AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.13 ELECTRONICS: DEVICES

SCORE	PERCENTAGE
/134	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a) Q = ($\overline{A}$.B) + (A.$\overline{B}$) ✓✓ (allow written format)
Do not allow (A ⊕ B)

- *Correct two terms* ✓
- *Correct operator for OR gate* ✓

2

(b)

B	A	C	D	E	F	Q
0	0	1	1	0	0	0
0	1	0	1	0	1	1
1	0	1	0	1	0	1
1	1	0	0	0	0	0
		✓		✓		

Correct column C
Correct column E

2

(c) Any two criteria ✓✓

Less complex circuit – easier to manufacture
Only uses one type of chip – more economical to buy
Uses fewer ICs so saves space
Uses fewer ICs so saves on power consumption
Accept any other valid reason

2

(d) EOR ✓
Also allow EXOR, XOR

1

[7]

Q2.

(a) Voltage in = Voltage out / Voltage gain

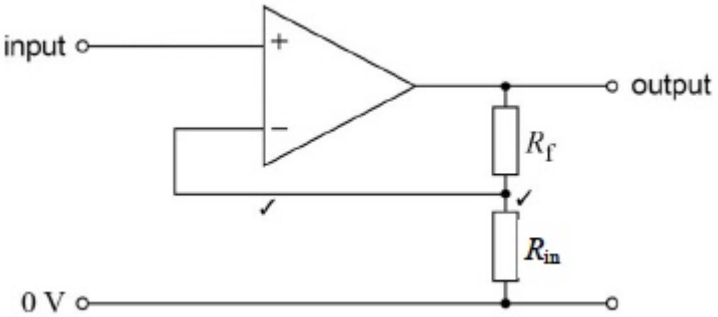
= 3 V / 40

= 75 × 10^{-3} V ✓

1

STEMUP.CO.UK

(b)



Two resistor chain, correctly labelled connected between output and ground

Inverting input connected to mid-point of resistor chain

2

(c) $\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}}$

$40 = 1 + \frac{R_f}{R_{in}}$ calculation to give resistor ratio of 39 ✓

R_{in} = 1 kΩ ; R_f = 39 kΩ ✓

2

(d) Desired gain × bandwidth is 40 × 50 kHz = 2 MHz ✓

The Op Amp can only provide ½ the amplification needed. Not suitable. ✓

1 mark - relevant calculation

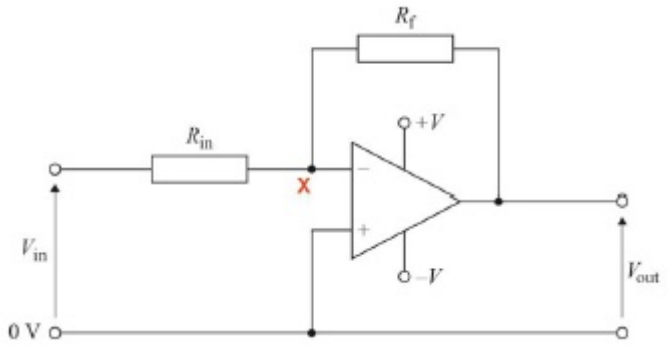
1 mark - reference to only providing ½ require amplification / gain so not suitable

2

[7]

Q3.

(a)



Correct position of X:

1

(b) The non-inverting input

(non-inverting)

1

(c) $I = (V_{in} – V_x) / R_{in} = (V_x – V_{out}) / R_f$

But V_x = 0 V (a virtual earth)

$I = V_{in} / R_{in} = – V_{out} / R_f$

STEMUP.CO.UK

Making use of: $I_{in} = - I_F$

$$\frac{V_{out}}{Vin} = \frac{R_f}{R_{in}}$$

Making use of virtual earth concept

2

(d) Voltage gain (Channel 1) = $– R_f / R_{in}$ 1

$–(150\ k\Omega / 7.5\ k\Omega)$

–20

*Both number **and** sign must be correct*

1

(e) $V_{out} = – R_f (V_{in\ Ch1} / R_1 + V_{in\ Ch2} / R_2)$

$= – 150\ k\Omega ((15mV / 7.5k\Omega) + (–100\ mV / 30\ k\Omega))$

$= – ((0.3) + (–0.5)) = 0.2$ Volts

Evidence of correct method

*Answer **and** correct sign*

1

(f) By using variable resistors

The gain can easily be changed
or
the relative levels of the two channels can be set
or
the required balance between the two signals can be made

One relevant point made

1

[6]

Q4.

(a)

Number shown on die	Logic inputs			Logic outputs						
	C	B	A	L1	L2	L3	L4	L5	L6	L7
1	0	0	0	0	0	0	0	0	0	1
2	0	0	1	1	0	0	0	0	1	0
3	0	1	0	1	0	0	0	0	1	1
4	0	1	1	1	0	1	1	0	1	0
5	1	0	0	1	0	1	1	0	1	1
6	1	0	1	1	1	1	1	1	1	0
Reset 6 → 1										

*One mark for each full pattern of **L1** and **L6:***

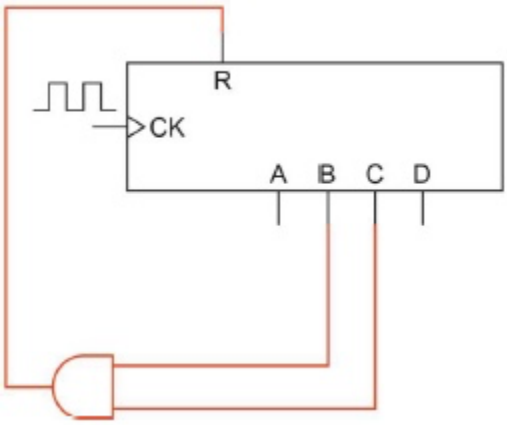
2

(b) **L7 = NOT A;** Accept: L7 = $\bar{A}$

1

STEMUP.CO.UK

(c)



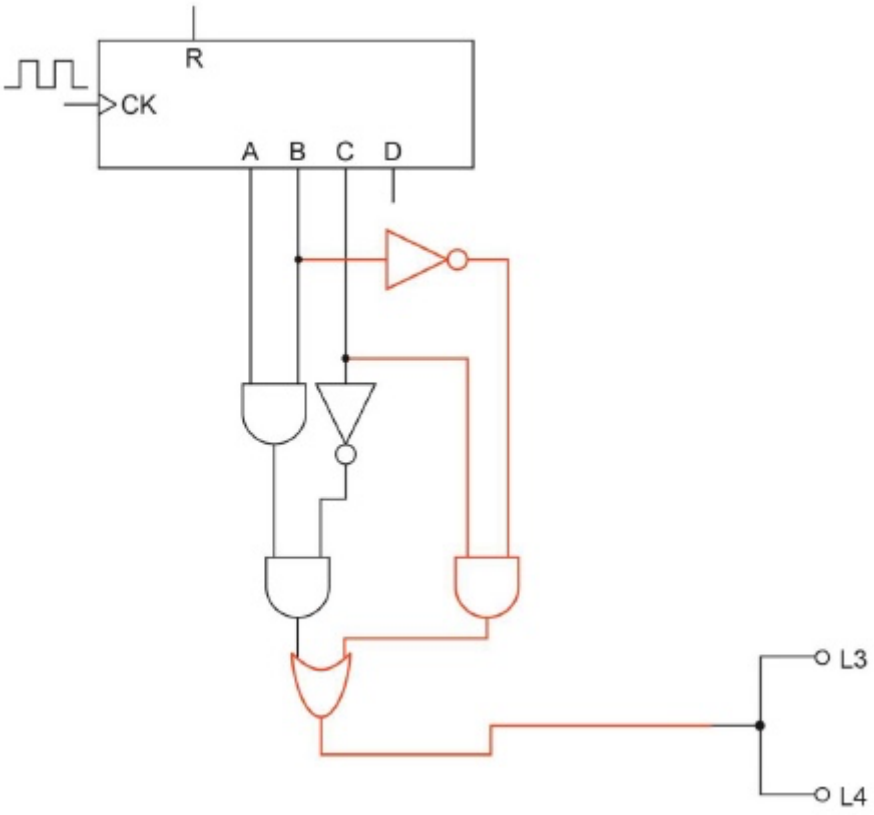
1 mark for reset condition from B and C

1 mark for use of a single 2-input AND gate

(accept correct implementation of the full reset code $\overline{A}$.B.C for 1 mark)

2

(d)



1 mark - NOT gate from B:

1 mark - AND gate from $\overline{B}$ and C:

1 mark - OR gate connecting the two conditions:

3

[8]

Q5.

(a) $f = 1 / (2\pi \sqrt{LC})$

$C = 1/ f^2 4\pi^2 L$

$C = 1/ (910 \times 10^3)^2 \times 4 \times \pi^2 \times 1.1 \times 10^{-3}$

$C = 27.8$ pF (accept 28pF)

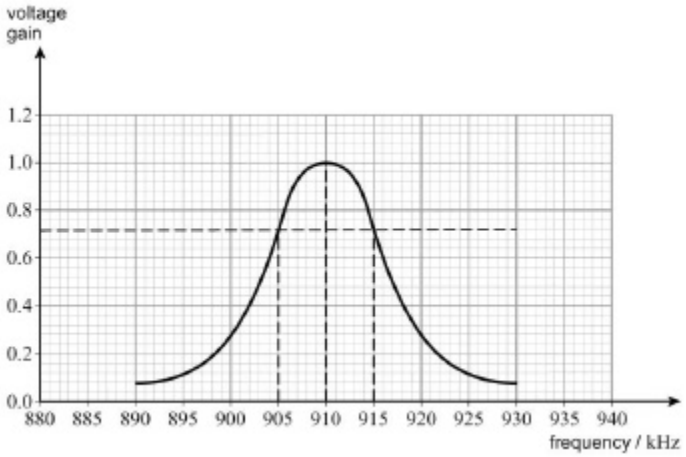
STEMUP.CO.UK

Formula with correct substitution / evidence of correct working

Answer

1
1

(b)



General shape around f_0 and to max of 1.0 on relative voltage gain axis

1

10 kHz bandwidth

at 0.71 gain

1

Frequencies (905 – 910 – 915) kHz (identified / used)

1

(c) Smaller Q factor leads to:

(Any **two** from)
(i) Broader bandwidth
(ii) More noise / (hiss) detected
(iii) Less selectivity
(iv) More susceptible to crosstalk from neighbouring stations on the frequency spectrum.
(v) Less gain due to energy loss / loss of signal detail

2

[7]

Q6.

(a) Photoconductive (accept reverse bias)

1

(b)

	Tick (✓) if correct
Non-inverting amplifier	
Comparator	✓
Summing amplifier	
Difference amplifier	

1

(c) Light level ~ 1000 lux +/- 10%

1

STEMUP.CO.UK

(d) $V_x = IR$; $V_x = 100\ \mu A \times 20\ k\Omega = 2\ V$

1

(e) Rule that if $V_- > V_+$ then V_{out} is 0 V (low)

1

Voltage drop across LED so LED is ON

Do not allow LED is ON if supported by incorrect reason

1

[6]

Q7.

(a) Period T (= 11.3 − 3.2) = 8.1 ± 0.2 ms.✓

Number of revolutions per second $\left(=\frac{1}{T}=\frac{1}{8.1\times10^{-3}}\right)$ = 120 (± 10) (rev s^{-1}).✓

2

(b) Signal is noisy **OR** output is not at appropriate levels for logic circuit.✓

1

(c) $V_A\left(=\frac{12}{12+8.2}\times5\right)=(+)2.97\,V$ ✓

1

(d) Output pd switches between 0 and +5V.✓
Output pd is inverted compared to input pd.✓
Waveform has vertical sides cutting curve at about 3V.✓

MAX 2

[6]

Q8.

(a) V_B (= IR = 5 × 10^{-10} × 22 × 10^6) = 0.011 V (11 mV)✓

1

(b) Resistance of voltmeter and 22 MΩ in parallel ≈ 1MΩ ✓

Current of 5 × 10^{-10} A in this combination gives pd ≈ 0.5 mV✓

Qualitative answer can score both marks.

2

(c) Operational amplifier has very large input resistance.✓
This ensures that the 22 MΩ resistor is not shunted by a lower resistance **or** ensures that (almost) all the current is in resistor rather than shared.✓

2

(d) Two resistors labelled e.g. R_1 and R_F in correct connections.✓✓

i.e. R_F between –ve input and output, R_1 between 0V and –ve input.

1 mark only if resistors are labelled wrong way round or are unlabelled.

2

STEMUP.CO.UK

(e) 9.5 MΩ ✓

1

(f) $\text{Voltage gain} = \frac{R_1 + R_F}{R_1}$ gives $20 = \frac{0.5 + R_F}{0.5}$

from which 10 = 0.5 + R_F (giving R_F = 9.5 M Ω) ✓

1

[9]

Q9.

(a) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the *'Mark Scheme Instructions'* document should be used to assist marking this question.**

L3 5-6 marks	All three bullet points of the question are addressed in good detail.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3-4 marks	The answer includes some discussion of two or three of the three bullet points.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1-2 marks	The answer addresses one bullet point in some detail but the others may be neglected.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0 marks	Little or no discussion of relevant content.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

The following statements could be present:

- *description of variable amplitude of AM carrier wave*
- *description of variable wavelength of FM carrier wave.*

For AM :

- *amplitude of carrier wave varies at frequency of superimposed signal whilst frequency (or wavelength) of carrier wave is constant*

STEMUP.CO.UK

- *advantages of AM:*
  - *modulation is simpler to produce so equipment is less complex*
  - *fewer transmitters needed*
- *disadvantages of AM*
  - *more subject to interference and distortion*
  - *waveband has limited capacity.*

For FM:

- *frequency of carrier wave varies at frequency of superimposed signal whilst amplitude of carrier wave is constant*
- *advantages of FM:*
  - *less prone to interference*
  - *clearer reception*
  - *waveband has greater capacity*
- *disadvantages of FM:*
  - *signal less diffracted because of shorter wavelength so more difficult to receive*
  - *require more transmitters.*

6

(b) $\lambda\left(=\frac{c}{f}\right)=\frac{3.00\times10^{8}}{434\times10^{6}}=0.691\,(\text{m})$ ✓

Length of aerial = 0.173 (m).✓

2

(c) At 4 °C $f = 7.3(6\theta + 273)$ gives $f = 7.3(6 \times 4 + 273) = 2170$ Hz = 2.2 (kHz).✓

1

(d) Bandwidth calculation based on higher frequency signal f_H i.e 3.0 kHz ✓ required bandwidth = 2 f_H = 6.0 kHz.✓

2

[11]

Q10.

(a) Connections shown from Q_B and Q_D to AND gate inputs.✓
Connection shown from output of AND gate to re-set terminal R of counter.✓

2

(b) Process numbers identified as 2, 5, 7, 8 and converted to 10, 101, 111, 1000 respectively.✓

1

(c) Q_A, Q_B, Q_C and Q_D [or **A**, **B**, **C**, **D**] identified with 1, 2, 4 and 8 respectively [**or** with 1, 10, 100, 1000 **or** 2^0, 2^1, 2^2 and 2^3].✓

Interpretation of expression as

$\overline{\mathbf{D}}.\overline{\mathbf{C}}.\mathbf{B}.\overline{\mathbf{A}}$ meaning (0+0+2+0) = 2

OR $\overline{\mathbf{D}}.\mathbf{C}.\overline{\mathbf{B}}.\mathbf{A}$ meaning (0+4+0+1) = 5

OR $\overline{\mathbf{D}}.\mathbf{C}.\mathbf{B}.\mathbf{A}$ meaning (0+4+2+1) = 7

STEMUP.CO.UK

OR **D.$\overline{C}$.$\overline{B}$.$\overline{A}$** meaning (8+0+0+0) = 8

(i.e. 2 OR 5 OR 7 OR 8).✓

Allow 1 mark for confusing whether A or D is the least confusing bit.

*Allow ECF from incorrect process numbers in part **(b)** but only allow MAX 1 if 3 process numbers or fewer are identified.*

2

[5]

Q11.

(a) No pd across 100 kΩ (since no current through it) so both inputs are 0 V / logic 0 and output there for logic 1.✓

1

(b) $\left(V = V_0\left(1 - e^{-\frac{t}{RC}}\right)\right)$ and RC = 10 s gives $2.5 = 5.0\left(1 - e^{-\frac{t}{10}}\right)$ ✓

Solution gives t = 6.93 s.✓

2

(c) Any appropriate time delay application that leaves a device switched ON or OFF for a short time after activation or deactivation.✓

e.g. Car interior light as driver leaves vehicle, intruder alarm exit delay.

1

[4]

Q29.

(a)

A	B	a	b	c	d	e	f	g	Display
0	0	**0**	**0**	**0**	**1**	**1**	**1**	**0**	L
0	1	**1**	**0**	**1**	**1**	**0**	**1**	**1**	S
1	0	**1**	**0**	**1**	**1**	**0**	**1**	**1**	S
1	1	**0**	**1**	**1**	**0**	**1**	**1**	**1**	H

1 mark for row L

1 mark for row S (both)

1 mark for row H

3

(b) EXOR gate

1

(c) (i) Different combinations produce different brightness

1 Disadvantage

1

STEMUP.CO.UK

(ii) R=V/I; (5V − 2.2V) / 20mA; 2.8V / 20mA = 140Ω

1 mark for 2.8V drop

1 mark for answer

2

(iii) E24 = 150Ω

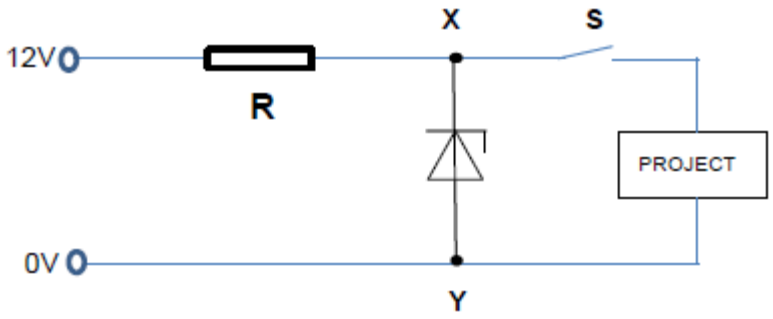
1 mark for answer

1

(8)

Q30.

(a)



1 mark for Zener symbol
1 mark for orientation

2

(b) (i) 80mA + 5mA = 85mA

Answer − 1

1

(ii) 12V − 5.1 V = 6.9V

Calculation and answer − 1

1

(iii) R = 6.9V / 85mA = 81Ω

Calculation and answer − 2

2

(c) (i) $P = V^2 / RP = (6.9 \times 6.9) / 75P = 0.64W$

Hence P is approx. 0.6W

Calculation and answer − 2

2

(ii) I = V / R I = 6.9 / 75 I = 92mA

Calculation and answer − 2

2

[10]

Q31.

(a) D = C + B

1

E = $\overline{A}$

STEMUP.CO.UK

G = $\overline{A+B}$ *1*

1

3

(b)

INPUTS			INTERMEDIATE OUTPUTS		
C	**B**	**A**	**D**	**E**	**G**
0	0	0	**0**	**1**	**1**
0	0	1	**0**	**0**	**0**
0	1	0	**1**	**1**	**0**
0	1	1	**1**	**0**	**0**
1	0	0	**1**	**1**	**1**
1	0	1	**1**	**0**	**0**
1	1	0	**1**	**1**	**0**
1	1	1	**1**	**0**	**0**

2 marks for each of correct columns D & G

1 mark for column E

5

(Total 8 marks)

Q32.

(a) (i) Log graph enables a wide range of values to be displayed on the same axis.

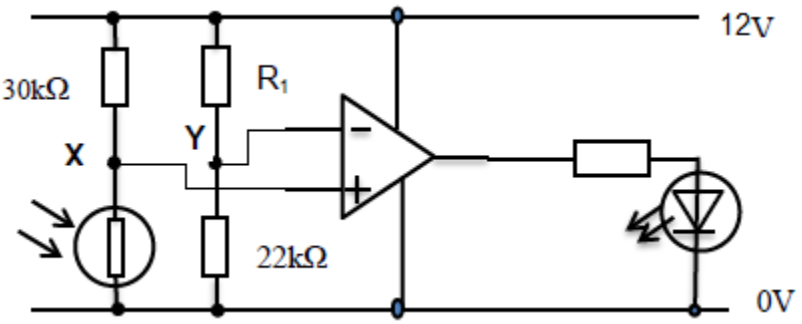
Allow − (enables values to be displayed as straight line)

1

(ii) 7 lux

1

(b)



1 mark for connections correct way round

1

STEMUP.CO.UK

(c) (i) 60 kΩ / (60kΩ + 30kΩ)) × 12V = 8V

Working − 1

Answer − 1

2

(ii) R_1 = 11kΩ to give same value at Y as switching voltage at X (2:1 ratio)
(No ecf on value)

Reason / calculation − 1

Answer − 1

2

(d) The op-amp is not ideal and will saturate above 0V

Saturation − 1

Need to drop voltage

Voltage drop − 1

Acceptable method

Method − 1

3

(Total 10 marks)

Q33.

(a)

INPUTS			**OUTPUTS**		
Tunnel Sensor T	**Car Sensor C**	**Lorry Sensor L**	**Message Display M**	**Red Stop light R**	**Green Go light G**
0	0	0	**0**	0	**1**
0	0	1	**0**	0	**1**
0	1	0	**0**	0	**1**
0	1	1	**1**	1	**0**
1	0	0	**0**	1	**0**
1	0	1	**0**	1	**0**
1	1	0	**0**	1	**0**
1	1	1	**1**	1	**0**

Column M − 2 marks
Column G − 2 marks

4

(b) **R = T + (C.L)**

1 mark for terms

1 mark for OR

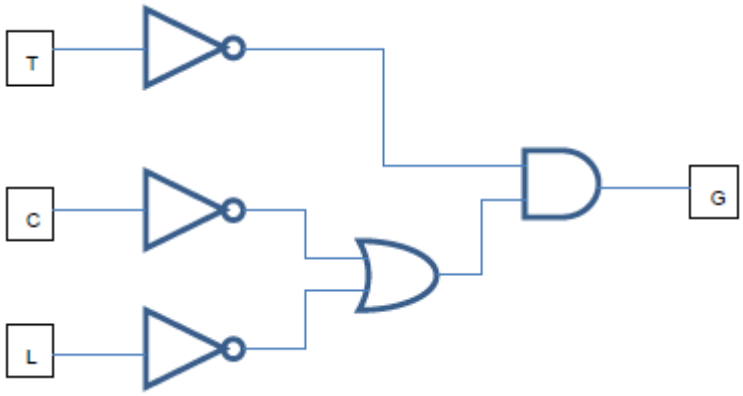
STEMUP.CO.UK

Or for full expression **S = T +($\overline{T}$.C.L)**

Max 1 mark

2

(c)



3

(Total 9 marks)

Q34.

(a) (i) A

(at inverting input)

1

(ii) a point on the circuit where the voltage is 0v / ground
but not connected to 0v / is almost 0v / simulates 0v
assuming that the op-amp has not saturated

2 max

(iii) 10kΩ (must have units unless 10,000 which assumes standard)

***oe** 10,000Ω / 10K etc*

1

(b) correct formula rearranged
calculation / substitution
470kΩ

3 for just correct answer with units

3

(c) inverted,
same frequency,
shape shows evidence of correct gain
maximum amplitude 3v to 5v

4

[11]

STEMUP.CO.UK

Q1.

(a) This question tested the ability of students to write a Boolean expression to represent a given logic circuit. The question was answered well (70% of students gained both marks) and most students opted for the algebraic version, although a few gave a written version which received equal credit. Future questions of this nature will probably be written asking specifically for the **algebraic** version.

(b) This question tested the knowledge of truth tables for a range of logic gates and the ability to analyse a combinational logic system. Overall, the question was answered well, with 79% of students scoring two marks.

(c) This question was a little more demanding. A few students became side-tracked by expecting the manufacturer of the system also to make the logic IC's. However, most students were able to produce a viable answer based on cost and space. 86% gained at least one mark here. *Students should be shown a diagram of a typical 2-input logic gate arrangement on an IC, even if they do not use the IC*.

(d) This was a straight recall question. Many students (79%) correctly identified the **Q** column in the truth table as being that of the exclusive OR gate.

Q2.

(a) This proved to be a simple calculation for most students, with 84% gaining the mark.

(b) Just under 50% of the students picked up maximum marks for correctly drawing the non-inverting amplifier. Although many produced the arrangement shown in the mark scheme, other arrangements of the resistor chain were accepted. However, a significant proportion of students (40%) were unable to score on this question.

(c) The first mark here was given for identifying the correct formula and then for showing the resistor ratio to be 39. When faced with this information, it is always worth checking to see if using 1 kΩ for the lower resistor leads to a sensible value for the top resistor. This produced the second mark. Most students scored well on this question, with 68% gaining both marks.

(d) The best answers for this question came from students who appreciated that there would be a 50 kHz signal going into an operational amplifier having a gain-bandwidth product of 1 MHz, leading to a maximum gain of only 20. This approach comes from the question which asked candidates to: 'Discuss whether **this** operational amplifier is suitable...' 29% of students scored both marks. However, one mark was given if students got as far as showing that the operational amplifier really needed to have a gain-bandwidth product of twice that of the amplifier used in the circuit. The main error here was produced by students thinking that the 50 kHz signal was being transmitted by an AM system wrongly leading to a total bandwidth of 100 kHz. *It will always be made clear in the question if AM/FM transmission is in use.*

Q3.

(a) The virtual earth point was identified correctly by many students.

(b) The terminal was correctly identified by most students.

STEMUP.CO.UK

(c) A significant number of students did not explain their thinking behind the derivation. The key points in the mark scheme included the same current flowing in the input and feedback resistors, and the use of the virtual earth point when considering the voltage across the resistors.

(d) Unfortunately, a number of students ignored or forgot the sign in this relatively straightforward calculation. Both sign and number were needed for the single mark.

(e) This calculation was a little more complex, particularly involving the signs. The allocation of two marks enabled students who showed proof of a correct method to gain some credit, even if an error was made in the final step.

(f) A range of sensible answers was accepted. It was a pity that some students lost sight of the application, but on this occasion the mark was awarded just for a simple statement of fact.

Q4.

(a) Most students did not appear to be distracted by the context of this question and the truth table was done well.

(b) A small number of students committed to analysing this using a complex piece of Boolean algebra, which did not lead to the simplest solution. Most, however, spotted the short-cut.

(c) A number of students were thrown by two aspects of this circuit which has been designed so that '0' or a blank is never shown on the display.

(i) The counter starts at 0000, but the logic process allows the display to be '1' (1 dot). Effectively the display is always one ahead of the decimal equivalent of the binary code on the counter.

(ii) The reset binary code is 0110 and only lasts for a split second, so no output is shown for this code. However, when the reset has been completed then the counter code will be 0000 and the display will show decimal '1' (1 dot).

As a result of the above, students were still able to gain credit for using a single AND gate, even if they did not use the correct tap off points on the counter.

(d) Most students were able to draw/complete the logic diagram form the Boolean expression provided. This is a vital skill in the digital section of the specification.

Q5.

(a) Some students struggled with extracting C from the formula, and one or two lost some powers of ten. Again, it is recommended that students always show all stages of their working, so that some credit can be gained even if the final answer is wrong.

(b) Most students answered this question well, although a significant number failed to show on the graph the appropriate frequencies matched to the ~ 0.7 voltage gain point.

(c) Some students were rather 'clinical' in their response to this question and forgot to relate their answer to the context of the 'listener'.

Q6.

(a) This proved to be a straightforward question.

(b) This also proved to be straightforward.

(c) This was a complex graph, but most students produced a result that was within the acceptable range of values given in the mark scheme.

(d) It was disappointing to see a number of students not being able to follow through an Ohm's Law calculation when given all necessary values. Otherwise the question was answered well.

(e) This question required students to correctly apply the comparator rule to give 0 Volts output, then to appreciate that the voltage drop across the LED would turn it on.
A number of students successfully gained the first mark but then wrongly assumed that a 0 Volt output would turn the LED off, forgetting that the comparator would sink current.

Q29.

(a) A high percentage of candidates correctly completed the truth table.

(b) Only a few candidates who achieved success in section (a) did not go on to gain the mark here.

(c) Answers relating to the dimming of segments as more segments were lit were less evident, but the calculation and selection of the E24 resistor proved to be straight forward.

Q30.

(a) An easier start than last year as the position for the component was already given. A large number of candidates were successful here although one or two protective resistors crept in and some symbols had the circle with a free-floating centre character which detracted from the quality of the answer.

(b) This section of the question was straight forward for the majority of candidates.

(c) The power calculations proved to be more selective in terms of response. Good candidates spotted the need for a V^2 / R approach in (i), whilst the easier calculation in (ii) proved to be a more demanding concept as the calculation needed to be centred on the data for the series resistor R.

Q31.

(a) This part was answered well with a high proportion of candidates gaining full marks.

(b) The truth table proved to be slightly more demanding, but still allowed a large percentage of the candidature access to some marks.

Q32.

(a) The mark in part (i) was most often lost by the explanation being too general − e.g. 'it's better'. However, the reading required from the graph in part (ii) was accurately achieved by most candidates.

STEMUP.CO.UK

(b) A significant number of candidates were able to connect the inputs to the correct pins of the op-amp to make the circuit function as described.

(c) The question appeared to expose the lack of understanding of how a transistor-based control circuit can be used to interact with an independent power circuit via an interface (relay).

(d) This part follows the established question of looking at how saturation affects the output voltage characteristics of real op-amps and how this differs to the characteristic for an ideal one. Candidates are expected to formulate their answer based on the limitations of the op-amp in comparator mode as given in the question.

The latter part of the answer should have focused on how to make the low output voltage from the op-amp smaller than the forward voltage of the LED rather than just reducing the current. Solutions that would have appreciably affected circuit operation when the op-amp gave a high output or potentially cause damage to the LED did not gain credit.

Q33.

(a) A high percentage of candidates correctly completed the truth table. The loss of just a single mark was mainly due to the green light being left on when a lorry was detected.

(b) Just over half of the candidates were able to construct the correct Boolean expression for the red light from the given completed column in the truth table.

(c) Part (c) was done very well, with most candidates opting for the solution given on the mark scheme. However, a few candidates also produced an equally valid design based on an expansion of the given expression for **G**.

Q34.

(a) (i) Most candidates selected the correct option.

(ii) A large number of answers tended to repeat the word ‘earth’ used in the question, scoring only one point.

(iii) The vast majority gave the correct answer.

(b) Many gave the correct answer, but workings showing clearly how it was arrived at were less common.

(c) Many were able to sketch an inverted wave of the same frequency, several gave evidence of using the gain to calculate a theoretical peak voltage, but few noticed the power supply limitation of the circuit.

STEMUP.CO.UK