Unit 7 Power ratios and decibels

- The ratio of the power output from a circuit to the power input to a circuit is quoted in decibels or dB.

$$\text{Power ratio} \quad = 10\log\left(\frac{P_{out}}{P_{in}}\right) = 20\log\left(\frac{V_{out}}{V_{in}}\right)$$

The ear and the eye do not have a linear response to sound intensity or brightness. The physiological response is logarithmic and it is found that equal increments in the logarithm of the stimulus give equal increments in sensation. Electrical quantities are therefore often measured on logarithmic scales so as to facilitate calculation of the perceived change of loudness or brightness.

There is also another advantage which is that a very useful compression of scales is obtained when we take the logarithm of the ratio of two quantities. The unit used is the *bel*, named after Alexander Graham Bell. To spread the range somewhat, we can use the *decibel* which is usually abbreviated to dB.

The power dissipated in a circuit is proportional to the square of the voltage. The logarithm of a squared term is 2 times the logarithm of the term; hence the change from 10 to 20 when we go from power ratio to voltage ratio. It is usually assumed that the resistance which comes into the equation $P = \frac{V^2}{R}$ is the same value for the input and the output side but this is not always the case.

In carrying out calculations using the dB scales you must always distinguish carefully between power ratios and voltage ratios and use a multiplier of 10 or 20 as appropriate.

Also, since the dB is essentially a ratio, it is important to specify the reference level so as to facilitate subsequent recovery of the absolute value of the quantity. (See Problem 7.4.)

7.1 Examples

7.1 Calculate the ratio of the output to input for the potentiometer circuit in Figure 7.1.

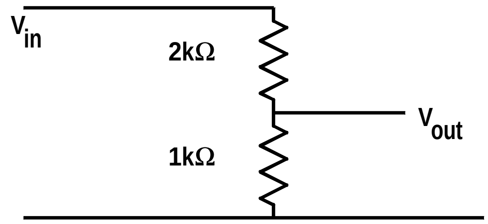

Figure 7.1: Example 7.1.

$$\begin{aligned}
\text{Attenuation} &= 20\log\left(\frac{1\,\text{k}\Omega}{1\,\text{k}\Omega + 2\,\text{k}\Omega}\right) \\
&= -20 \times 0.477 \\
&= -9.54\,\text{dB}
\end{aligned}$$

(Note that a reduction of signal or an attenuation will always give a negative quantity when quoted in dB. We will see later that an amplifier gives a gain which is a positive quantity when quoted in dB.)

7.2 Calculate the value of resistor R in the circuit in Figure 7.2, which will give an attenuation of -35 dB between the input and output signals.

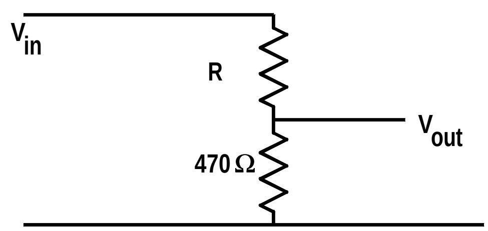

Figure 7.2: Example 7.2.

$$\begin{aligned}
\text{We have} \quad -35 &= 20\log\left(\frac{V_{out}}{V_{in}}\right) \\
&= 20\log\left(\frac{470\,\Omega}{R + 470\,\Omega}\right) \\
\text{Therefore} \quad \frac{470\,\Omega}{R + 470\,\Omega} &= 10^{\left(\frac{-35}{20}\right)} \\
&= 0.01778 \\
\text{giving} \quad 470 &= 470 \times 0.01778 + R \times 0.01778 \\
\text{and} \quad R &= 25.96\,\text{k}\Omega
\end{aligned}$$

7.2 Problems

7.1 Calculate the attenuation in dB of the potential divider in Figure 7.3.

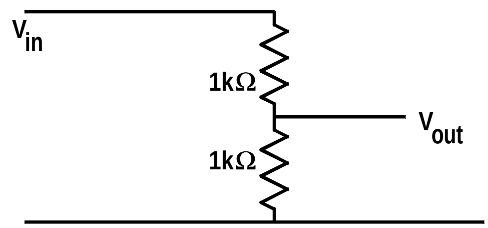

Figure 7.3: Problem 7.1.

7.2 Calculate the values for the resistors in a potential divider which has an attenuation of -50 dB and where the total resistance in the divider is 25 kΩ.

7.3 Calculate the output voltage from the circuit in Figure 7.4 for $V_{in} = 3\,\mathrm{V}$. Calculate the attenuation of this circuit. (Suggested approach: Find the voltage at point X and then use this voltage to find the voltage at the output.)

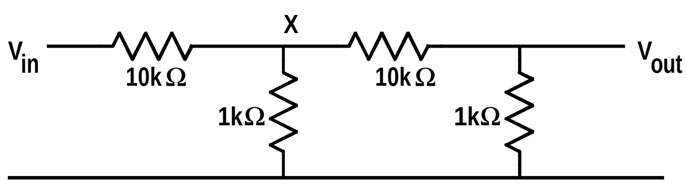

Figure 7.4: Problem 7.3.

7.4 The threshold of hearing is, by convention, taken to be at a sound intensity of $10^{-12}\,\mathrm{Wm}^{-2}$ and this is assigned the level on the dB scale of 0 dB. Calculate the sound intensity for a conversation for which the sound intensity level is 60 dB and for a position near the end of a runway with an aircraft taking off for which the sound intensity level is 120 dB.