

# Control Electronics

## Revision Questions

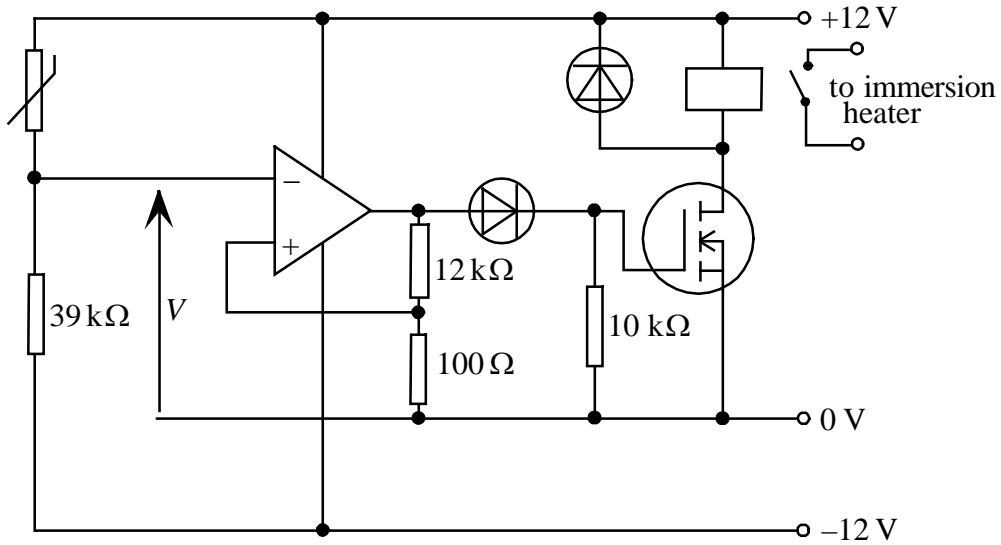
### from

## previous syllabi.

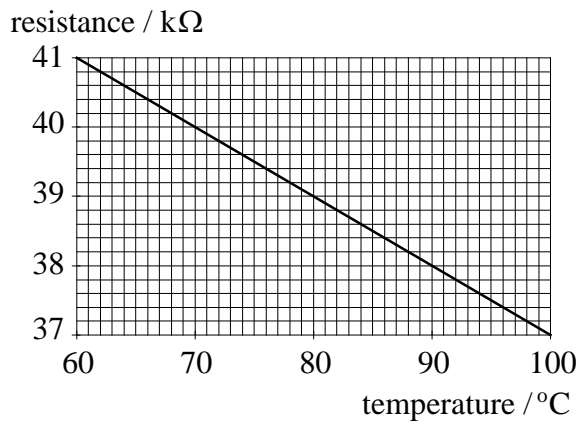
These do not cover the complete specification but may provide useful examination practice.

When considering these questions please remember that approximately 40% of each A2 module examination must consist of synoptic questions.

1). The circuit diagram for a thermostat for a hot water system is shown below.



The characteristic for the thermistor is shown in the graph below.



(a) The op-amp is arranged as a Schmitt trigger. Calculate the values of the input voltage,  $V$ , which make the output of the op-amp switch from +12 V to -12 V and from -12 V to +12 V.

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(3)

(b) Calculate the maximum and minimum temperatures of the hot water system.

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(3)

- (c) Explain which resistor would have to be changed to alter the mean temperature of the hot water.

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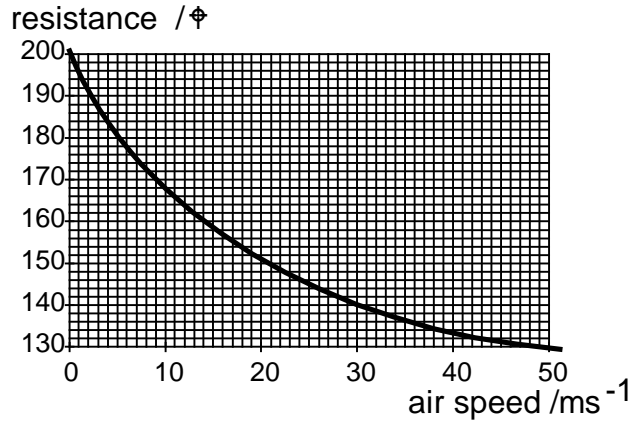
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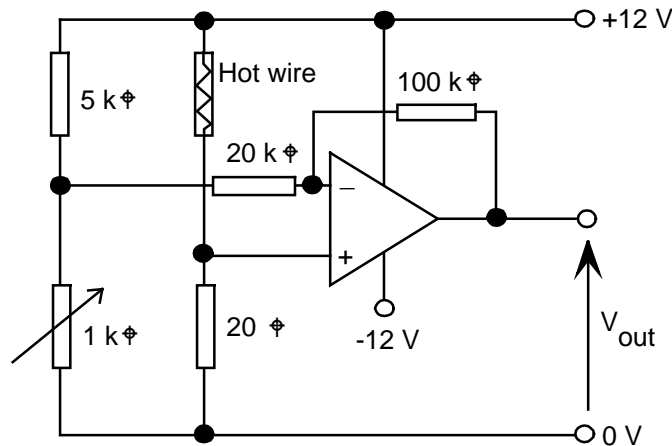
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- 2). A hot wire anemometer is an instrument used to measure wind speed. It consists of a small piece of wire heated to a temperature of approximately  $300^{\circ}\text{C}$ , in still air, by passing an electric current through it. As the wind blows air past it the hot wire is cooled and the resistance of the wire changes. The diagram below shows how the resistance of the hot wire changes with wind speed.



The hot wire is connected to the circuit shown below



- (a) (i) Calculate the power dissipated in the hot wire when it is in still air.

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- (ii) What would be a suitable power rating for the  $20\ \Omega$  resistor?

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(1)

- (b) (i) Determine the value of the variable resistor so that  $V_{out}$  is zero when the air speed is zero.

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(1)

- (ii) What will be the resistance of the hot wire when the wind speed is 50m/s

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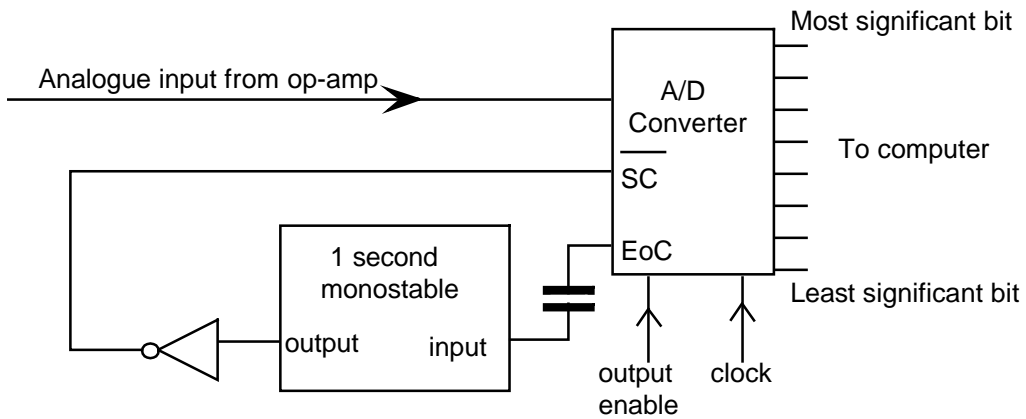
(1)

- (iii) Calculate  $V_{out}$  when the wind speed is 50m/s.

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- (c) To enable the wind speed to be monitored by a computer,  $V_{out}$  is converted into an eight bit number using the circuit shown below



Explain the function of:-

- (i) the Start Conversion input (SC)

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(1)

(ii) the End of Conversion output (EoC).

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(1)

(d) How often would the wind speed be converted to a digital value by the circuit.

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(1)

(e) (i) Draw a circuit diagram of a NAND gate monostable and explain how it functions.

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(4)

(ii) State suitable values of R and C for the monostable to give a time period of 1 second.

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(2)

(f) An output of  $1111111_2$  is obtained for an analogue input voltage of 2.55V.

(i) What wind speed does this correspond to?

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(1)

(ii) What is the smallest change in wind speed that could be detected by the computer?

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(1)

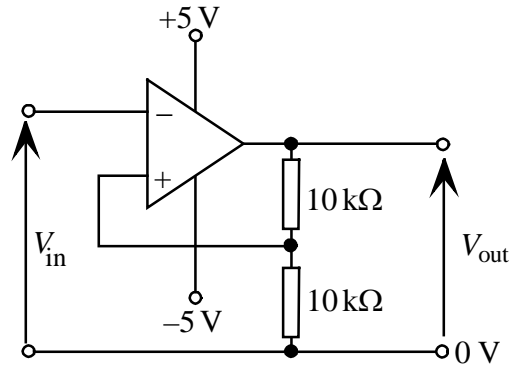
(g) Explain **one** advantage and **one** disadvantage of using this system of storing wind speed in a computer compared to recording the analogue voltage,  $V_{out}$ , using a chart recorder.

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3). The circuit diagram for a Schmitt trigger is shown below. Assume that the op-amp saturates at  $\pm 5\text{ V}$ .



(a) (i) Calculate the trigger levels of the circuit.

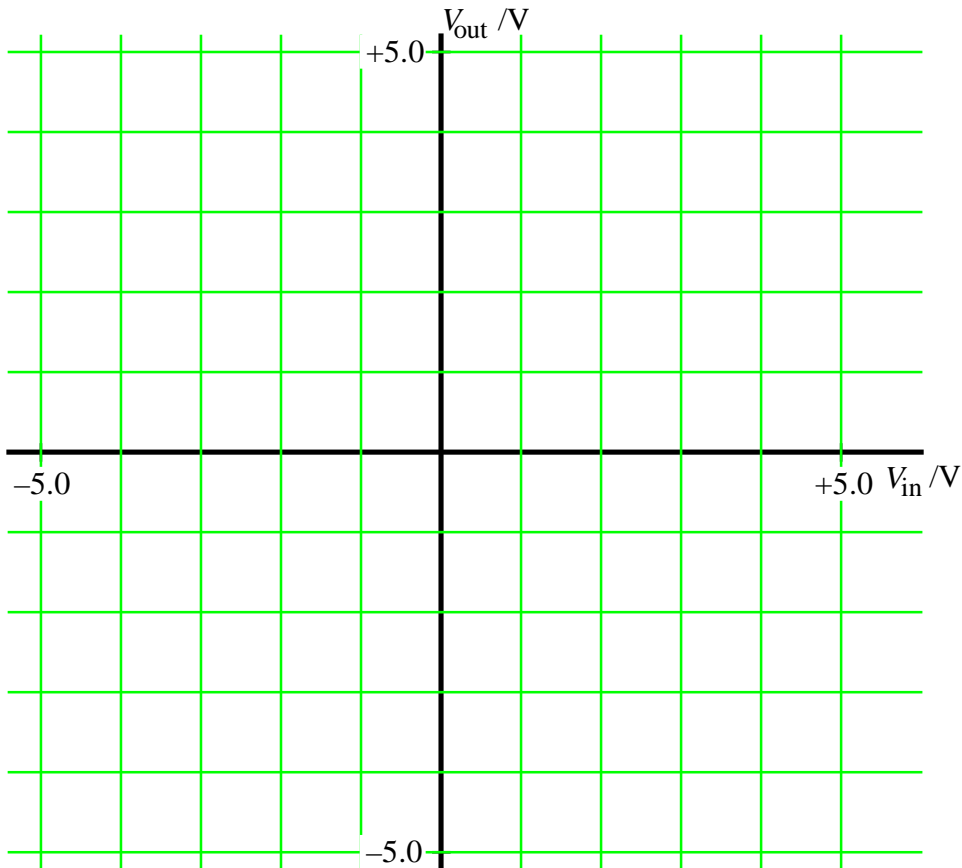
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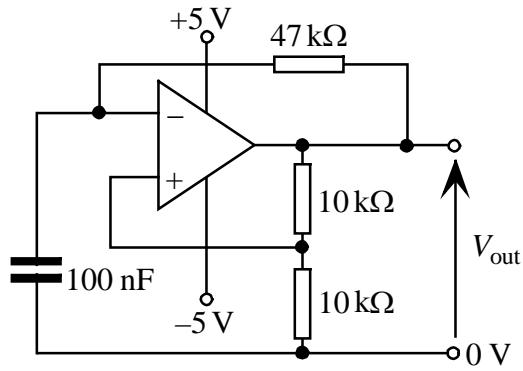
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(ii) On the axes below sketch a graph to show  $V_{out}$  as  $V_{in}$  varies from  $-5\text{ V}$  to  $+5\text{ V}$ . (2)



(2)

- (b) A capacitor and resistor are now connected to the Schmitt trigger circuit as shown below.



The capacitor is fully discharged and  $V_{out}$  becomes +5 V when the circuit is first switched on.

Describe the subsequent changes that occur to the voltage across the capacitor.

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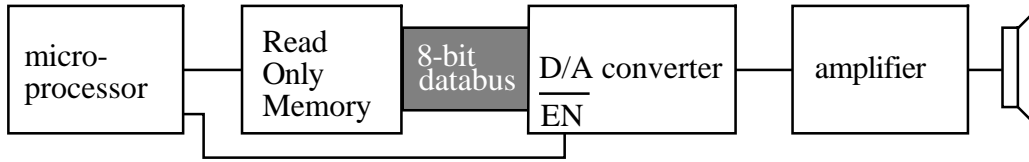
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(4)

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- 4). Instead of producing a detailed instruction booklet, a telephone answering machine manufacturer decides to incorporate 'spoken instructions' for the user. These 'spoken instructions' are stored in a Read Only Memory (ROM) and the whole system is controlled by a microcontroller. A block diagram of the audio output part of the system is shown.



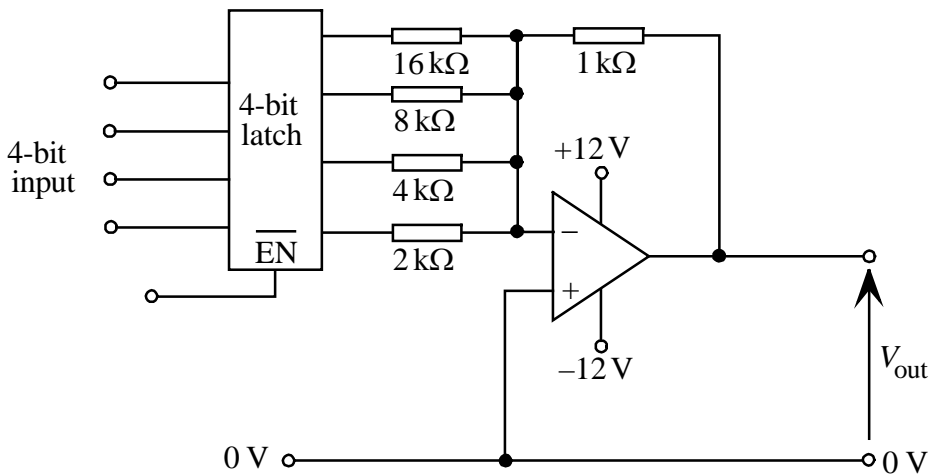
- (a) The D/A converter has an 8-bit data input. How many different analogue voltages can be obtained from the output?

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 (1)

- (b) Explain the function of the  $\overline{EN}$  input on the D/A converter.

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 (2)

- (c) The circuit diagram for a 4-bit D/A converter is shown below.



Each of the digital outputs from the latch is either at +3 V for logic 1 or 0 V for logic 0. What is the value of  $V_{out}$  when the input is 1011?

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- (d) Explain what changes would have to be made to the circuit above to make it into an 8-bit D/A converter. Give the values of any other components that you would add.

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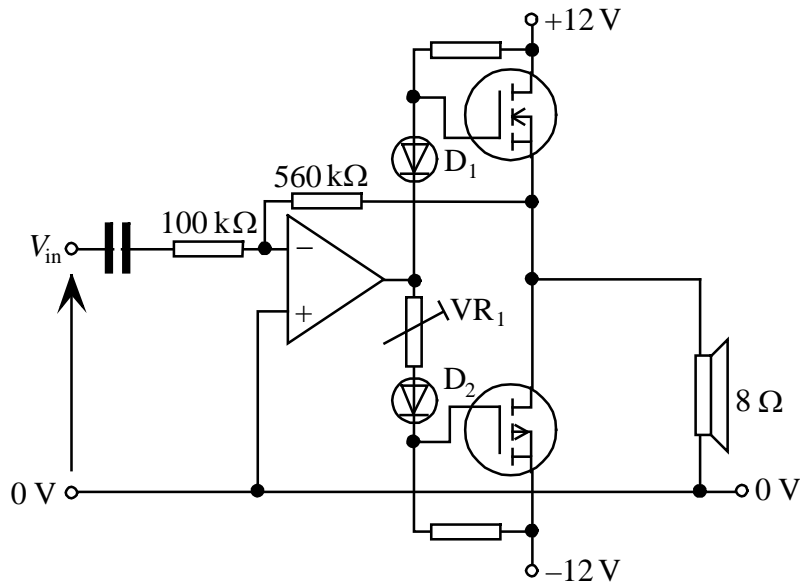
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- (e) There is inadequate power from the D/A converter to operate a loudspeaker, so it is connected to the amplifier circuit shown below.



- (i) Using a diagram, explain what is meant by cross-over distortion.

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(2)

- (ii) Explain how  $D_1$ ,  $D_2$  and  $VR_1$  minimise this effect.

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(1)

(iii) Calculate the voltage gain of the circuit.

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(1)

(iv) Estimate the maximum power output to the speaker.

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(3)

(f) To store incoming messages the answering machine contains a 256 Kbyte RAM. The IC has 8 data lines.

(i) How many memory address inputs does it have?

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(1)

(ii) If the message is sampled 4000 times per second, what is the maximum duration of the message that can be stored?

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(g) By referring to:-

- the address bus,
- the  $\overline{CS}$  input and
- the R /  $\overline{W}$  input

explain how a byte of data is stored in the RAM.

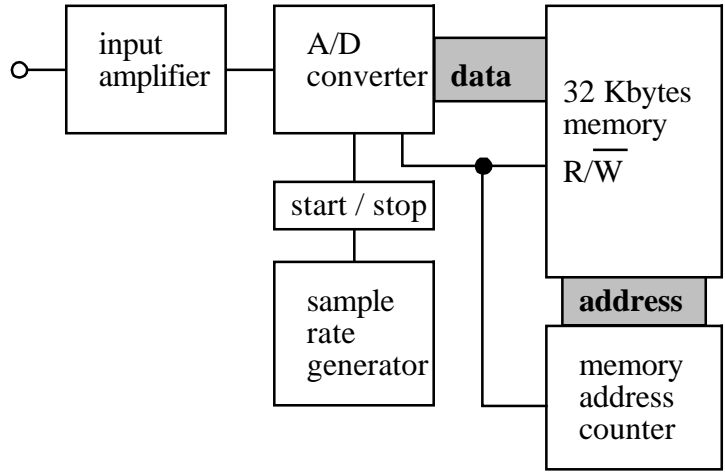
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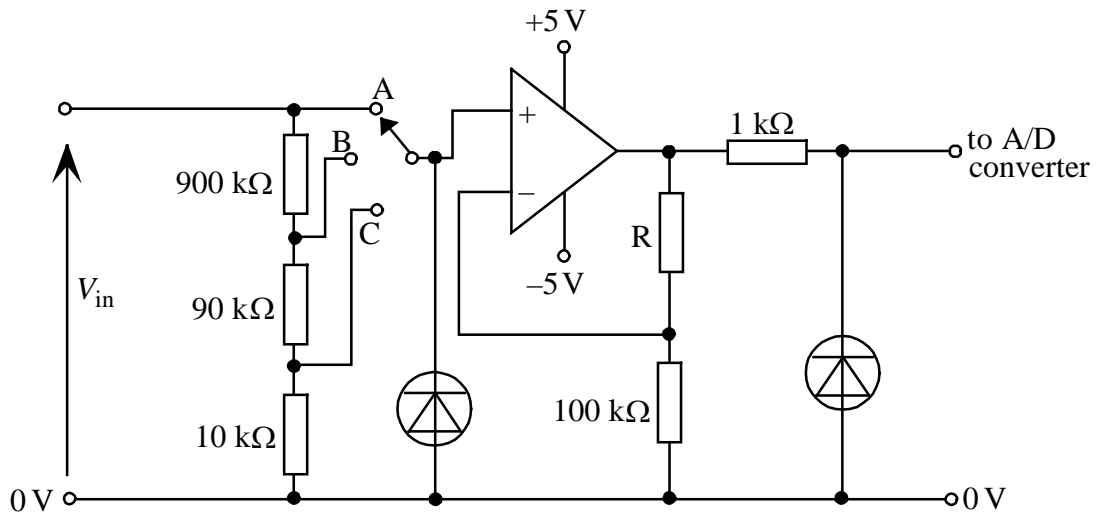
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5). The diagram shows part of the block diagram of an environmental monitoring system.



(a) The input amplifier circuit, shown below, has three input ranges with the most sensitive, position A, being 0 - 250 mV. The output of the amplifier is 0 - 1 V and is connected to the A/D converter.



(i) What is the function of the two diodes?

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(ii) Calculate the value of R.

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(3)

(iii) What is the input range when the switch is set to B and C respectively?

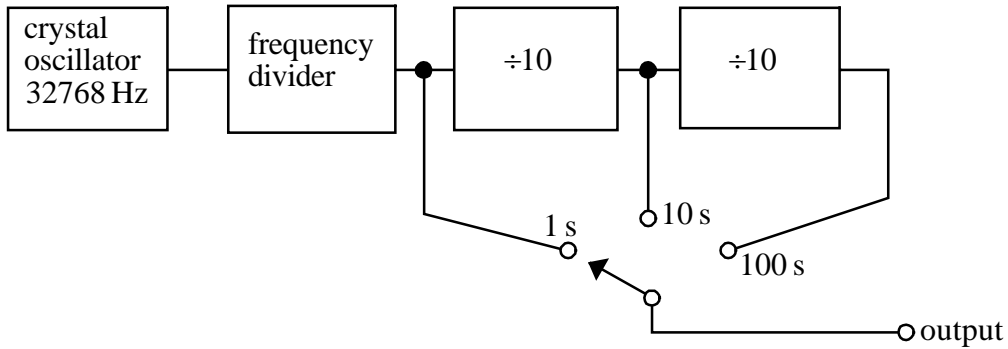
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(b) The diagram below shows the sample rate generator which allows the unit to be set to make samples every 1 s, 10 s, or 100 s.



(i) Explain why a crystal oscillator is used rather than a free running oscillator.

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(ii) How many flip-flops are needed in the frequency divider to give an output of 1 Hz from the 32768 Hz crystal oscillator?

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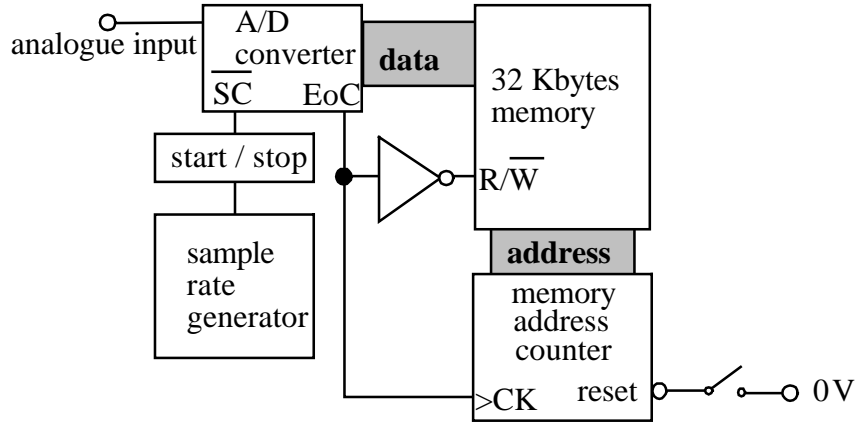
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(iii) Draw a diagram to show how four D-type flip-flops can be connected so as to divide the input frequency by 10 and provide a mark to space ratio of 1:1.

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(c) The system uses an 8-bit A/D converter connected as shown below.



(i) With reference to the diagram above, describe the sequence of events that occur when a measurement is made.

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(6)

(ii) If the A/D converter gives a converted value of  $11111010_2$  for an input of 1.00 V, what will be the converted value of an input of 125 mV?

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(iii) Estimate the percentage uncertainty in the measured value of 125 mV as a result of the digital conversion.

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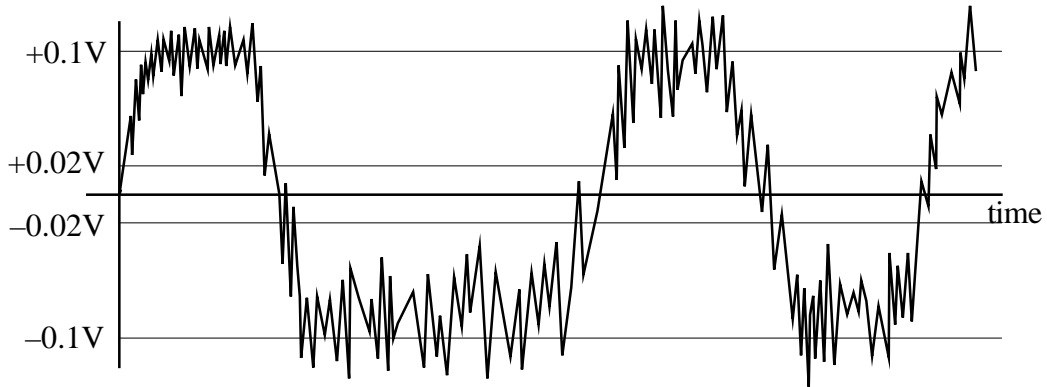
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6). The diagram shows the output signal from a digital communication device.



(a) Before the signal can be used it has to be converted into a square wave form. Explain why a voltage comparator is unsuitable for this application and why a Schmitt trigger circuit could solve the problem.

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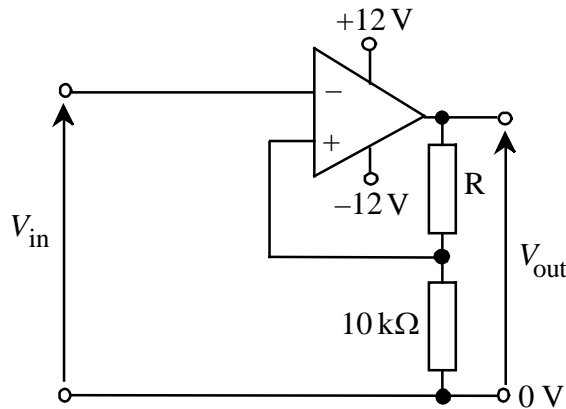
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(b) The signal is fed into the Schmitt trigger circuit shown below.



Calculate a suitable value for the resistor R if the voltage switching levels of the Schmitt trigger are to be  $\pm 0.02$  V.

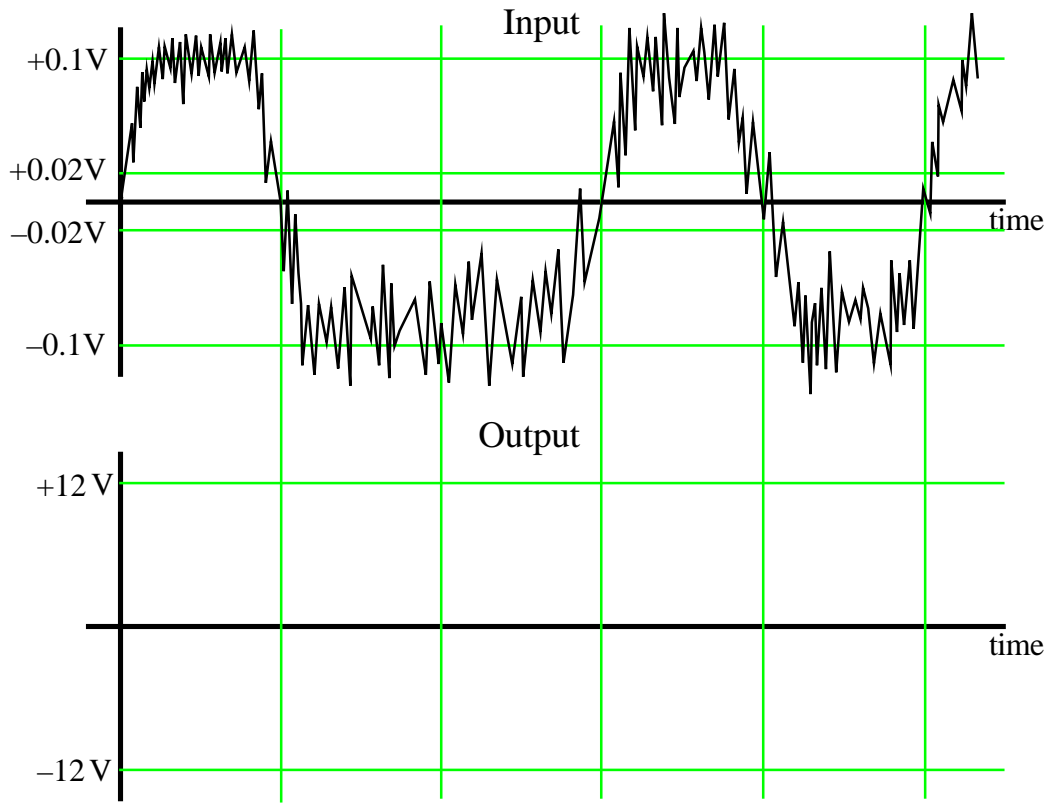
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- (c) The signal shown is fed into the Schmitt trigger. Mark the output waveform onto the axes below



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(9)  
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7). This question is about the subsystems used in a digital storage unit which can be added to an analogue oscilloscope.

(a) An ADC (A/D converter) has control lines of Start Conversion ( $\overline{\text{SC}}$ ), Output Enable ( $\overline{\text{OE}}$ ) and End of Conversion ( $\text{EoC}$ ).

(i) Describe the sequence of signals on the control lines for the ADC to make a conversion.

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(2)

(ii) What is the function of the Output Enable ( $\overline{\text{OE}}$ ) control line?

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(1)

(b) A RAM IC has control lines of Chip Select ( $\overline{\text{CS}}$ ), Read/Write ( $\text{R}/\overline{\text{W}}$ ) Output Enable ( $\overline{\text{OE}}$ ) and connections to the address bus and data bus.

(i) Explain the purpose of the *address bus*.

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(1)

(ii) Describe the sequence of events for a byte of data to be written to a RAM IC.

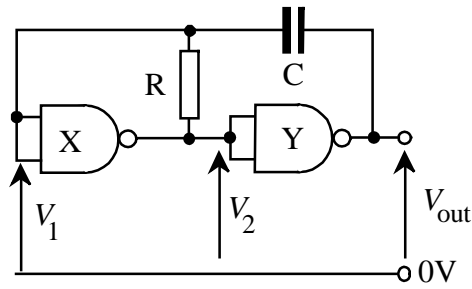
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(4)

(c) An 8-bit counter is made from D-type flip-flops. Draw a circuit diagram to show how a D-type flip-flop can be connected to operate as part of the counter.

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(d) The clock oscillator is a NAND gate astable as shown in the circuit diagram below.



Explain how the astable works.

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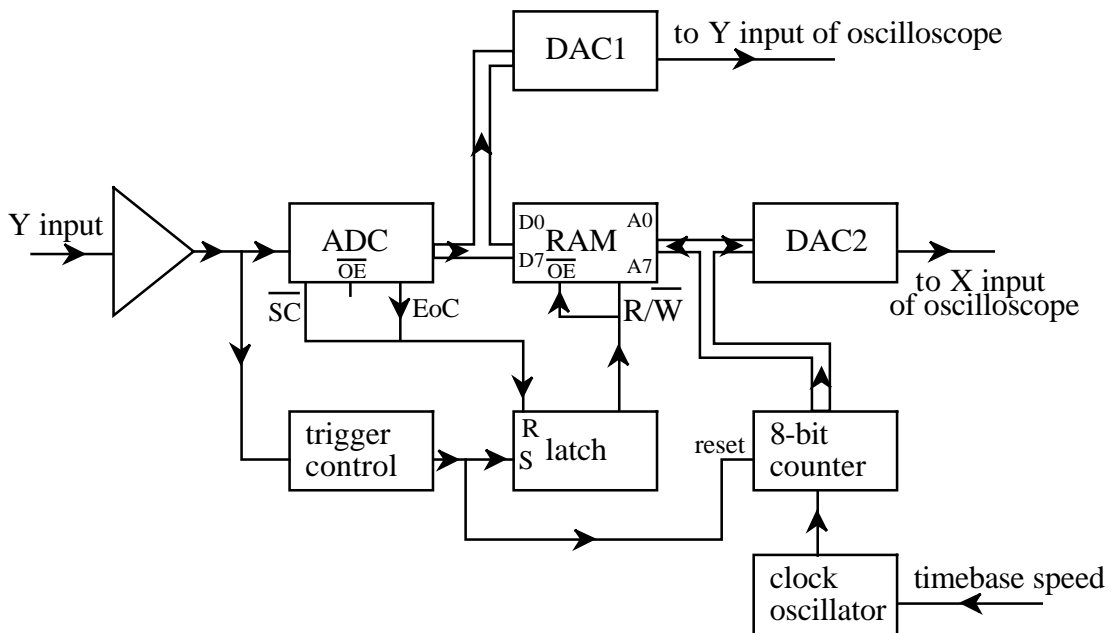
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The block diagram for the digital storage unit is shown below. The Y-input is scaled to provide a voltage in the range  $-1.27V$  to  $+1.27V$ . This analogue voltage is converted into an 8-bit binary number by the ADC, the most significant bit when set being used to represent negative numbers. Each measured value is then stored in the RAM. The timebase is derived from an 8-bit counter which is converted to an analogue voltage by DAC2 (D/A converter 2) before being passed to the X-input of the oscilloscope.



(e) The oscilloscope has a 10cm wide screen and a display that is scanned the full width of the screen.

(i) How many display points can be stored by the system?

..... (1)

(ii) Estimate, showing your working, how far apart each display point is on the screen.

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..... (1)

(iii) Estimate, showing your working, the frequency of the clock oscillator when the system is recording a signal with a timebase speed of 1ms/cm.

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..... (4)

(iv) Estimate the voltage at the input of the ADC that would be represented by the binary number output of 11011001.

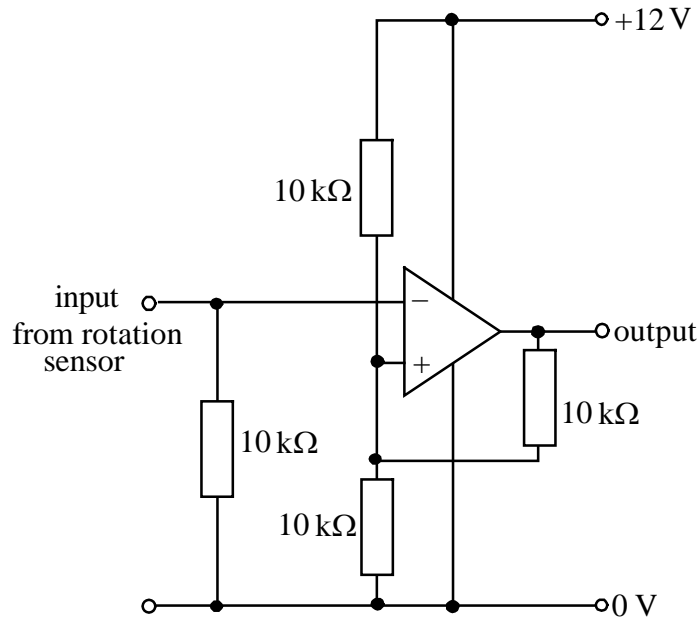
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(v) When displaying a very rapidly changing input voltage, the screen can sometimes become covered in random white dots. Suggest a reason for this.

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(24)  
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8). The engine management unit in a modern car measures the speed of the engine using a rotation sensor. The sensor normally has a logic 0 output ( $<3\text{ V}$ ) and gives a logic 1 pulse ( $>9\text{ V}$ ) for every  $10^\circ$  of rotation of the engine. The output from the rotation sensor is connected to the Schmitt trigger circuit shown below.



(a) Suggest a reason why a Schmitt trigger is needed in this application.

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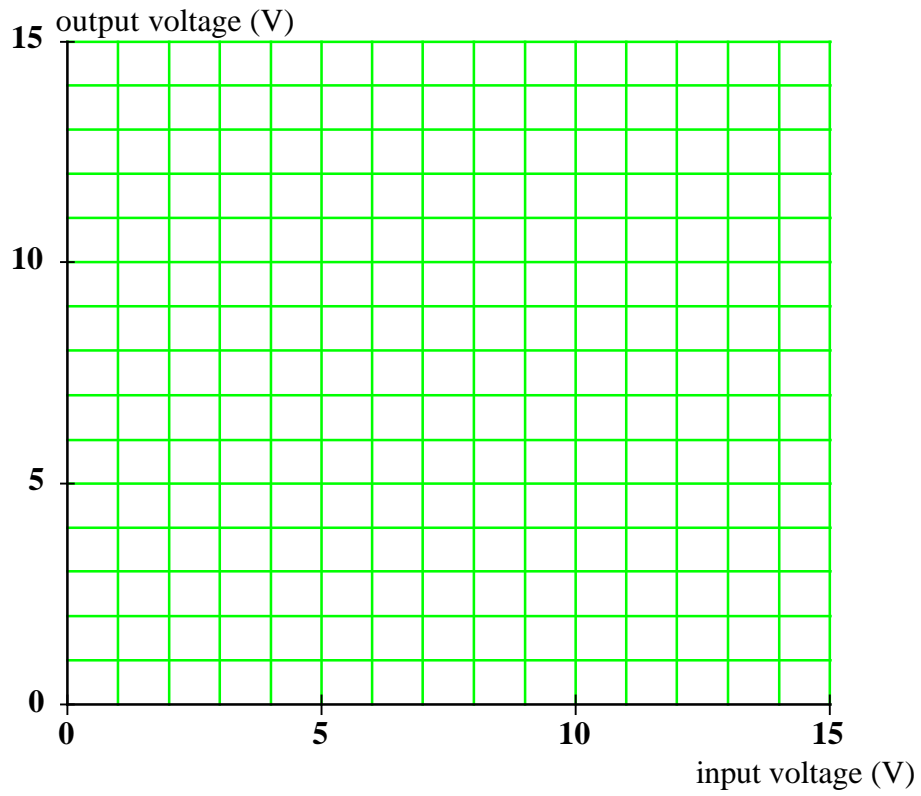
(1)

(b) Show that the upper and lower switching voltages of the Schmitt trigger in the circuit above are 8 V and 4 V respectively. Assume that the op-amp output is either +12 V or 0 V.

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- c). Draw a sketch on the axes below to show how the output voltage varies with the input voltage.

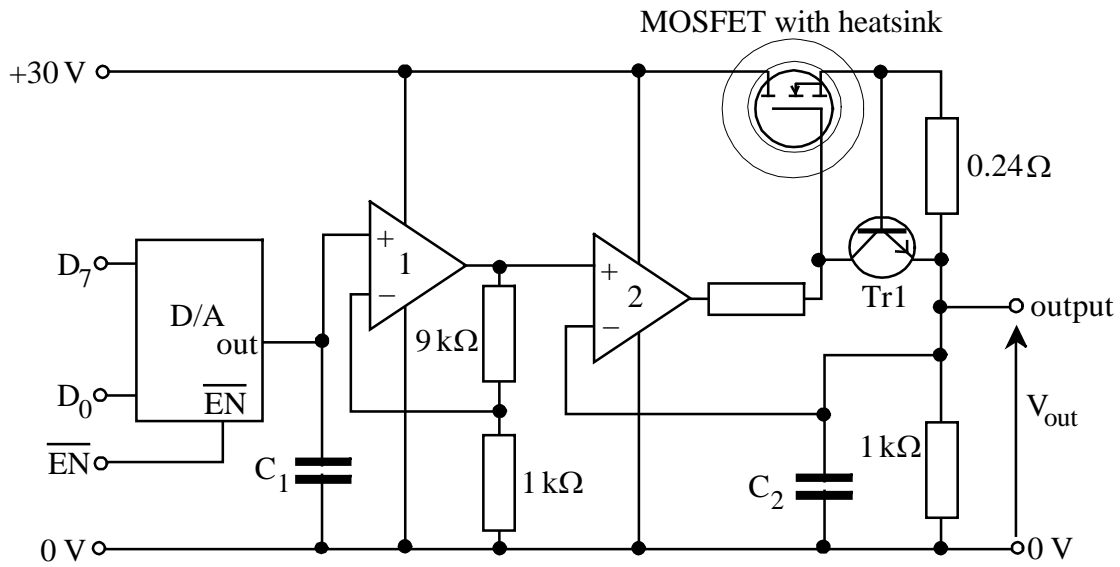


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9). The circuit diagram for a simple computer controlled power supply is shown below.



- (a) State the sequence of signals necessary for a byte of data to be written to the D/A converter.
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- ..... (2)
- (b) The maximum output voltage from the D/A converter is 2.55 V.
- (i) Show that the smallest increment that the output voltage of the D/A can change by is 0.01 V.
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- ..... (1)
- (ii) What would be the output voltage of the D/A converter if the binary input were 11001000?
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- ..... (2)
- (c) (i) What is the voltage gain of op-amp 1?
- ..... (1)
- (ii) What is the function of op-amp 2?
- ..... (1)

- (d) (i) Explain how the circuit is able to produce an output voltage,  $V_{out}$ , that is controlled by the byte of data stored in the D/A converter.

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- (ii) What is the purpose of  $C_1$  and  $C_2$ ?

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(1)

- (e) The power supply is providing 12 V at 2 A to a circuit connected to its output terminals.

- (i) Show that the power dissipated in the MOSFET is approximately 36 W.

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(2)

- (ii) To enable the MOSFET to dissipate this power it is bolted to a heat sink. State **three** essential features in the design of an efficient heat sink.

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(3)

- (iii) The MOSFET is mounted onto a heat sink with a thermal resistance of  $1.1\text{ }^\circ\text{C/W}$ . If the ambient temperature is  $20\text{ }^\circ\text{C}$ , what temperature will the MOSFET be at when the power supply is producing 12 V at 2 A?

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(f) TR1 is included to limit the maximum current that the power supply can provide.

(i) Explain how this is achieved.

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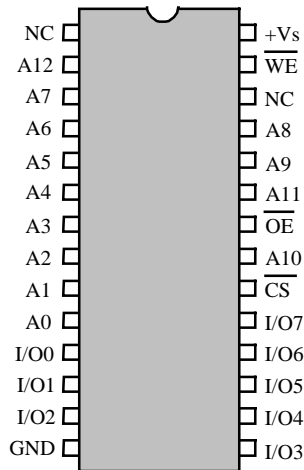
(ii) Estimate the maximum output current of the power supply.

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10). The diagram below shows the pin connections for a static CMOS RAM IC.



(a) Calculate how many bytes of data the RAM IC can store.

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(b) By describing the signals that are put onto each of the pins of the IC, explain how a byte of data can be written into the IC.

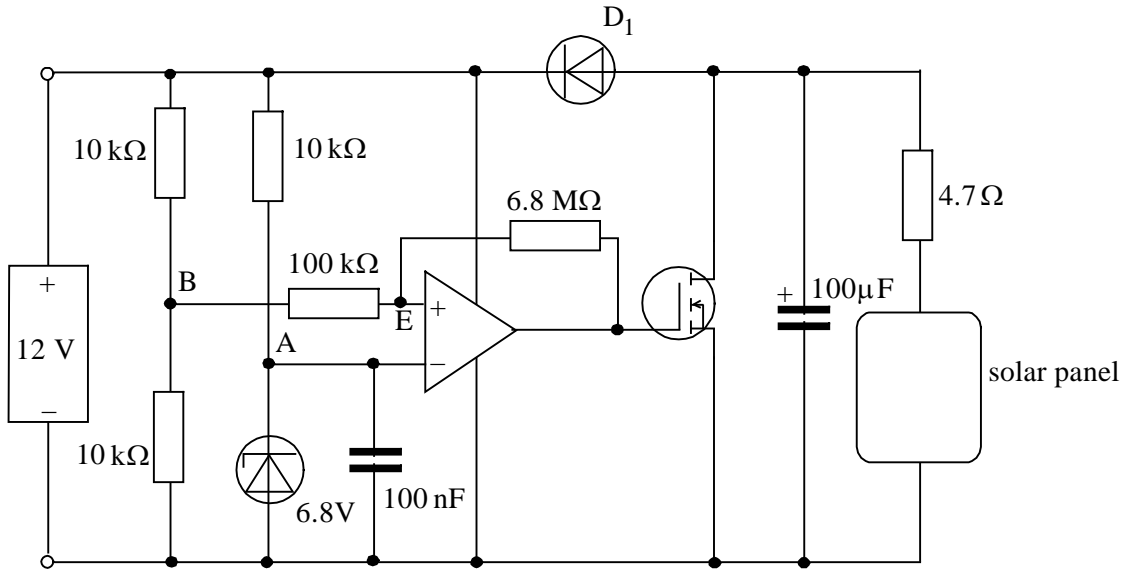
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11). A 12 volt lead acid battery is to be kept charged by a solar panel. The output voltage from the solar panel varies from 0V in total darkness to 20V in bright sunlight. The battery needs to be charged at a voltage not exceeding 13.8V. The circuit diagram is shown below.



(a) What is the function of diode  $D_1$ ?

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..... (2)

(b) (i) What is the voltage at point A?

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(ii) If the voltage across the battery is 13.8V, what is the voltage at point B?

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..... (1)

(c) The op-amp is arranged as a Schmitt trigger. Briefly state **two** properties of a Schmitt trigger.

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- (d) When the op-amp output is low it has a voltage of zero. Show that the voltage at point E is 6.8V when the voltage across the battery is 13.8V.

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(2)

- (e) If the voltage across the battery increases above 13.8V, describe what will happen.

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(3)

(11)  
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