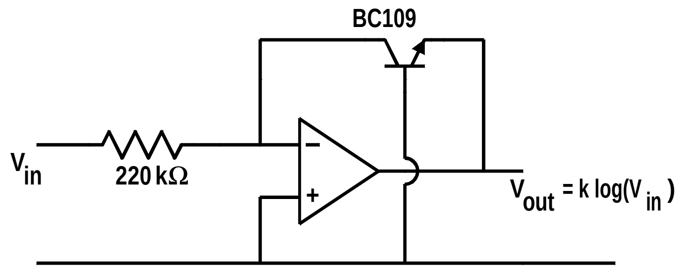

Figure 46.6: Problem 46.4. Log function using transdiode.

46.5 Use the relationship $V_{out} = -f^{-1}\left(\frac{V_{in}}{R}\right)$ to show that the output from the circuit in Figure 46.7 is given by $V_{out} = -\frac{1}{RC}\int V_{in}dt$.
Calculate the amplitude of the output voltage waveform if the input sinusoidal signal is at a frequency of 800 Hz and has an amplitude of 2 V. Note that for a capacitor $I = C\frac{dV}{dt}$.

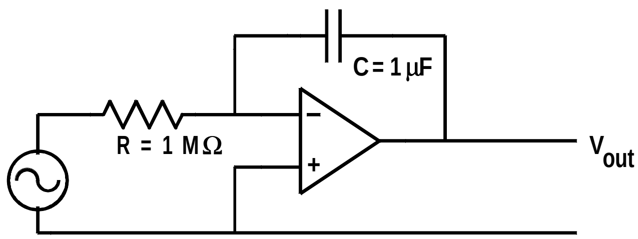

Figure 46.7: Problem 46.5.

46.6 What is the characteristic I–V function for an inductor? A sinusoidal signal of 1 kHz and amplitude 2 V is applied at the input to the circuit in Figure 46.8. Derive the function which describes the output voltage waveform and calculate the amplitude of the output voltage.

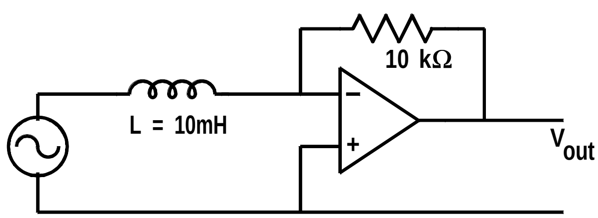

Figure 46.8: Problem 46.6.

46.7 The input signal to an amplifier is applied to the X input of an oscilloscope operating in XY mode and the amplifier output is applied to the oscilloscope Y input. Show that this configuration causes the response curves for Problems 46.2 to 46.6 to be displayed on the screen.