Surname	Centre Number	Candidate Number
Other Names		2

GCE A Level – LEGACY

1145/01

S19-1145-01

ELECTRONICS – ET5

MONDAY, 10 JUNE 2019 – AFTERNOON

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**15**	
2.	**16**	
3.	**10**	
4.	**10**	
5.	**11**	
6.	**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

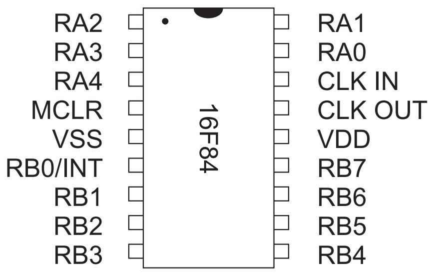
Power amplifier $P_{MAX} = \dfrac{V_S^2}{8R_L}$ where V_S is the rail-to-rail voltage

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:



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

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Answer **all** *questions.*

1. *(a)* A ripple counter has a propagation delay of 70 ns.

(i) Explain the meaning of the term *propagation delay*. [1]

....

....

(ii) How is the problem of propagation delay overcome in synchronous counters? [1]

....

....

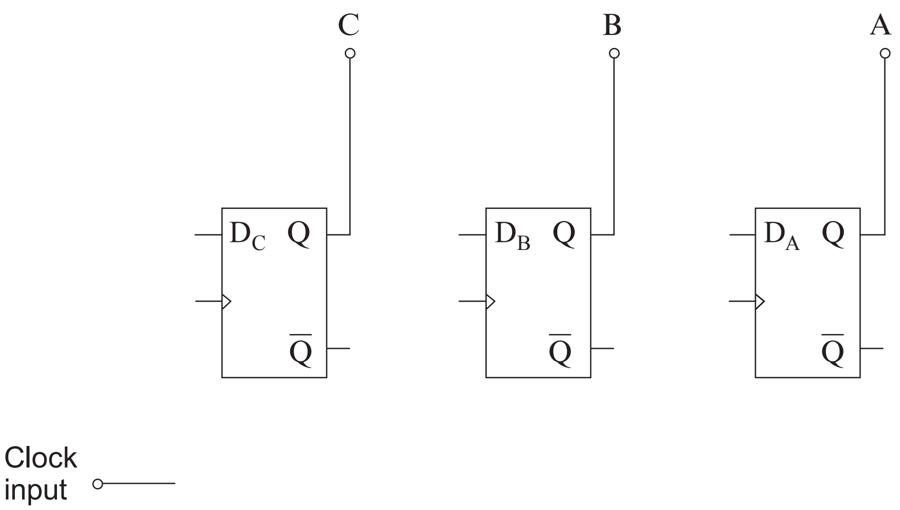
(b) A sequence generator is governed by the following Boolean equations.

$$D_A = \overline{A}$$

$$D_B = B \oplus A$$

$$D_C = \overline{B \oplus A}$$

(i) Complete the circuit diagram for this sequence generator. [4]



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(ii) Complete the following truth table to show the main sequence for this sequence generator. It contains only four states. [3]

	Current state			Next state		
State	**C**	**B**	**A**	D_C	D_B	D_A
0	0	1	0			
1						
2						
3						

(iii) Identify the unused states for this system.
For each, show the state into which the unused state leads. [4]

Unused state			Next state		
C	**B**	**A**	D_C	D_B	D_A

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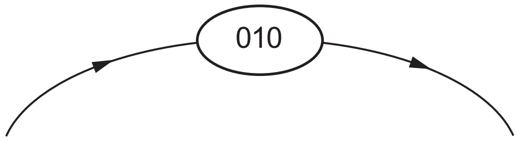
(iv) Hence draw the state diagram for this sequence generator. [2]



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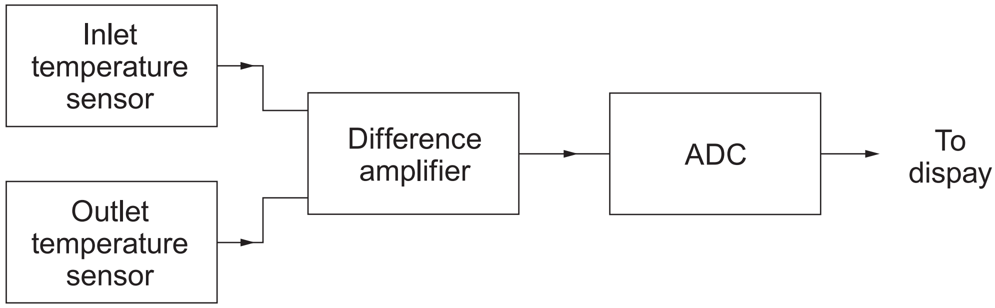
2. A student designs a system to monitor the performance of a solar water heater. It displays the temperature difference between the cold water entering the inlet and the water leaving the outlet of the solar heater.

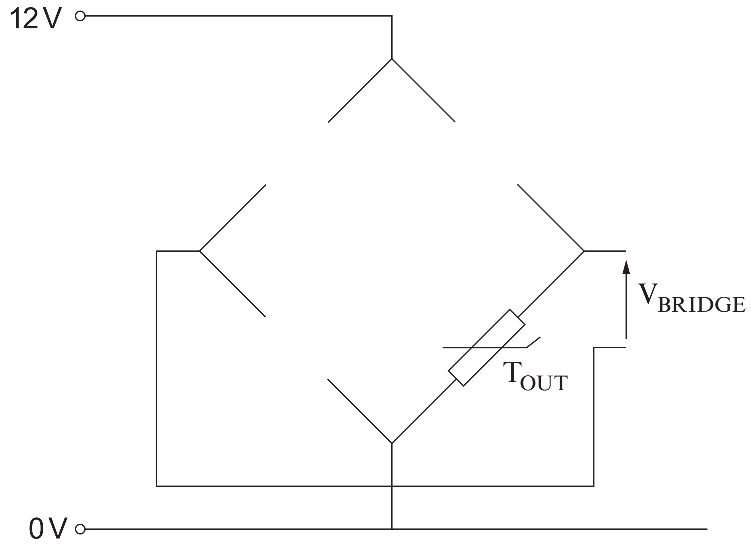
Part of the block diagram for the instrumentation system is shown below.



(a) The inlet temperature sensor uses thermistor T_{IN} while the outlet sensor uses thermistor T_{OUT}.

Design a bridge circuit that uses these thermistors to generate an output voltage that:
- can be adjusted to zero when the inlet and outlet temperatures are the same;
- is negative when the water leaving the heater is hotter than the water entering.

Complete the circuit diagram below with your design for the bridge circuit.
Label all components clearly. [3]



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(b) The difference amplifier boosts the signal from the bridge circuit.

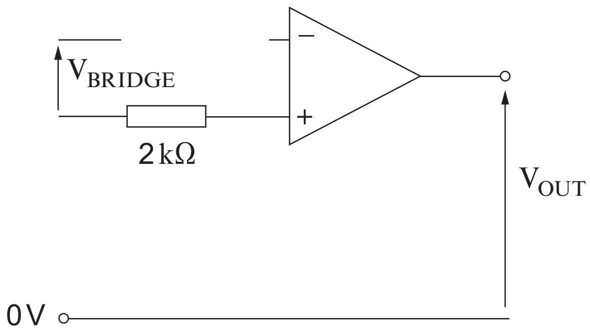
When the bridge circuit output, V_{BRIDGE}, = –2 mV, the difference amplifier output, V_{OUT} = +100 mV.

(i) Complete the circuit diagram for the difference amplifier. [2]

(ii) Calculate suitable resistance values for all resistors added to the circuit.
Label the resistors with these values on the circuit diagram. [1]

....

....



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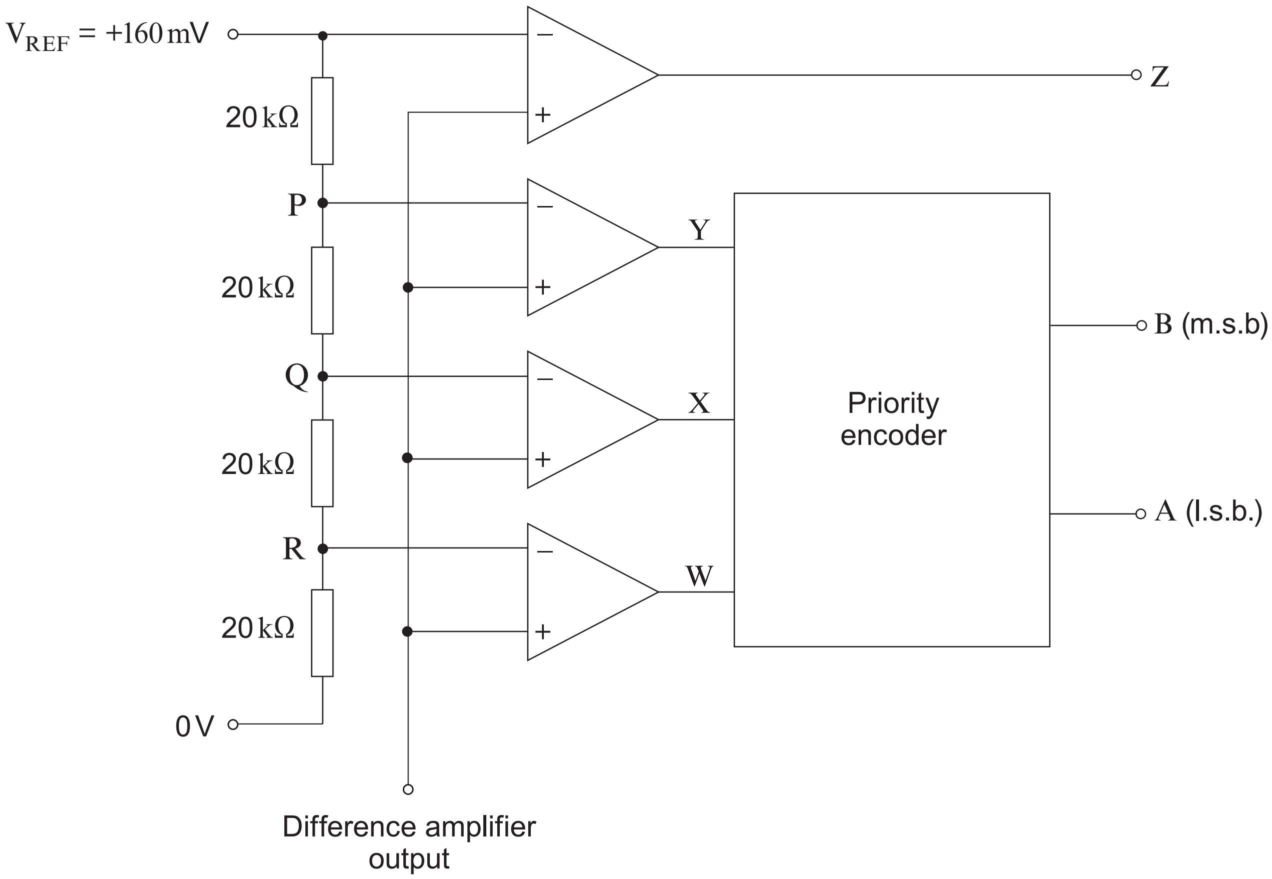
(c) The next diagram shows the ADC circuit.



(i) Calculate the voltages on the resistor chain at points P, Q and R. [3]

....

....

Voltage at P = ... V Voltage at Q = ... V Voltage at R = ... V

(ii) The first column of the table below gives two typical output voltages from the difference amplifier.

Complete the table to show the corresponding output voltages of the op-amps, at W, X and Y, and the binary output BA of the ADC.

The saturation voltages of the op-amps are + 12 V and 0 V. [4]

Output of difference amplifier / mV	Voltage at W / V	Voltage at X / V	Voltage at Y / V	Binary output	
				B	A
30					
100					

Examiner only

(iii) What is the purpose of output Z? [1]

....

....

(iv) The reference voltage, V_{REF}, is increased to 250 mV.
What is the effect on the performance of the ADC? [1]

....

....

(v) The student decides to replace the 2-bit ADC with an 8-bit ADC.
How many comparators are needed to make an eight-bit flash converter? [1]

....

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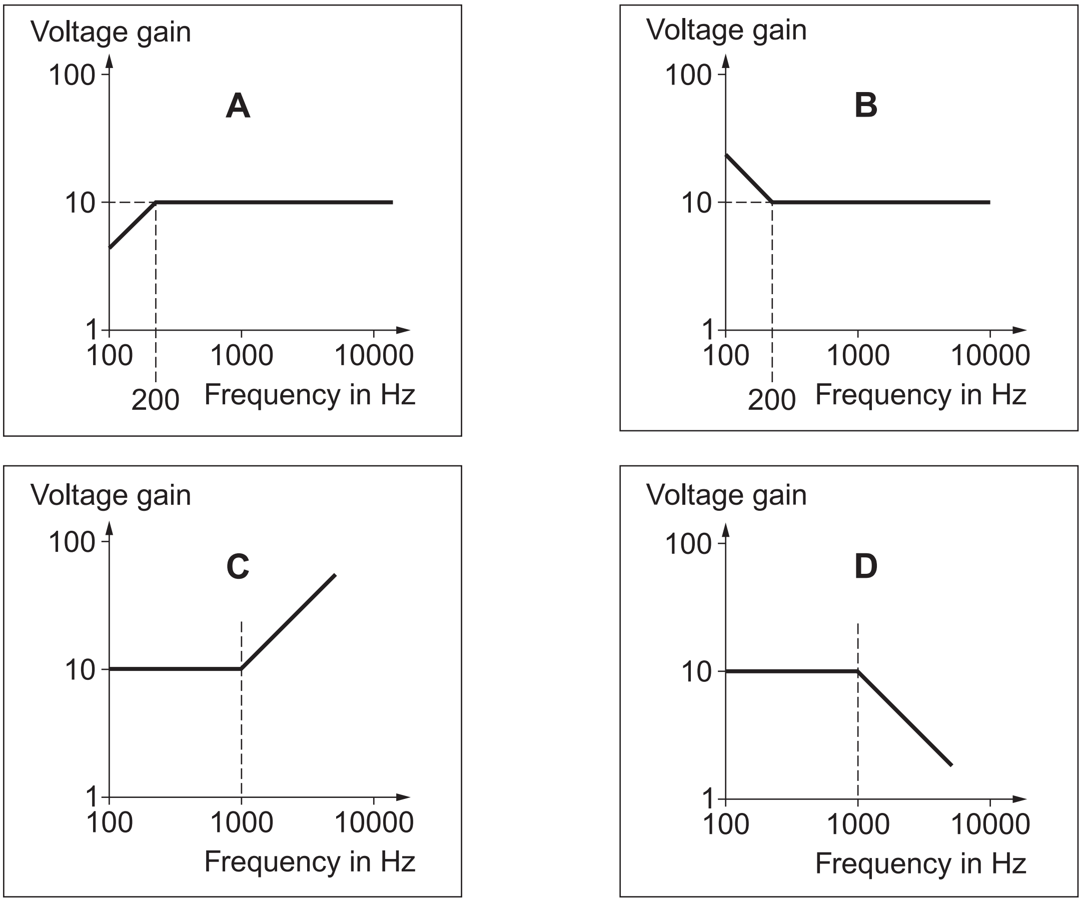
3. *(a)* In terms of voltage gain, what is the difference between the performance of an active filter and a passive filter? [1]

....

....

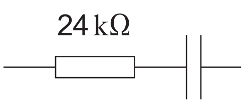
(b) Here are the frequency responses of four filters:



Which one of these filters is:

- a treble cut filter; .... [1]
- a bass boost filter? .... [1]

(c) The following RC network determines the frequency response for filter **B**:



At what frequency, in Hz, does the reactance of the capacitor equal 24 kΩ? [1]

.... Hz

Examiner only

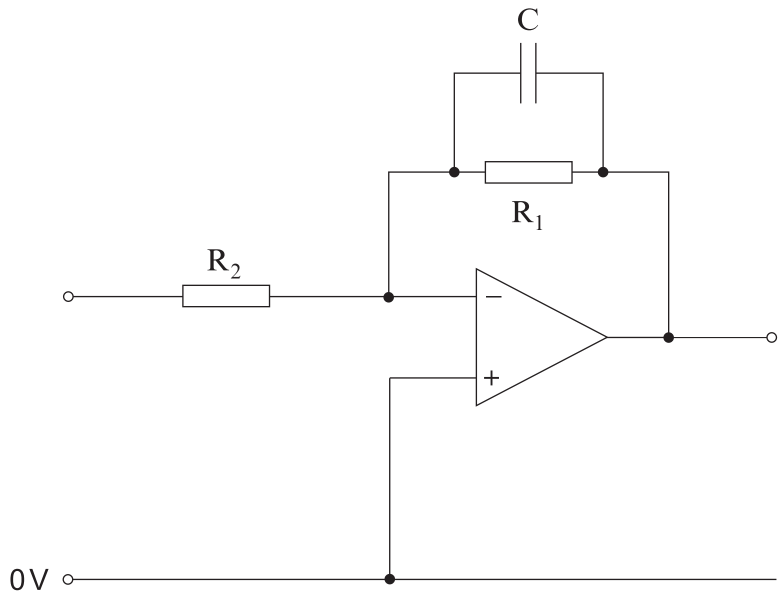
(d) A signal of amplitude 20 mV and frequency 500 Hz is applied to the **input** of filter **A**.

At the **output** of this filter, what is:

(i) the amplitude of the signal; .... [1]

(ii) the frequency of the signal? .... [1]

(e) The circuit diagram for a filter is shown below:



It has:

- a break frequency of 750 Hz;
- a voltage gain of 20 at a frequency of 500 Hz.

The following resistors are available.

10 Ω 50 Ω 200 Ω 1 kΩ 10 kΩ 50 kΩ 200 kΩ

(i) Select the one pair of resistors that is most suitable to give the specified voltage gain. [2]

R_1 ....

R_2 ....

(ii) Calculate the value of capacitor required to give this break frequency. [2]

....

....

....

....

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4. The control system for a robot arm uses a microcontroller.

It includes a **stop** button that suspends the operation and gives a visual warning.

The visual warning pulses two lamps, **X** and **Y** until a **reset** button is pressed.

(a) Why is it best to have the **stop** button connected to trigger an interrupt rather than being checked as part of the main program? [1]

....

....

....

....

(b) Complete the following instructions to:

- clear all interrupt flags;
- enable the RB0/INT external interrupt;
- disable all other interrupt sources. [2]

```
movlw     b'.............................'
movwf     INTCON
```

(c) (i) The interrupt service routine (ISR) starts with the instruction

```
movwf     tempstore
```

Why is this instruction needed? [1]

....

....

....

....

(ii) Before leaving the ISR, there needs to be an instruction with the opposite effect.

What is this instruction? [1]

....

Examiner only

(d) (i) When the **stop** button is pressed, warning lamps **X** and **Y** pulse alternately, each on for one second and then off for one second.

This part of the ISR uses a one second delay subroutine called 'onesec'.
Lamp **X** is driven from Port A bit 0 and lamp **Y** from Port A bit 1.

Complete the instructions to make the lamps pulse as described above.
No other bits of Port A should be affected by the instructions. [3]

206	**repeat**	**bsf**	....	; switch on lamp **X** only
207		**bcf**	....	; switch off lamp **Y** only
208		**call**	....	; wait one second
209		**bsf**	....	; switch on lamp **Y** only
210		**bcf**	....	; switch off lamp **X** only
211		**call**	....	; wait one second

(ii) The **reset** button is connected to Port B bit 2.

When pressed, it outputs a logic 1 signal. When released, it outputs logic 0.

Until it is pressed, the program keeps looping back to the instruction labelled **repeat**.

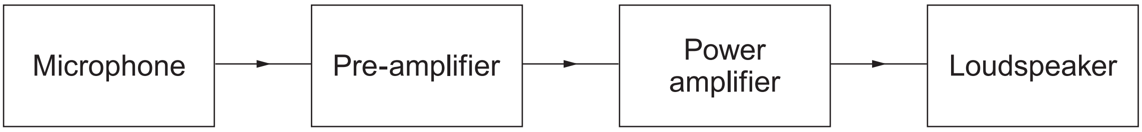
When the **reset** button is pressed, the ISR continues to completion and does not loop back.

Complete the instructions to check if it has been pressed and respond appropriately. [2]

212		**btfss**	....	; check if the **reset** button is pressed
213		**goto**	....	; loop back to continue flashing lamps

Examiner only

5. *(a)* The block diagram for an audio system is shown below:



In this system:

- the microphone has an impedance of 160 kΩ;
- the loudspeaker has an impedance of 16 Ω.

Correct impedance matching ensures that a sub-system efficiently transfers a voltage signal, or transfers power to the following subsystem.

(i) Which value of input impedance for the pre-amplifier would maximize the **voltage** signal transferred from the microphone to the pre-amplifier?

16 Ω   160 Ω   16 kΩ   160 kΩ   1600 kΩ   [1]

Answer = ...

(ii) Which value of output impedance for the power amplifier would maximise the **power** transferred from the power amplifier to the loudspeaker?

16 Ω   160 Ω   16 kΩ   160 kΩ   1600 kΩ   [1]

Answer = ...

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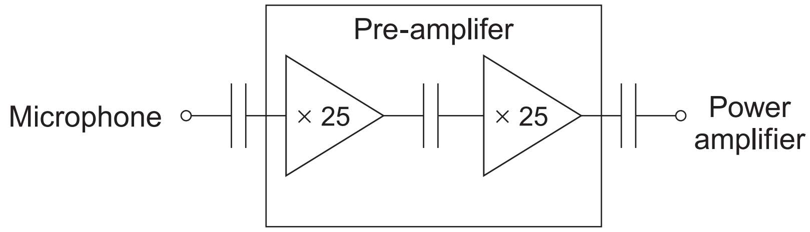
(b) The pre-amplifier consists of a 2-stage non-inverting amplifier, shown in the following diagram:



(i) What is the overall voltage gain of the pre-amplifier? [1]

....

....

(ii) The table gives some data on the op-amps used in the pre-amplifier.

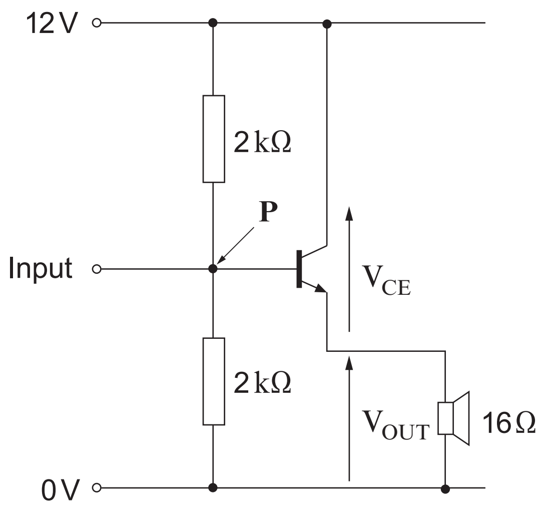
Parameter	Typical Value
Open-loop voltage gain	1×10^5
Gain bandwidth product	6 MHz
Slew-rate	$10\ \text{V}\,\mu\text{s}^{-1}$
Common mode rejection ratio	85 dB

What is the bandwidth of the pre-amplifier? [2]

....

....

(c) The circuit diagram for the power amplifier is shown below:



The loudspeaker has an impedance of 16 Ω.

With no input signal present a current of 330 mA flows through the loudspeaker.

With no input signal present calculate:

(i) the DC voltage at point **P**; [1]

....

(ii) the DC output voltage V_{OUT}; [1]

....

(iii) the DC voltage drop across the transistor, V_{CE}; [1]

....

(iv) the DC power dissipated in the transistor; [1]

....

(v) the DC power dissipated in the loudspeaker. [2]

....

....

....

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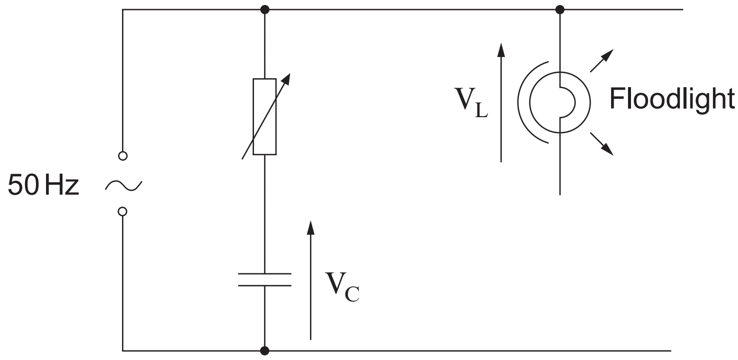
6. The brightness of a floodlight is controlled by a thyristor, using a phase-control sub-system. The circuit diagram shows part of the control system.



(a) Complete the circuit diagram for the control system by adding:

- the thyristor;
- a diac, connected to shorten the turn-on time for the thyristor. [2]

(b) The capacitor has a capacitance of 10 μF.
The variable resistor is set to a resistance of 1 kΩ.
Calculate the phase shift between the AC supply voltage V_S and the voltage across the capacitor V_C. [3]

....

....

....

....

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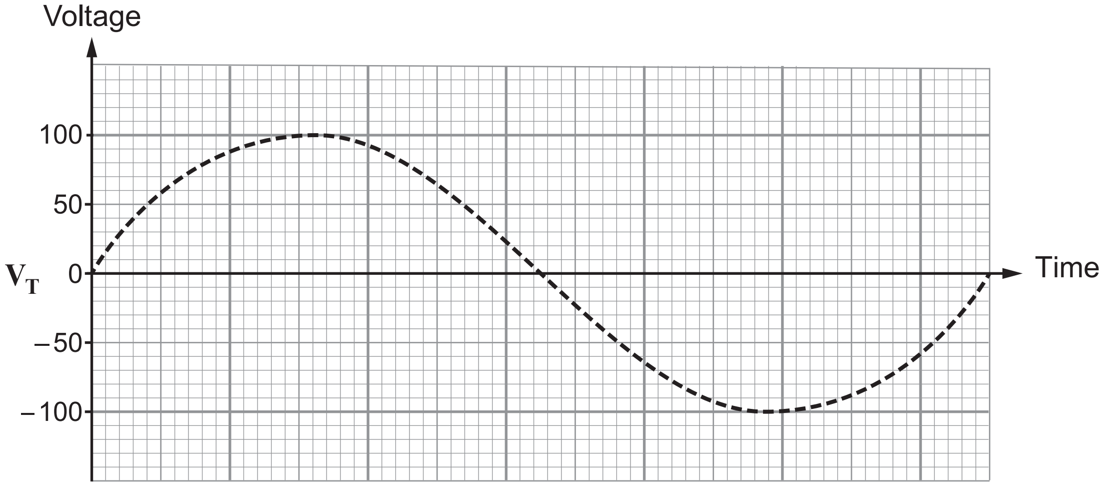
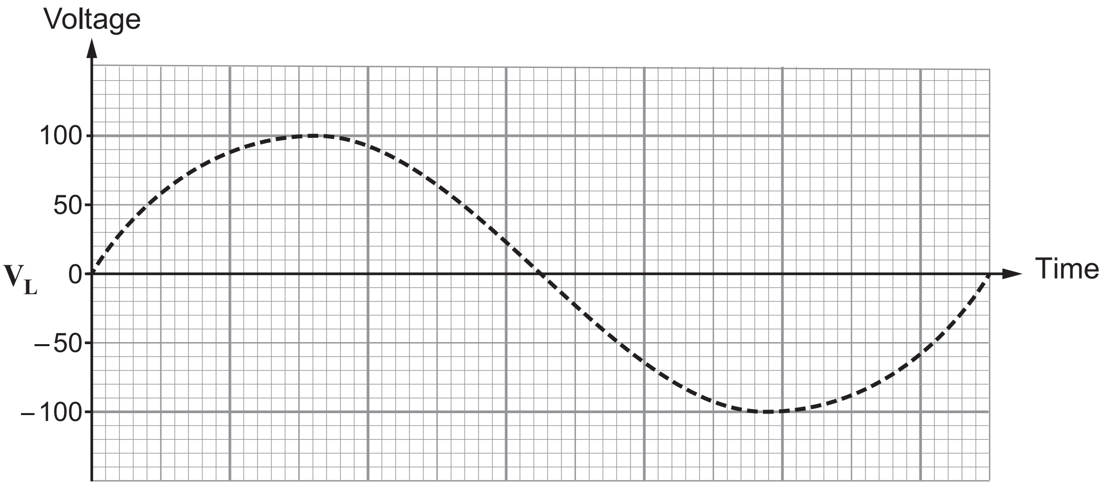
(c) The thyristor conducts when V_C reaches 25 V.
The variable resistor is set to give a phase shift of 0°.

Use the axes provided to sketch waveforms for the voltage V_T across the thyristor, and V_L across the floodlight. The waveform of the supply voltage V_S is shown as a dashed line. [3]





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