Surname	Centre Number	Candidate Number
Other Names		2

GCE A Level – LEGACY

1145/01

S18-1145-01

ELECTRONICS – ET5

WEDNESDAY, 13 JUNE 2018 – AFTERNOON

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**12**	
3.	**10**	
4.	**8**	
5.	**7**	
6.	**7**	
7.	**5**	
8.	**8**	
Total	**70**	

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ADDITIONAL MATERIALS

A calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 70.
The number of marks is given in brackets at the end of each question or part-question.
You are reminded of the necessity for good English and orderly presentation in your answers.
You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

INFORMATION FOR THE USE OF CANDIDATES

Preferred Values for resistors

The figures shown below and their decade multiples and sub-multiples are the E24 series of preferred values.

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91.

Standard Multipliers

Prefix	Multiplier
T	$\times 10^{12}$
G	$\times 10^{9}$
M	$\times 10^{6}$
k	$\times 10^{3}$

Prefix	Multiplier
m	$\times 10^{-3}$
μ	$\times 10^{-6}$
n	$\times 10^{-9}$
p	$\times 10^{-12}$

Alternating Voltages $V_0 = V_{rms}\sqrt{2}$

Silicon Diode $V_F \approx 0.7\,V$

Operational amplifier

$G = -\dfrac{R_F}{R_{IN}}$ Inverting amplifier

$G = 1 + \dfrac{R_F}{R_1}$ Non-inverting amplifier

$V_{OUT} = V_{DIFF}\left(\dfrac{R_F}{R_1}\right)$ Difference amplifier

$V_{OUT} = -R_F\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right)$ Summing amplifier

$V_L \approx V_Z\left(1 + \dfrac{R_F}{R_1}\right)$ Stabilised power supply

Emitter follower $V_{OUT} = V_{IN} - 0.7\,V$

Filters

$f_b = \dfrac{1}{2\pi RC}$ Break frequency for high pass and low pass filters

$X_C = \dfrac{1}{2\pi fC}$ Capacitive reactance

Thyristor phase control

$\phi = \tan^{-1}\dfrac{R}{X_C}$

$\tan\phi = \dfrac{R}{X_C}$

Signal conversion $\text{resolution} = \dfrac{\text{i/p voltage range}}{2^n}$ ADC

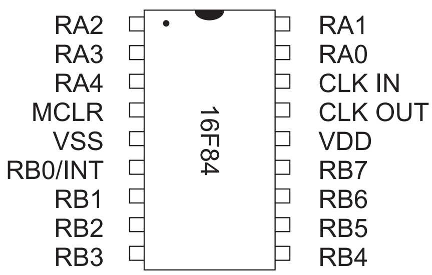
Power amplifier $P_{MAX} = \dfrac{V_S^2}{8R_L}$ where V_S is the rail-to-rail voltage

PIC Information

The PIC programs include ‘equate’ statements that define the following labels:

Label	Description
PORTA	input / output port A
PORTB	input / output port B
TRISA	the control register for port A
TRISB	the control register for port B
STATUS	the status register
INTCON	the interrupt control register
W	the working register (= h ‘0’)
F	the file register (= h ‘1’)
RP0	the register page selection bit 0
Z	the zero flag status bit
GIE	the global interrupt controller bit
INTE	the external interrupt enable bit

Pinout for 16F84 PIC IC:



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010003

List of commands:

Mnemonic	Operands	Description
bcf	f, b	Clear bit b of file f
bsf	f, b	Set bit b of file f
btfss	f, b	Test bit b of file f, skip next instruction if bit is set
call	k	Call subroutine k
clrf	f	Clear file f
goto	k	Branch to label k
movf	f, d	Move file f (to itself if d = 1, or to working register if d = 0)
movlw	k	Move literal k to working register
movwf	f	Move working register to file f
retfie		Return from interrupt service routine and set global interrupt enable bit GIE

Comparison of TASM and MPASM languages:

Version		TASM	MPASM
Number system notation	Decimal	153	d'153'
	Hex	$2B	h'2B' or 0x2B
	Binary	%10010110	b'10010110'
Opcode Notation		.equ	equ
		.org	org
		.end	end
		label:	label

Structure of the INTCON register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	EEIE	TOIE	INTE	RBIE	TOIF	INTF	RBIF

Structure of the STATUS register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IRP	RP1	RP0	TO	PD	Z	DC	C

Examiner only

Answer **all** *questions.*

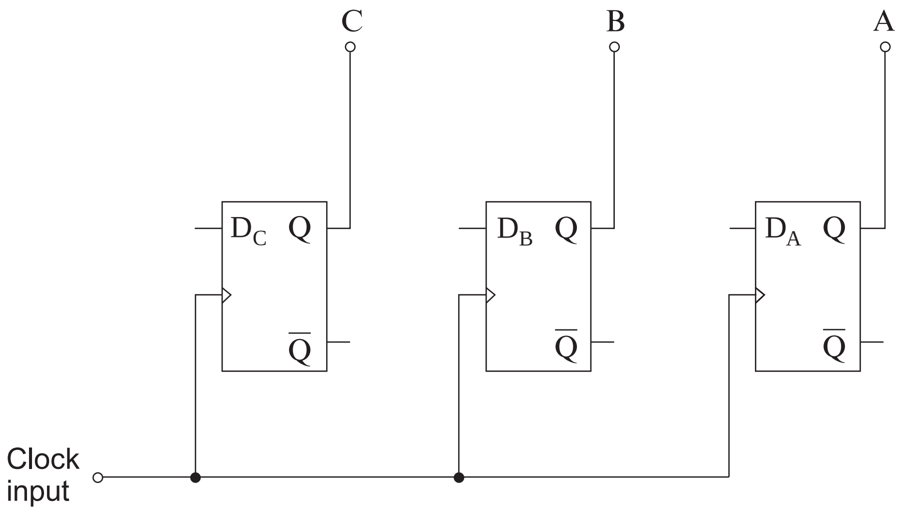
1. A synchronous counter generates a sequence of states governed by the Boolean equations:

$$D_A = \overline{B}$$

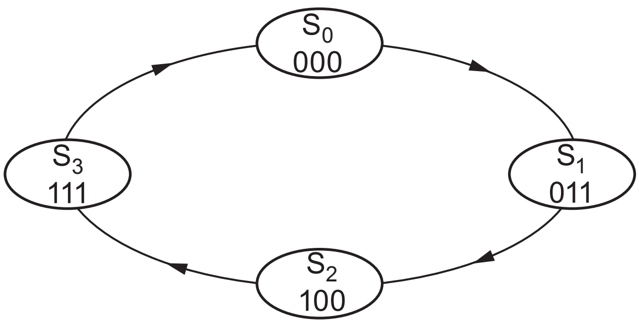
$$D_B = \overline{B . A}$$

$$D_C = C \oplus B$$

(a) Complete the circuit diagram for the counter. [4]



(b) The main sequence for this counter is shown below:



Three different situations can occur when the system powers up.
It can start either in an unused state, a stuck state or a main sequence state.

Examiner only

For each of the following, determine which situation applies by completing the corresponding table, using the Boolean equations or otherwise.

(i) On power up, the counter starts in the **011** state. [3]

Clock pulse	Current Outputs			Next Outputs		
	C	B	A	D_C	D_B	D_A
1	0	1	1			
2						

Type of state (main sequence, unused or stuck state): ....

(ii) On power up, the counter starts in the **010** state. [3]

Clock pulse	Current Outputs			Next Outputs		
	C	B	A	D_C	D_B	D_A
1	0	1	0			
2						

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Type of state (main sequence, unused or stuck state): ....

(iii) On power up, the counter starts in the **001** state. [3]

Clock pulse	Current Outputs			Next Outputs		
	C	B	A	D_C	D_B	D_A
1	0	0	1			
2						

Type of state (main sequence, unused or stuck state): ....

Examiner only

2. *(a)* A hi-fi system contains a filter to intensify the low-frequency content in the audio signal.

What kind of filter is this? [1]

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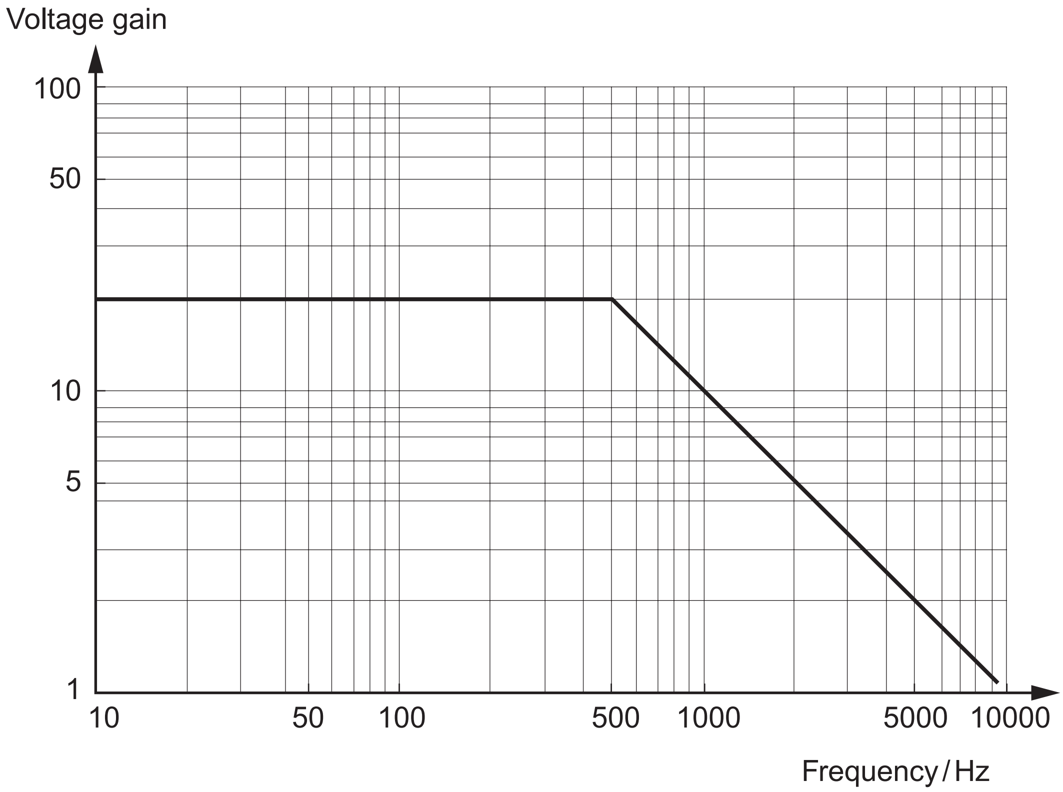
(b) A **different** audio filter has the frequency response shown in the following graph:



(i) What type of filter is this? .... [1]

(ii) What is the break frequency for this filter? .... [1]

(iii) A sine wave with a frequency of 200 Hz and amplitude of 20 mV is applied to the input of the filter.

What is the frequency and amplitude of the resulting output signal? [2]

Frequency = ... Hz

Amplitude = ... mV

(iv) How do you know that this is an active filter rather than a passive filter? [1]

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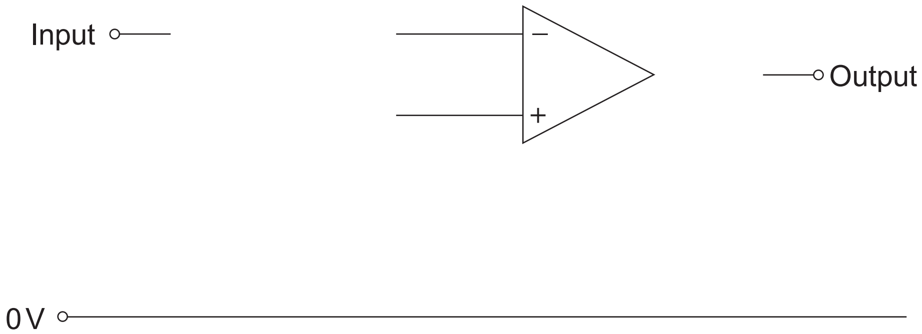
Examiner only

(c) The circuit for this filter uses a 1 nF capacitor.

(i) Complete the circuit diagram for this filter, based on an op-amp. [3]



(ii) Calculate suitable values for the resistors used in it.

Label the resistors with their ideal resistance. [3]

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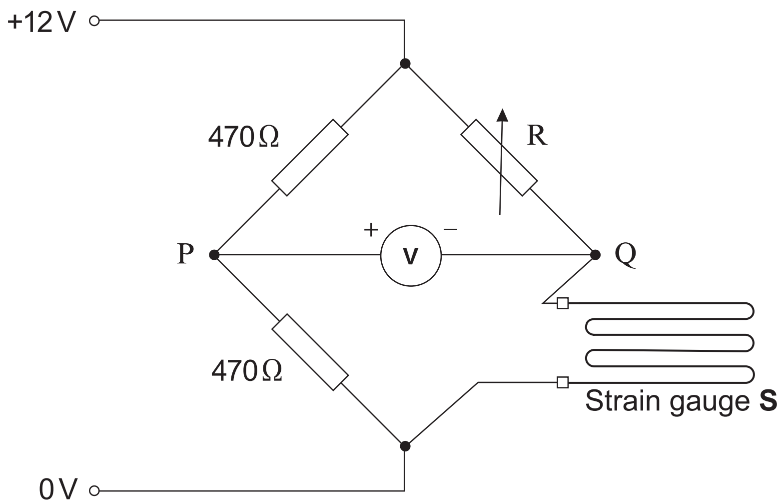
Examiner only

3. A strain gauge **S** is fixed to the top surface of a long metal beam, used in the construction of a motorway bridge. It monitors bending of the beam. When under no stress, its resistance is 350 Ω.

It is connected as shown below:



(a) (i) Calculate the voltmeter reading when the variable resistor R is set to a resistance of 360 Ω and the strain gauge is under no stress. [2]

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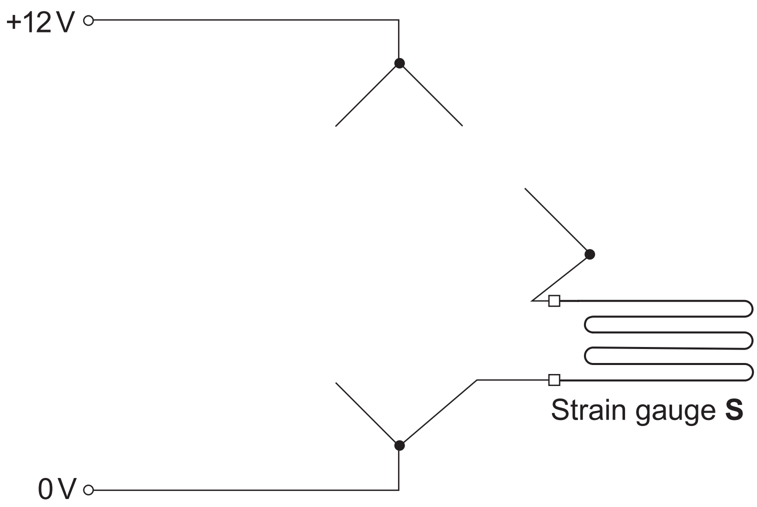
Examiner only

(ii) The design is found to be flawed as the voltmeter reading is affected by temperature changes in the beam. Complete the following circuit diagram to show a modification that can eliminate this and describe the important features of our modification. [3]



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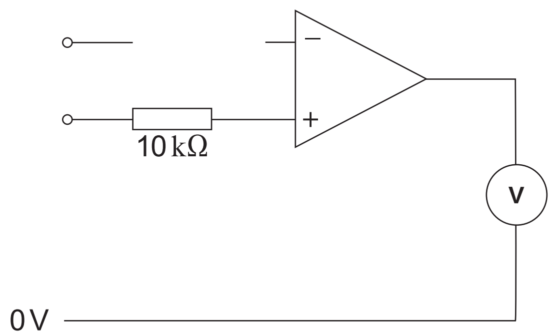
Examiner only

(b) A difference amplifier is added to increase the sensitivity of the system.

It has a voltage gain of 100.

Part of the difference amplifier circuit is shown below.



(i) Complete the circuit diagram, including labels to show the resistance of all resistors. [3]

....

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(ii) Add labels **P** and **Q** to show how the bridge circuit is connected to the difference amplifier.

The voltmeter reading should decrease when the resistance of the strain gauge increases. [1]

(iii) Calculate the voltmeter reading when the conditions are those specified in part *(a)*. [1]

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010011

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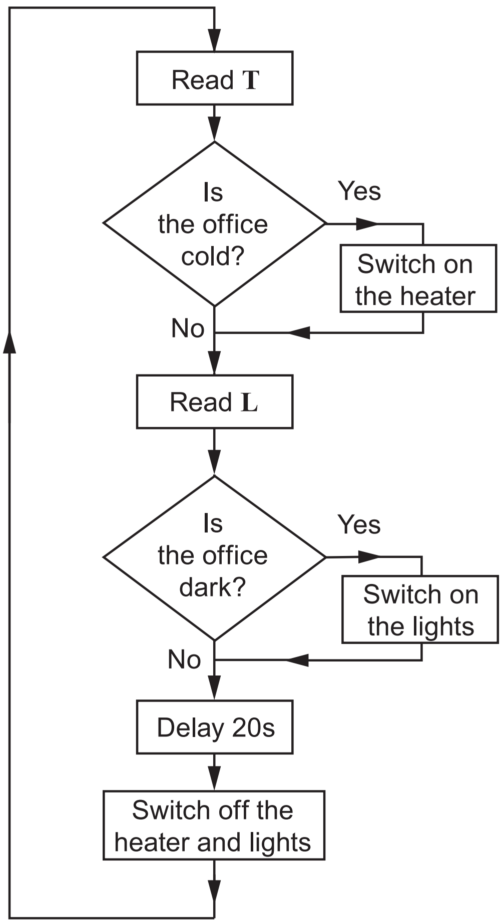
Examiner only

4. A microcontroller controls the heating and lighting in an office and warns of a possible fire. It monitors signals from a temperature sensor **T**, a light sensor **L** and a smoke sensor **S**.

T and **L** are used in the heating and lighting control program, developed from the flowchart shown below.



(a) Why is it better to have the smoke alarm **S** trigger an interrupt, rather than build it into the heating and lighting control program? [1]

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(b) The smoke sensor **S** triggers an interrupt on Port B, bit 0.

Complete the instructions to clear the INTF interrupt flag and enable this interrupt, **while disabling all other interrupt sources**. [2]

movlw	b'..'
movwf	INTCON

Examiner only

(c) The following connections are in place:

- all five bits of Port A have active-high LEDs attached;
- the reset switch is connected to Port B bit 2;
- sensors **T** and **S** and all output devices are connected to other bits of Port B.

When the smoke alarm triggers an interrupt:
- the LEDs connected to bits 1 and 3 of Port A light for three seconds;
- they then turn off;
- the LEDs connected to bits 0, 2 and 4 of Port A light for three seconds;
- they then turn off.

This sequence continues until the reset switch is pressed.

Here is part of the Interrupt Service Routine (ISR). It uses a subroutine called 'threesec' to create a three second delay.

```
201  inter     movwf        store
202            bcf          INTCON,1
203  loop      ..........   ..........
204            movwf        PORTA
205            ..........   ..........
206            ..........   ..........
207            movwf        PORTA
208            call         threesec
209            btfss        PORTB,2
210            goto         loop
211            movf         store
212            retfie
```

(i) Complete the ISR by adding appropriate instructions to lines 203, 205 and 206. [3]

(ii) Just before the interrupt is called, the Working Register contains the number b'00001010'.

What does it contain after the ISR is completed and the processor returns to the main program? [1]

....

(iii) During execution of the ISR, what does the Working Register contain just after the processor executes the instruction in line 207? [1]

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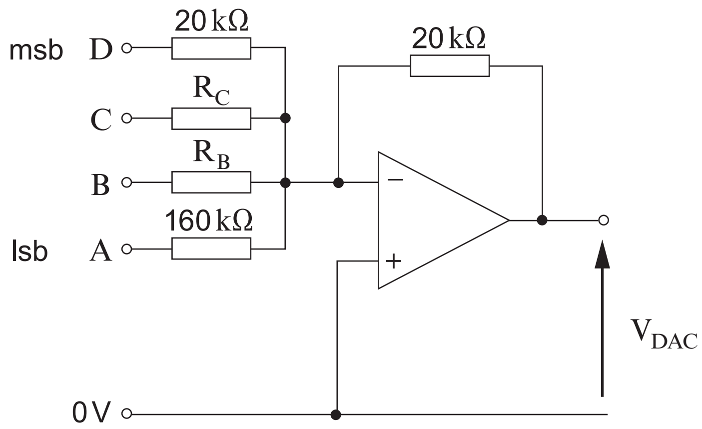
5. A microcontroller controls the brightness of a lamp. It outputs a four-bit binary number to a linear digital-to-analogue converter (DAC). Its output drives the lamp.
The circuit diagram for the DAC is shown below.



Input D is the most-significant bit (msb) of the binary number outputted by the microcontroller.

- A logic 1 signal from the microcontroller has a voltage of 8 V.
- A logic 0 signal has a voltage of 0 V.
- The op-amp output saturates at +/–18 V.

(a) What is the resistance of R_B and R_C? [1]

R_B = ...

R_C = ...

Examiner only

(b) Calculate the output voltage, V_{DAC}, when the input is the binary number 0001. [1]

V_{DAC} = ...

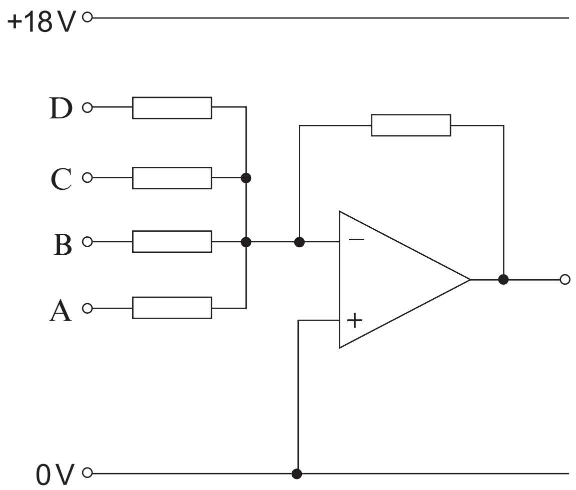
(c) Calculate the maximum value of V_{DAC} that the microcontroller can create. [1]

Max V_{DAC} = ...

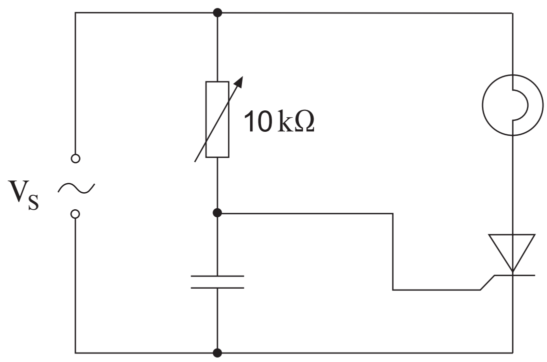
(d) Modify the circuit diagram below by adding:

(i) a second amplifier, to invert the signal V_{DAC} without changing its amplitude. (Label any resistors used with suitable values.) [2]

(ii) a lamp, driven by an emitter follower based on a npn transistor, controlled by the DAC. [2]



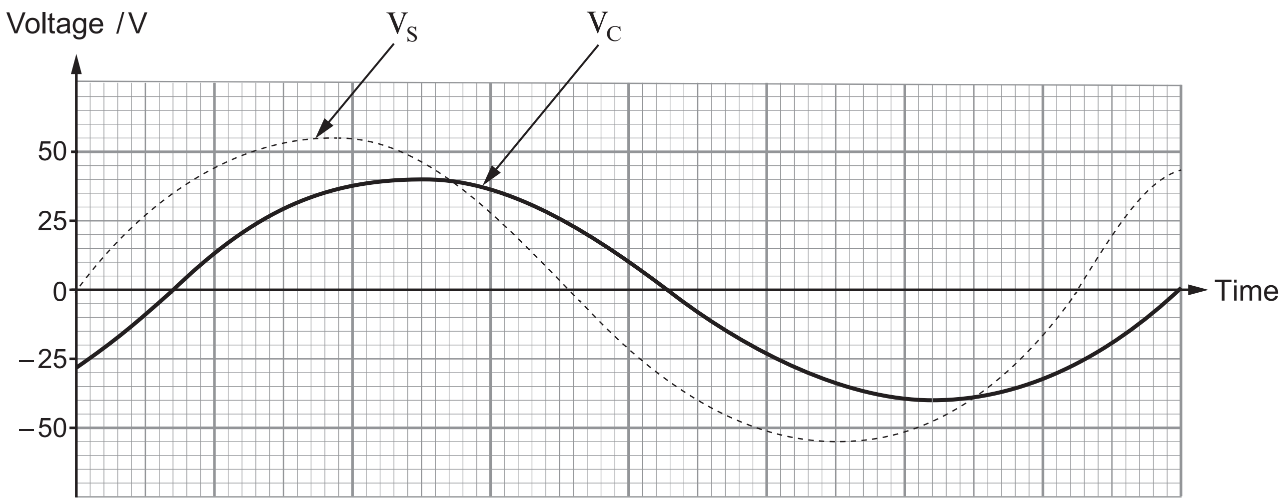
6. A thyristor is used to control the brightness of a lamp, using phase control.



The thyristor switches on when the voltage between the gate and the cathode exceeds 5V.

(a) The variable resistor is initially set to a value of 8 kΩ.

The signal, V_C, across the capacitor is shown below.



(i) Label the time at which the thyristor turns on, with the letter **X**. [1]

(ii) Label the time at which the thyristor turns off, with the letter **Y**. [1]

(iii) Estimate the phase shift between V_S and V_C. [1]

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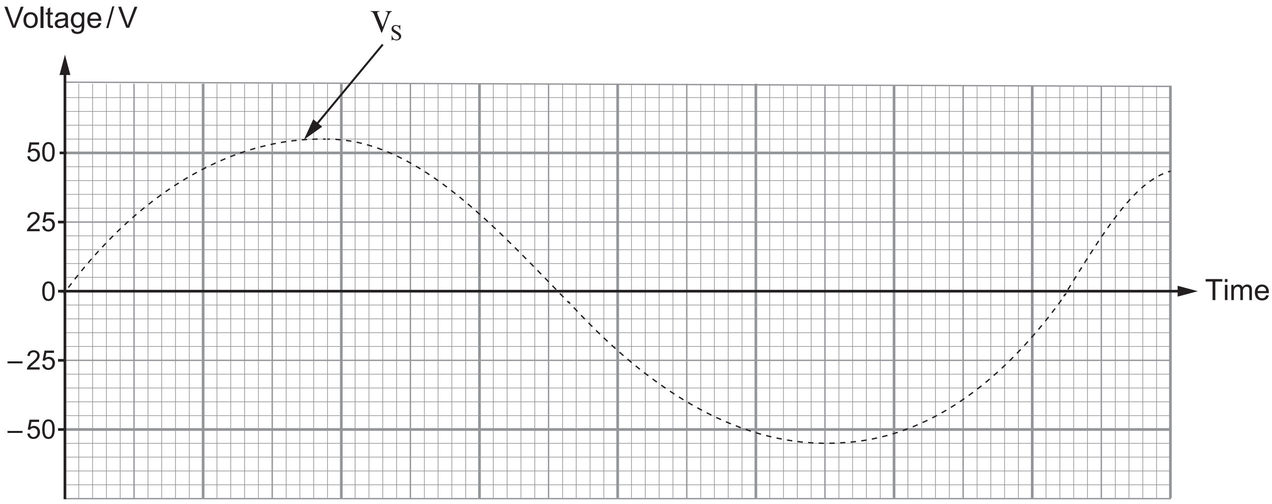
(b) The variable resistor is now set to a value of 0 Ω.
Use the axes below to sketch the resulting signal across the capacitor. [2]



(c) It is found that the thyristor gets warm when operating the lamp in this way.

(i) Add a diac to the circuit diagram, using the correct symbol, to reduce this. [1]

(ii) Explain why this can reduce the heating effect. [1]

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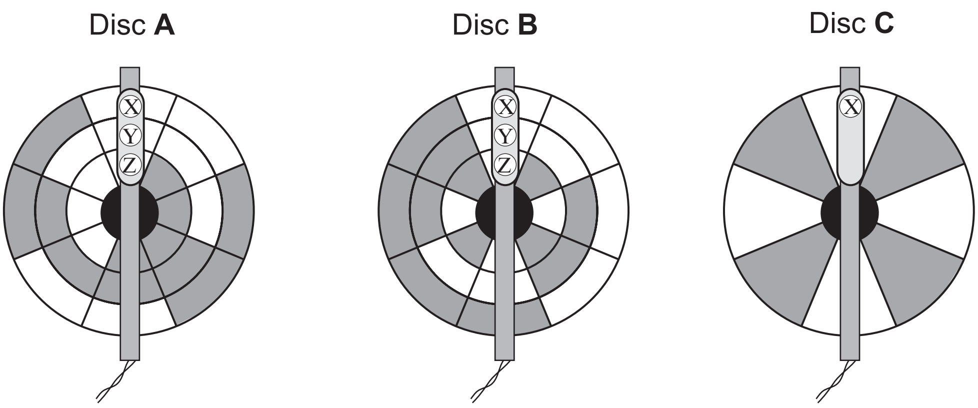
7. The diagram shows three types of encoded disc. **X**, **Y** and **Z** are optoswitches.



(a) Name the types of binary coding used in discs **A** and **B**. [1]

Disc **A** ....

Disc **B** ....

(b) What kind of measurement is disc **C** primarily designed for? [1]

....

(c) (i) Describe the problem that could occur as disc **B** rotates from the position shown in the diagram. [1]

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(ii) Illustrate this problem by giving an example. [1]

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(iii) Why does this problem not occur in disc **A**? [1]

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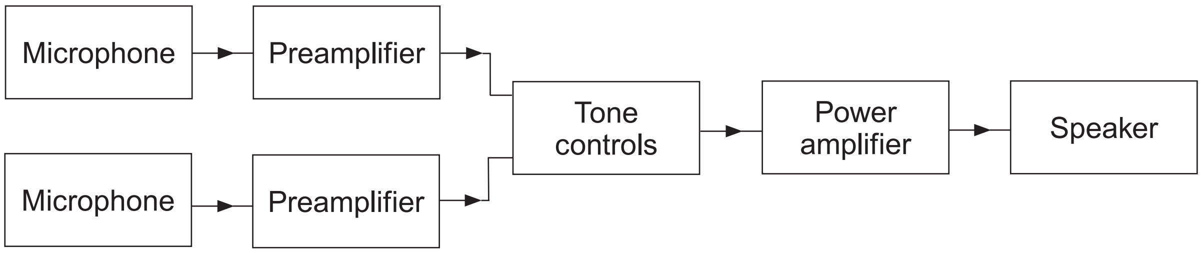
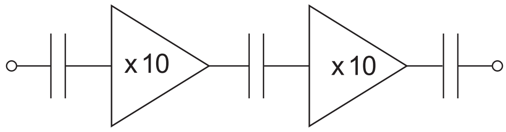
8. The diagram shows the structure of a public-address system.



(a) The preamplifiers are designed in the following way:



(i) Why are two separate voltage amplifiers used instead of a single amplifier with a voltage gain of 100? [1]

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(ii) What is the purpose of the capacitors in this design? [1]

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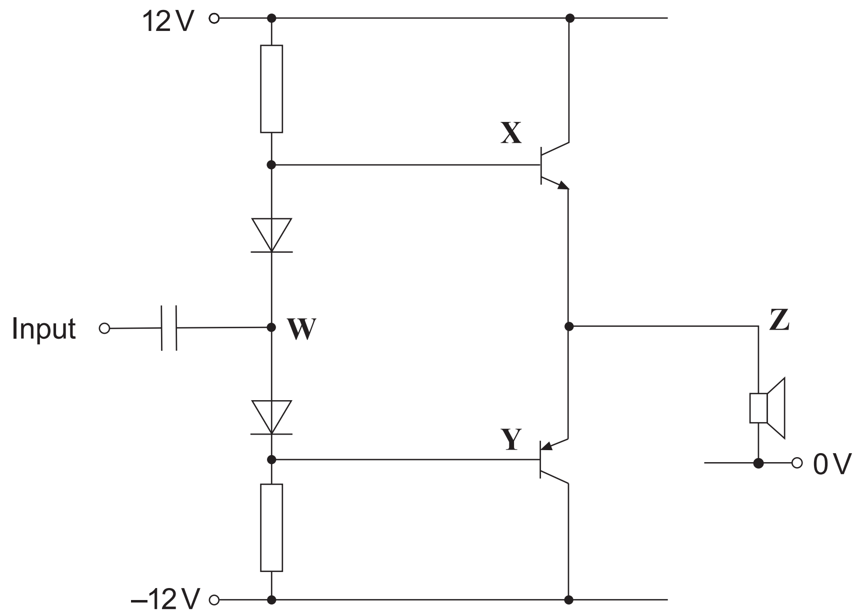
(b) The circuit diagram for the power amplifier is shown below.



(i) The voltage at **W** = 0 V.

What is the voltage at:

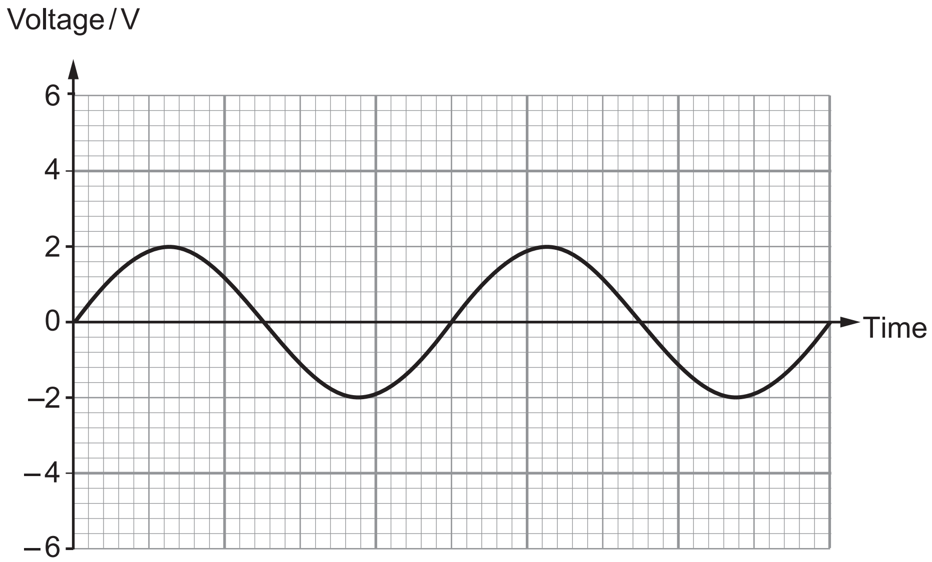
X; Answer = ... V [1]

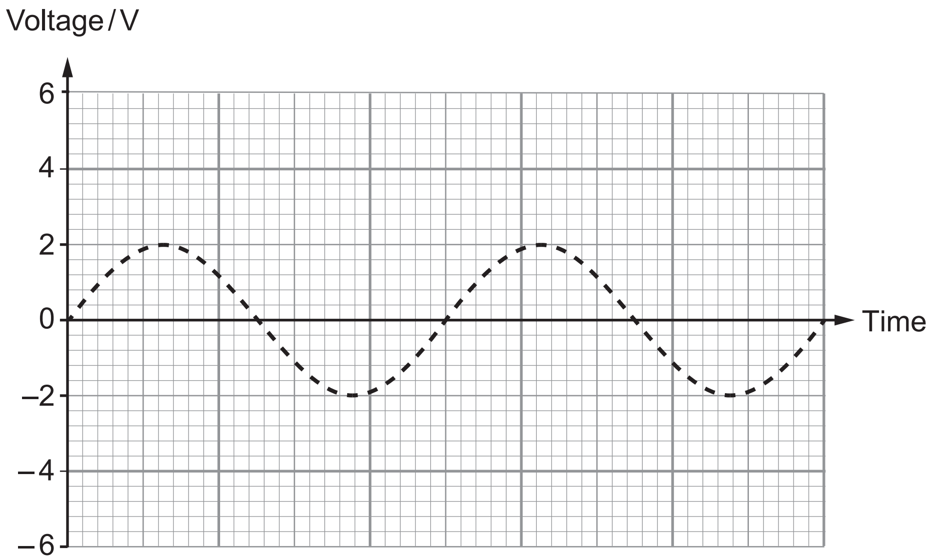
Y; Answer = ... V [1]

Z? Answer = ... V [1]

Examiner only

(ii) The upper graph shows a signal applied to the input of the power amplifier. Complete the lower graph by drawing the corresponding output signal at **Z**. (The input signal is shown as a dotted line.) [2]





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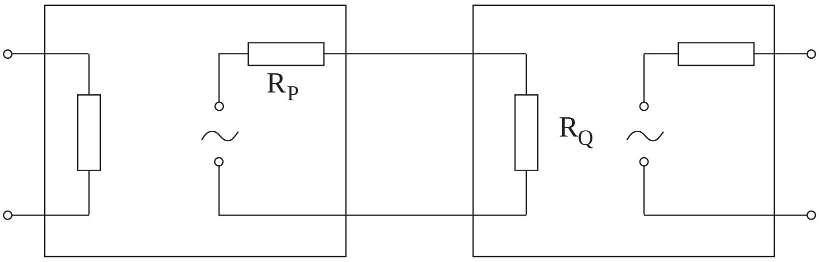
(c) The following diagram shows the equivalent circuit for two sub-systems, **P** and **Q**.



Subsystem **P**　　　　Subsystem **Q**

To ensure maximum voltage transfer of the signal from **P** to **Q**, what must be the relationship between R_P and R_Q? [1]

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END OF PAPER

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