Overview

In this unit your students should:

- learn about the transfer characteristics of an op-amp
- find out about the behaviour of silicon and zener diodes
- be able to analyse the behaviour of op-amp circuits
- know about ways of converting op-amp outputs into signals for logic gates

This should not require more than 6 hours of class time.

Hour	Suggested Activity
1	Launch them straight into the **Op-amp transfer characteristic** practical. As they finish, get them to answer question 2 of the **Op-amps and Diodes** exercises. Introduce the silicon diode as a device which only lets charge flow one way through it. Show how it can be used with a voltage divider to convert the output of an op-amp into a signal which is high (1) or low (0), compatible with a logic gate. Ask them to answer question 1 on page 33 of the text book before the next session.
2	Students should do the **Transfer characteristic for a silicon diode** practical in this session. As students finish, they could answer questions 3 and 4 of the **Op-amps and Diodes** exercises. Ask them to answer question 2 on page 34 of the text book before the next session.
3	Launch them straight into the **Conversion to digital** practical. As students finish, they could answer question 5 of the **Op-amps and Diodes** exercises. Discuss their conclusions to the practical. Ask them to answer question 3 on page 34 of the text book before the next session.
4	Students could spend this session on the **Light sensor** practical. Step 7 is an extension activity which only a minority of students should attempt. Ask them to answer question 6 of the **Op-amps and Diodes** exercises before the next session.
5	Launch them straight into the **Transfer characteristic of a zener diode** practical. As students finish, they could answer question 7 of the **Op-amps and Diodes** exercises. Ask them to answer question 4 on page 34 of the text book before the next session.
6	Students who have managed to completely answer all four questions on page 34 should do the **Loading an op-amp** practical. Students who need to have another go at answering any of the exercises or questions could use this session for that, while their peers get on with the practical. Ask them to study **2.3** from the text book before the next session.

Model Answers

1 (a) C is at +13 V when B has a higher voltage than A, otherwise C is at -13 V.

(b) $R_{total} = 22 + 68 = 90$ kΩ

$I = V/R = 5 / 90\times10^3 = 5.6\times10^{-5}$ A

$V_B = IR = 5.6\times10^{-5} \times 68\times10^3 = 3.8$ V

(c) Increasing the temperature of the thermistor reduces its resistance, raising the voltage at A. Once the voltage at A is above +3.8 V, the op-amp output C saturates at -13 V. The diode is now reverse biased, so there is no current in the resistors at the output, so they hold the output at 0 V.

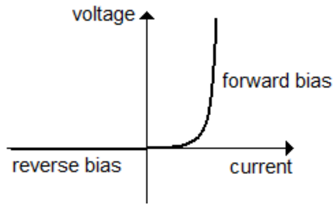
(b) $I = 10 \times 10\ \mu A = 100\ \mu A$

$R_{total} = V/I = (13 - 0.7) / 100\times10^{-6} = 1.2\times10^5\ \Omega$ or 120 kΩ

$R_{bottom} = V/I = 4 / 100 \times10^{-6} = 4\times10^4\ \Omega$ or 40 kΩ

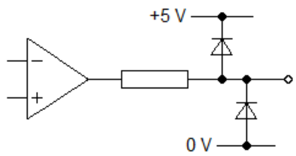
$R_{top} = 120 - 40 = 80$ kΩ

2 (a)



(b) The current in a forward biased diode rises rapidly as the voltage goes above 0.7 V, so its resistance drops rapidly. In reverse bias there is no current, so the resistance is infinite.

(c)



3 (a) $R = V/I = (26 - 2) / 10\times10^{-3} = 2.4\times10^3\ \Omega$ or 2.4 kΩ

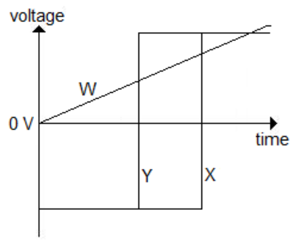
(b) $R_{total} = 20 + 10 + 30 = 60$ kΩ

$I = V/R = 15 / 60\times10^3 = 2.5\times10^{-4}$ A

$V_Z = IR = 2.5\times10^{-4} \times 30\times10^3 = 7.5$ V

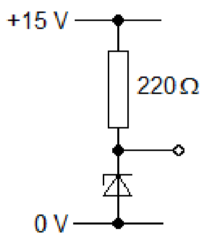
$V_U = IR = 2.5\times10^{-4} \times (30\times10^3 + 10\times10^3) = 10$ V

(c)

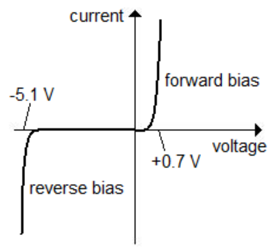


(d) When W is between 7.5 V and 10 V, Y is at +13 V and X is at -13 V, the LED is forward biased and the current in it allows it to glow. For other voltages at W, X and Y have the same voltage so there is no current in the LED.

4 (a)



(b)



(c) $I = V/R = (15 - 5.1) / 220 = 4.5\times10^{-2}$ A

$P = VI = 5.1 \times 4.5\times10^{-2} = 0.23$ W

230 mW is less than 500 mW

(d) As the top rail moves up and down in voltage, the voltage across the zener diode hardly changes. For a voltage divider, the output is always a fixed fraction of the supply voltage, so variations in the supply voltage result in changes at the output.