Answers

1.1

1 a The threshold voltage of the transistor is the minimum pd needed to form the conducting channel between the drain and the source.

b As the drain source pd increases from zero, the drain–source current increases from zero and gradually becomes constant. This constant current, called the saturation current, depends on the gate–source pd.

2 a The circuit diagram is the same as in Topic 1.1 Figure 3 but with a motor replacing the relay coil and a potential divider added to supply a variable pd between the gate and the source.

b i The drain–source current passes through the motor. Reducing the gate–source pd by adjusting the potential divider will reduce the drain–source current and hence reduce the motor speed.

ii An induced emf is created when the motor is switched on or off. Without the diode, such an induced emf would destroy the MOSFET. The reverse-biased diode is necessary to short-circuit the motor and thereby prevent an induced emf from damaging the MOSFET.

1.2

1 a See Topic 1.2 Figure 2.

b The minimum pd at which a reverse-biased zener diode breaks down.

2 a Resistor 7.3 V, 18 mA; zener diode 4.7 V, 13 mA

b The pd across *R* would still be 7.3 V, but the current through it would be $\frac{7.3\,\text{V}}{2.0\,\text{k}\Omega} = 3.7\,\text{mA}$. The radio needs a current of 5.0 mA, so it would not operate because the maximum current through it would be 3.7 mA.

c The series resistor should have a resistance between 100 and 120 Ω. A resistance of 120 Ω would mean the lamp lights at normal brightness and there would be 5 mA in the zener diode.

1.3

1 a The current through it when it is reverse-biased and the incident light intensity on it is zero.

b The circuit diagram should be as in Topic 1.3 Figure 3 with a voltmeter connected between the output terminals.

c In darkness, the saturation current is zero so the pd across the resistor is zero and the output pd is 6 V (= the supply pd). As the light intensity increases, the saturation current increases so the resistor pd increases. If the light intensity continues to increase, the output voltage decreases to zero when the saturation current is 2.0 mA.

2 a 0.5 mA

b 5.25 V

1.4

1 **a** The Hall voltage is directly proportional to the current and to the magnetic flux density. The current needs to be constant so that the Hall voltage depends only on the magnetic flux density.

b 57 ms

2 **a** An attitude sensor monitors or measures its orientation relative to an external frame of reference.

b **i** 58 μT

ii ±0.1 μT

2.1

1 An analogue signal can take any value between two limits. A digital signal only has two values.

2 **a** Random variations called noise occur in communication systems. The signal cannot be detected if noise is excessive. Noise can be eliminated from digital signals, but not from analogue signals.

b A regenerator amplifier is a digital circuit that removes the noise from a digital signal.

3 **a** **i** 1111 1111

ii 1000 1000

b 0.025 V

4 **a** An 8-bit signal has 256 equally spaced values from zero to its maximum value where all the bits are 1. A 4-bit signal has only 16 equally spaced values. The reconstructed analogue signal from 4-bit bytes would have much larger step changes than if 8-bit bytes were used.

b The digital signal would not reconstruct the original analogue signal. The higher frequencies of the analogue signal would be missing.

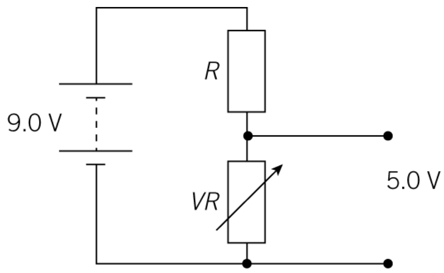
2.2

1 **a** 20 kΩ

b The thermistor resistance decreases, so the share of the battery pd across the thermistor decreases. Therefore the output pd increases.

2 The resistance of the thermistor increases, so the resistance of the variable resistor must be increased to keep the ratio of its resistance to that of the thermistor constant. The share of the battery voltage across the variable resistor and across the thermistor is then unchanged.

3



When *VR* is set at zero resistance, the output pd is zero. When *VR* is set at 100 kΩ, to obtain an output pd of 5.0 V, the pd across *R* must be 4.0 V (= 9.0 V − 5.0 V). Therefore the resistance of *R* must be equal to 100 kΩ multiplied by the pd across *R* divided by the pd across *VR*, which gives 80 kΩ $\left(= \dfrac{100\,\text{k}\Omega \times 4.0\,\text{V}}{5.0\,\text{V}}\right)$ for the resistance of *R*.

4 **a** 2.0 V

b 8.0 V

3.1

1 16 μH

2 The capacitance of the capacitor would need to be reduced so that the resonant frequency of the circuit is increased so it is equal to the frequency of a radio signal of higher frequency.

3 **a** **The bandwidth** of the circuit is the difference between the frequencies either side of the resonant frequency at $\sqrt{2}$ of the maximum pd.

b 91.8 MHz and 92.2 MHz

4 **a** The graph should be similar to p31 Figure 2 but sharper with its resonant frequency at 500 kHz and a bandwidth of 100 kHz.

b The curve would be taller and its maximum would be at a lower frequency.

3.2

1 **a** When the input pd applied to an operational amplifier is increased from zero, the magnitude of the output pd increases from zero and reaches a maximum value determined by the limits of the power supply. The output pd is then said to be saturated and does not change if the input pd is increased further.

b The output pd of an op-amp saturates if the pd between its two input terminals exceeds about 150 μV. If one of the two inputs of an op-amp is earthed and a potential is applied to the other input without causing the output pd to saturate, the potential at this other input must be less than 150 μV, and the input terminal is said to be at virtual earth.

2 **a** The LED emits light, so the output must be at positive saturation. Therefore, $V_B > V_A$.

b 6.4 kΩ

c The pd across the diode would be unchanged, so the resistor pd would be unchanged. Therefore, a resistor of less resistance would let too much current pass through the diode, and the diode would overheat and burn out.

3 **a** The pd at P is greater than that at Q.

b Higher. The temperature must be increased, so the resistance of the thermistor decreases, and the pd at P decreases until it is below the pd at Q.

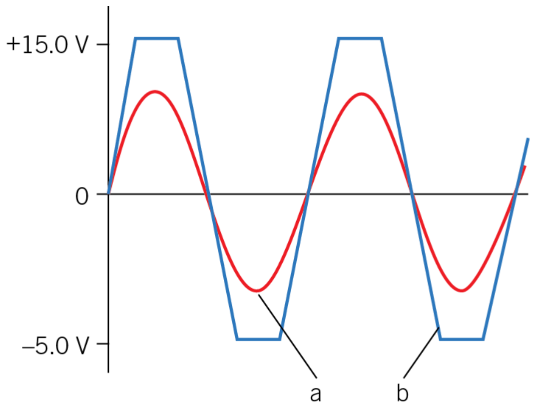
4 The circuit should be as shown in Topic 3.2 Figure 3 with an LDR replacing the resistor in series with the thermistor and the resistor *R* replacing the thermistor. By adjusting the variable resistor, the buzzer will switch on at the required light level.

3.3

1 **a** See Topic 3.3 Figure 2.

b 250 kΩ

2 **a & b**



3 **a** Negative feedback is where a fraction of the output pd is added to the input pd to reduce the output pd.

b The waveform would become a square wave with positive saturation throughout each positive half-cycle of the input pd and with negative saturation throughout each negative half-cycle.

4 **a** 9.0 V

b **i** 0–15 V

ii +1.0 V

4.1

1

INPUTS	OUTPUT			
A	**B**	**Top-left circuit**	**Right-hand circuit**	**Bottom-left circuit**
0	0	1	0	1
1	0	0	0	1
0	1	0	0	1
1	1	1	1	1

2 a

T	P	C
0	0	0
1	0	1
0	1	1
1	1	1

b The logic circuit is a single OR gate.

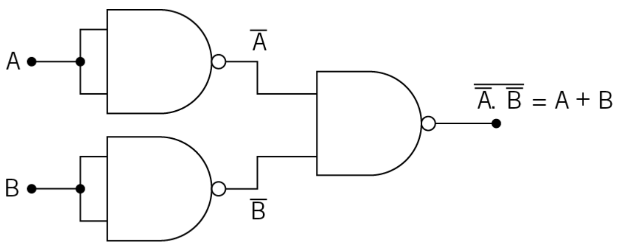
3 a

A	B	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$	C = $\overline{\overline{A}+\overline{B}}$
0	0	1	1	1	0
1	0	0	1	1	0
0	1	1	0	1	0
1	1	0	0	0	1

b i The column for C is the same as A.B Therefore, A.B = $\overline{\overline{A}+\overline{B}}$

ii Change A to $\overline{A}$ and B to $\overline{B}$ Therefore, $\overline{A}.\overline{B} = \overline{A+B}$. Hence, $\overline{\overline{A}.\overline{B}} = A+B$

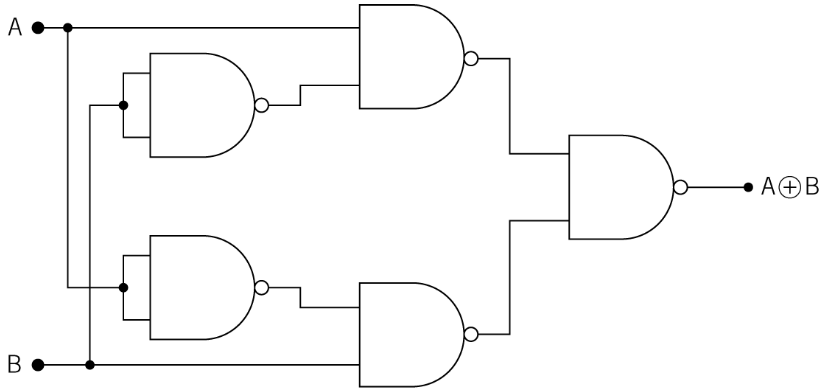
See the figure below for the circuit based on $\overline{\overline{A}.\overline{B}}$



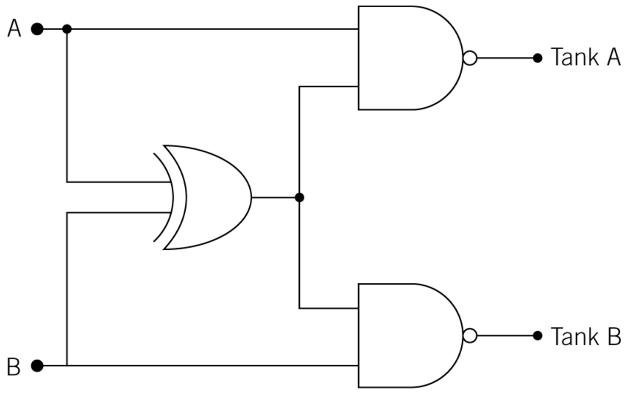
c i The last column of the truth table below is the same as the output of an EOR gate.

A	B	$\overline{A}.B$	$A.\overline{B}$	$\overline{A}.B + A.\overline{B}$
0	**0**	**0**	**0**	**0**
1	**0**	**0**	**1**	**1**
0	**1**	**1**	**0**	**1**
1	**1**	**0**	**0**	**0**

ii



4 Tank A only should receive logic 1 when A = 1 and B = 0, and Tank B when A = 0 and B = 1. The EOR gate provides a '1' when A and B differ. This signal is supplied to each tank via an AND gate when it receives a '1' directly from the appropriate nozzle and from the EOR gate. The circuit in the figure below achieves this.



4.2

1 **a** A binary counter counts the number of pulses received in cycles from 0 to 15 and can display the number received as a 4-bit binary number. A BCD counter counts the number of pulses received in cycles from 0 to 9 and can display the number received as a 4-bit binary number up to 1010.

b The clock pulses are supplied to the Ck input, so the rising edge of each pulse instead of the falling edge causes the flip-flops in the counter to change state. The rising edge of the first pulse sets all the Q outputs to 1111, and subsequent pulses make the counter count down to 0000.

2 **a** A BCD counter is a binary counter that counts from 0 to 9 then resets itself to 0. To do this, the inputs of a 2-input AND gate are connected to the Q_2 and Q_4 terminals, and the AND gate output is connected to the reset terminal of the counter. The 10th pulse (= binary 1010) causes the counter to reset because the AND gate receives a '1' on each input from the outputs Q_2 and Q_4.

b The inputs of a 3-input AND gate are connected to the Q_3, Q_2, and Q_1 outputs of the binary counter, and the AND gate output is connected to the reset terminal of the counter. Each time that Q_3 Q_2 Q_1 reaches 0110, which is decimal 6, the next pulse causes Q_3 Q_2 Q_1 to become 0111, so the AND gate output becomes 1, thus resetting the counter to 0000.

3 a

Q_1	Q_2	Q_3
0	0	0
1	0	0
1	1	0
1	1	1
0	1	1
0	0	1
0	0	0

b At 111, the $\overline{Q_3}$ output is 0, which means that the (internal) input to the counter is 0. The next pulse at the clock input shifts the 0 at the input onto Q_1, so the outputs Q_1 Q_2 Q_3 change to 011. Because the $\overline{Q_3}$ output is still 0, a further pulse shifts the 0 at Q_1 onto Q_2 and shifts the 0 at the input onto Q_1. The outputs Q_1 Q_2 Q_3 thus change to 001.

4 a The mark-to-space ratio is the ratio of the time interval during one cycle when the output is high to the time interval when it is low. See topic 5.2.

b i 40 μs

ii 15 μs

iii 37.5%

5.1

1 One advantage from: more secure; no interference; noise eliminated.

One disadvantage from: regenerators circuits would be needed at intervals; an optical cable would need to be laid down over 30 km.

2 A geostationary satellite is a satellite in an orbit directly above the equator and moving in a direction that keeps it directly above a fixed point on the equator. Signals are carried to the satellite by microwave beams from transmitter/receiver stations on the ground. The satellite sends the signals at a different carrier frequency to other ground stations directly or via other geostationary satellites.

3 a The bandwidth of a transmission link is the range of frequencies it can transmit. Outside this range, the signal is attenuated and is not transmitted through the link. The bandwidth of a coaxial cable is greater than that of the signal, so it can transmit the signal, whereas the bandwidth of a twisted wire pair is much less than that of the signal, so it cannot transmit the signal.

b The attenuation of a signal increases the further it travels. If the cable is too long, the signal will be attenuated too much and will not be detected because it will be indistinguishable from the noise.

4 a If two adjacent cells sent out signals of the same frequency, the two signals would interfere with each other in the overlap area. The user would be unable to detect either signal properly.

b Signal samples from the eight different users in the frequency channel are sent in successive time slots. Each user's signal is sampled every eighth time slot.

c 50 signals; 8.0 Mbps

5.2

1 International radio, National radio, FM radio, Satellite TV

2 a Amplitude modulation is where the amplitude of a carrier wave of constant frequency is modulated by the amplitude of the signal to be carried. Frequency modulation is where the frequency of a carrier wave is modulated by the amplitude of the signal to be carried.

b 30 kHz

3 The bandwidth of a signal is the range of frequencies in the signal. The limits are 100.75 MHz and 101.00 MHz.

4 An FM station in the HF waveband would cover too much of the frequency range of the waveband, thus reducing the number of channels in the waveband. In the UHF waveband, local radio stations would need to use more powerful transmitters to cover the same area because the carrier waves would be at higher frequency and would be attenuated more than in the VHF waveband.

b i 105 kHz

ii 101.37 MHz