NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2021

ELECTRICAL TECHNOLOGY: DIGITAL

MARKING GUIDELINES

Time: 3 hours 200 marks

These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.

The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.

GENERAL

- All marking is done by the marker in red.
- The marker may not make any corrections on the candidate's Answer Book.
- The memorandum serves as a guideline only.
- Alternative answers must be considered.
- A tick must be placed at each correct answer for which a candidate receives a mark.
- A cross "x" must be placed at each answer that is wrong.
- Calculations are marked as follows, unless stated otherwise:
  - 1 mark is awarded for the formula.
  - 1 mark is awarded for the substitution.
  - 1 mark is awarded for the answer with the correct applicable unit shown.
  - If the unit is indicated incorrectly, the answer is marked as wrong.
  - If an incorrect answer has to be used in the subsequent calculation, it is taken as correct in that calculation and the answer of the relevant calculation must be recalculated by the marker and marked accordingly. An arrow must be inserted from the incorrect answer to the subsequent calculation where substitution has been done with the incorrect answer to show that the incorrect answer has been taken into consideration.
- Sketches are marked by awarding 1 mark for the drawing if it was drawn correctly and all the other marks are awarded for the correct labels.
- See also the marking notes at some answers.
- A line must be drawn through all work that is not applicable to the answer, for example rough work.
- A diagonal line must be drawn through the space for questions that the candidate left open.
- A diagonal line must be drawn through all pages of the answer book that were not used by the candidate.
- A horizontal line must be drawn by the marker at the end of each question to indicate the end of the question.
- The marks for each question are written in a circle on the left-hand side at the beginning of the relevant question.
- The mark allocations for answers are written on the right-hand side of the page below one another. No circles are made around these marks.
- This memorandum consists of 15 pages.

QUESTION 1 GENERAL MULTIPLE-CHOICE QUESTIONS

1.1 C

1.2 D

1.3 A

1.4 B

1.5 B

1.6 D

1.7 A

1.8 B

1.9 C

1.10 B

1.11 D

1.12 D

1.13 C

1.14 A

1.15 B

QUESTION 2 SAFETY

2.1 The person who uses operational equipment or machinery to his own advantage or who has control over the use of operational equipment or machinery.

2.2 Each employer must, as far as is reasonably practicable, run his business in such a way that people who are not employed by him and who are not directly affected by his activities are not exposed by them to threats to their health or safety.

OR

Each employer must protect the people who are not employed by him from activities at his workplace.

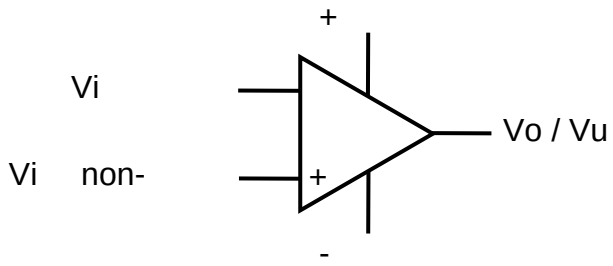
2.3
- Someone who designs, manufactures, imports, sells or supplies an article for use at the workplace must, as far as is reasonably practicable, ensure that the article is safe and without health risks when it is used properly and that it complies with all prescribed requirements.
- Someone who erects or installs an article on or in any premises for use at the workplace must, as far as is reasonably practicable, ensure that nothing about the way it is erected or installed makes it unsafe or creates a health risk when it is used properly.
- When someone designs, manufactures, imports, sells or supplies an article or substance for or to another person and that other person undertakes in writing to take certain steps that are sufficient to ensure, as far as is reasonably practicable, that the article or substance will comply with all prescribed requirements and be safe and without health risks when it is used properly, the undertaking has the effect to absolve the first-mentioned person of his duty in terms of this article to the degree that is reasonable considering the stipulations of the undertaking.

2.4 You may not switch on the plug of the drill press again to use the drill press.
The plug has been removed because there is something wrong with the drill press and should you use it, you may be injured by the drill press.

2.5 Yes
The safety legislation provides for the criminal prosecution of a worker if the worker refuses to obey safety rules and regulations.

QUESTION 3 SEMICONDUCTORS

3.1



Marking note
- 1 mark for the correct symbol with +Vcc and –Vcc indicated.
- 1 mark for indicating + and – on the symbol.

3.2 3.2.1 The signal will be 10 × greater than the input signal/the output will be 1 V and the output signal will be 180° out of phase with the input signal.

3.2.2 The signal will be 11 × greater than the input signal/the output will be 1,1 V and the output signal will be in phase with the input signal.

3.3 3.3.1 No the output signal is incorrect.
The output signal should be 180° out of phase with the input signal because the circuit is an inverting amplifier.

3.3.2 $V_O = V_I\left(-\frac{R_f}{R_I}\right)$

$3 = 20\times10^{-3}\left(\frac{150\times10^{3}}{R_I}\right)$

$R_I = 1\ k\Omega$

OR

$V_O = V_I\left(-\frac{R_f}{R_I}\right)$

$3 = 20m\left(\frac{150k}{R_I}\right)$

$R_I = 1\ k\Omega$

3.4 3.4.1 Discharge terminal is used to connect PIN 7 to the earth potential (0 V) when the output of the 555 timer is low.

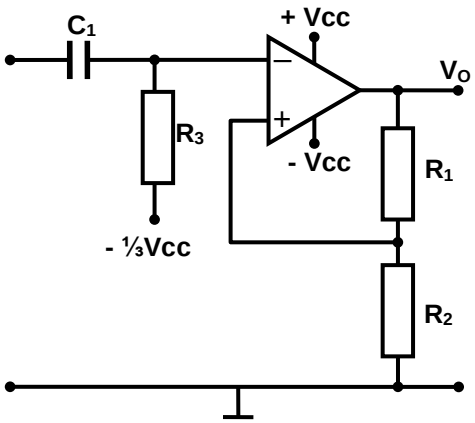
3.4.2 Threshold-voltage terminal is used to switch the output of the 555-timer to low if the voltage on the terminal is more than ⅔ Vcc.

3.4.3 The trigger terminal is used to switch the output of the 555-timer to high if the voltage on the terminal is less than ⅓ Vcc.

3.5
- Bistable multivibrator
- Monostable multivibrator

QUESTION 4 SWITCH AND CONTROL CIRCUITS

4.1



Marking note

- 1 mark is awarded for the correct IEC symbol of the 741-op-amp fully labelled with +Vcc and –Vcc and Vo shown.
- 1 mark is awarded per component with correct label correctly connected (numbers do not need to correspond to memo).

4.2 4.2.1

$T = CR_f$

$T = 1\times10^{-6}\times2\times10^{3}$

$T = 2\ ms$

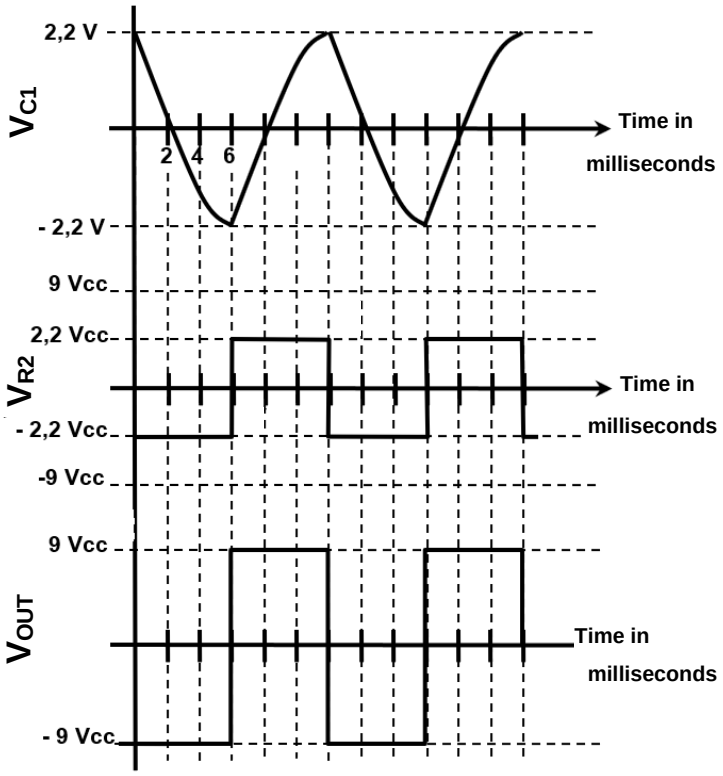
OR

$T = CR_f$

$T = 1\mu\times2k$

$T = 2\ ms$

4.2.2



4.3 $$V_O = -\left(V_{I1}\frac{Rf}{R_1} + V_{I2}\frac{Rf}{R2} + V_{I3}\frac{Rf}{R_3}\right)$$

$$V_O = -\left(150\ m\frac{4{,}7\ k}{2{,}2\ k} + (-300\ m)\frac{4{,}7\ k}{2{,}2\ k} + (-220\ m)\frac{4{,}7\ k}{2{,}2\ k}\right)$$

$$V_O = 790{,}904\ mV$$

4.4 4.4.1
- The positive 12 V output causes a 5 V feedback voltage across resistor R_2.
- The 5 V feedback voltage is applied to the non-inverting input of the circuit
- and serves as a reference voltage for the circuit.
- At 2 s the input voltage on the inverting input will exceed the reference voltage.
- The 741-operational amplifier will react to this input and the input will be amplified maximally out of phase to –12 V.
- The output of the circuit will now switch to –12 V.

Marking note
Any mention of the output that switches to –Vcc at 1 s is marked as incorrect.

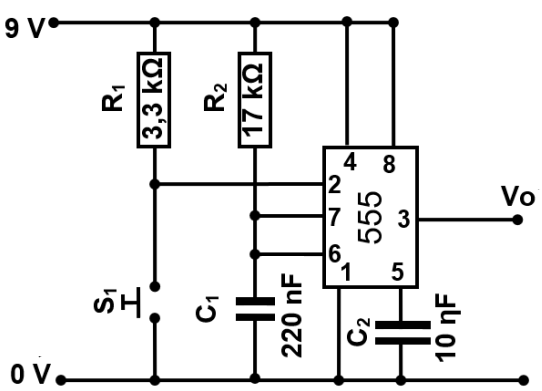
4.4.2
- Remove electrical noise from digital signals.
- Convert sine waves into square waves.
- Convert triangular waves into square waves.
- Switch cooling units between two preset values representing the minimum and maximum temperatures.

4.5 4.5.1 Bistable multivibrator

4.5.2 The Set switch S_1 is pressed. A low pulse is applied to the trigger input of the 555-timer. The 555-timer will react to this input and changes its output to high. The high output will put the LED under forward bias and therefore the LED will be switched on.

4.5.3 Resistor R_2 functions as a pull-up resistor. The resistor keeps the reset input of the 555-timer at a high value as long as pulse switch S_2 is open.

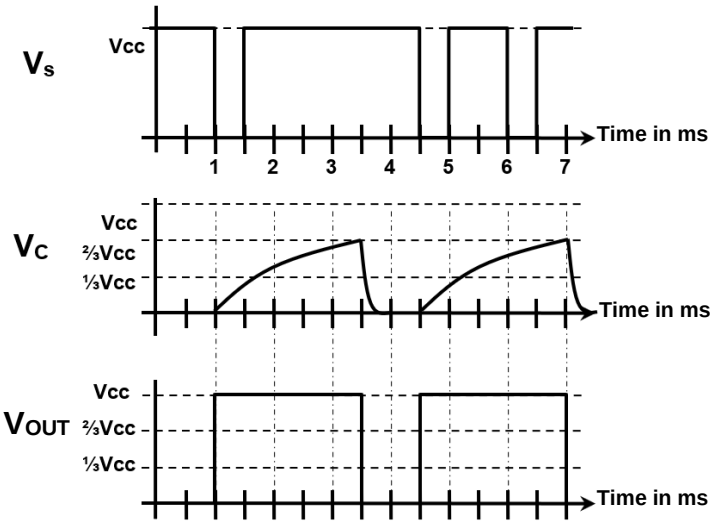
4.6 4.6.1



Marking note

1 mark is awarded per component if the component is labelled correctly and is correctly connected to the 555-timer.
Capacitor C_2 does not need to be shown in the circuit, but if it is left out, PIN 5 should NOT be connected to the 0 V line to receive the mark for the 555-timer.
1 mark is awarded for the 555-timer if it is connected correctly to positive and negative lines and PIN layout is indicated correctly.

4.6.2



Marking note

1 mark is awarded for each Vc wave that is drawn correctly in terms of time and amplitude.
1 mark is awarded for each Vout wave that is drawn correctly in terms of time and amplitude.

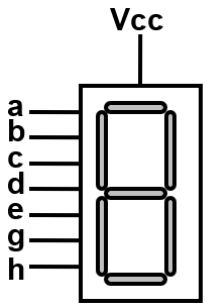
4.6.3 A low voltage is applied to the trigger input of the 555-timer. The 555-timer reacts to this input and switches its output to high. When output tends to be high, the capacitor will start charging at the RC time constant at the same time. When the voltage across the capacitor exceeds the threshold voltage of the 555-timer, the 555-timer switches the output to low. The output remains low until the trigger is pulsed again.

Marking note

Take answer in Questions 4.6.1 into account when marking Question 4.6.3 to avoid double penalisation.

QUESTION 5 DIGITAL AND SEQUENTIAL DEVICES

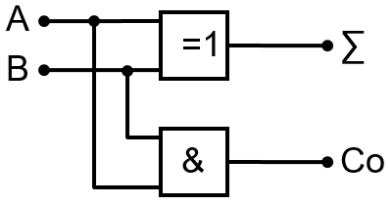
5.1



Marking note
1 mark is awarded to the correct symbol. NB: The line for Vcc must be drawn at the top.
1 mark is awarded to the correct labelling.

5.2 A four-bit binary code is received from a four-bit binary circuit and applied to the input of the driver. The driver then converts the incoming binary code into a seven-segment code that is applied to the inputs of the seven-segment display unit so that they can be displayed as a decimal number.

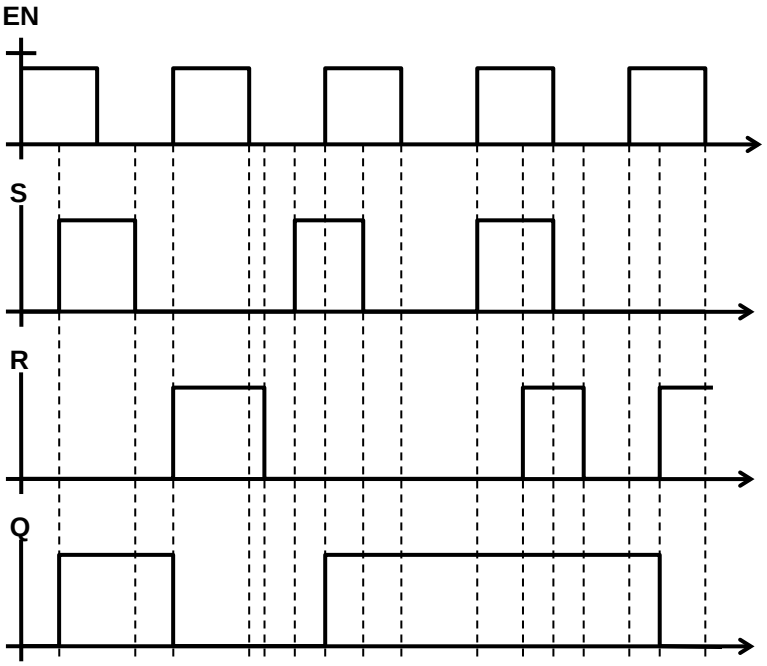
5.3



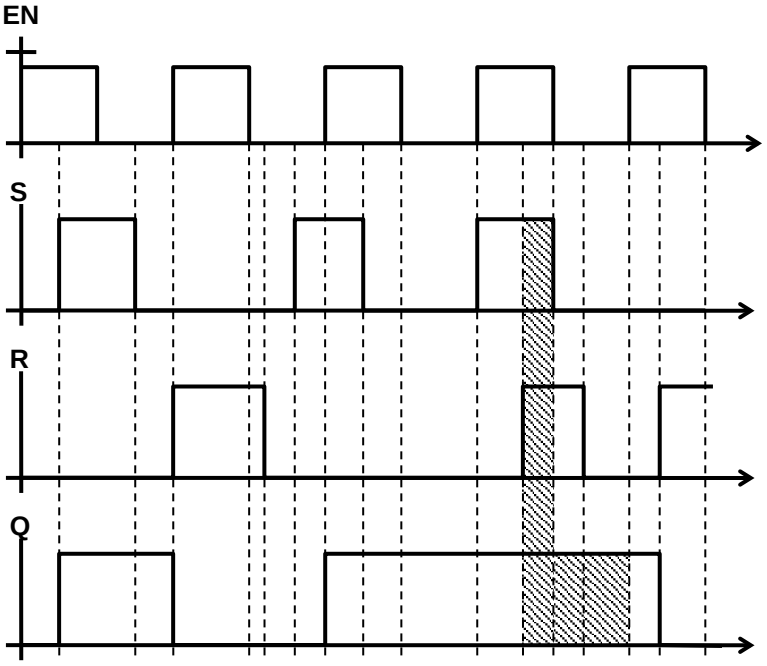
Marking note
1 mark is awarded for the labelling of the inputs.
1 mark is awarded per correct logic symbol.
1 mark is awarded for correct labelling of outputs.

5.4 From bit 2 and the subsequent bits provision must be made for a transfer from the preceding bit and a half adder does not make provision on the inputs for the transfer from a previous bit.

5.5 5.5.1 **Marking note**
Both Question 5.5.1 and Question 5.5.2 are indicated on the Answer Sheet 5.5.1.



5.5.2 This answer is done on the sketch of Question 5.5.1.



5.6
- All three the inputs of NAND gate A is high,
- therefore, the output of NAND gate A will change from 1 to 0.
- A 0 is fed back from the Q output to NAND gate C,
- therefore, the output of NAND gate C will remain 1 unchanged.
- NAND gate B reacts to the 0 that is applied to its input from NAND gate A
- and changes its output, output Q, to 1.
- The 1 of output Q is now fed back to the input of NAND gate D and NAND gate C.
- NAND gate D will react to this input and its output will change from 1 to 0, therefore NOT Q will now be 0.
- NAND gate C does not react to the change in the feedback value from output Q, because the clock of the circuit is a wave leading edge trigger.

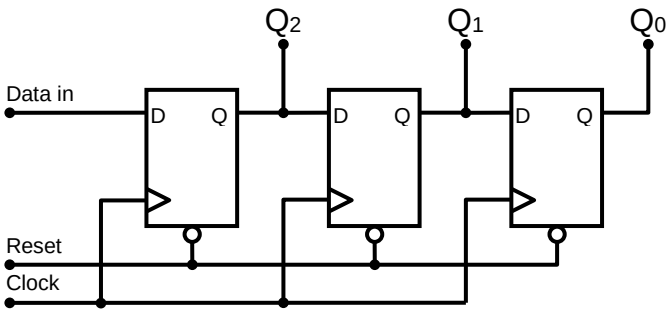
5.7 5.7.1 A full-sequence counter counts from zero/zero binary to the maximum/2^N value of the counter.
A truncated counter counts from zero/zero binary to a predetermined maximum value.

5.7.2 For **clock pulse 1**, the JK inputs of counters FFD, FFC and FFB are all 0 because of the low on the respective AND logic functions A and B, therefore the outputs of the counters will remain unchanged. The output of counter FFA will now toggle from low to high. Outputs QA and QC are now both high and the high value is applied to AND logic function C. AND logic C will react to these inputs and will apply a high to its output and the reset input of all the JK flip-flops. The JK flip-flops will react to this and will immediately switch their respective outputs to 0_2 to provide an output of 0000_2.

For **clock pulse 2**, the JK inputs of counters FFD, FFC are low as a result of the low value from the respective AND logic functions A and B and the JK inputs of counter FFB are low because FFA's low output is also their input. The JK inputs of FFA are permanently in the toggle function and FFA will react to the clock pulse and its output will toggle from low to high to provide output 0001_1.

5.8
- SIPO (Series-In-Parallel-Out)
- PIPO (Parallel-In-Parallel-Out)
- SISO (Series-In-Series-Out)
- PISI (Parallel-In-Series-Out)

5.9

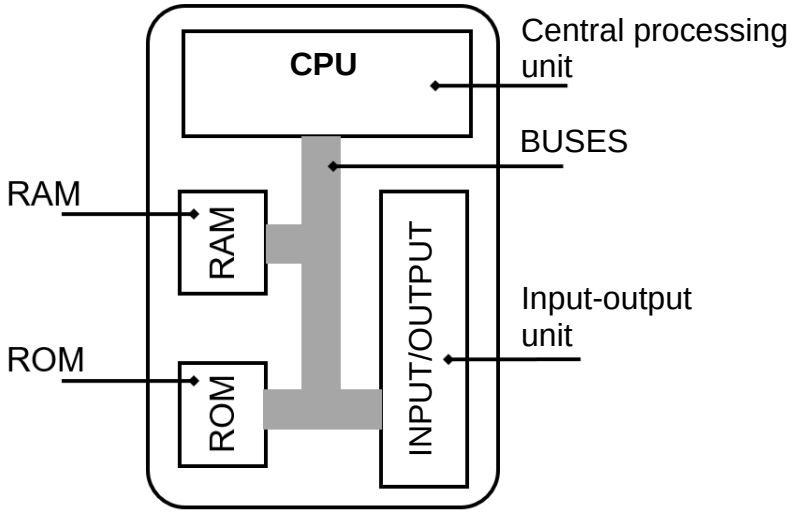


Marking note
- Each correct label receives 1 mark. NB: Q_0 to Q_2 together counts as one label.
- 1 mark is awarded for the sketch if it is correct.

5.10 Receives data in parallel format and converts the data into series format output by means of five clock pulses.

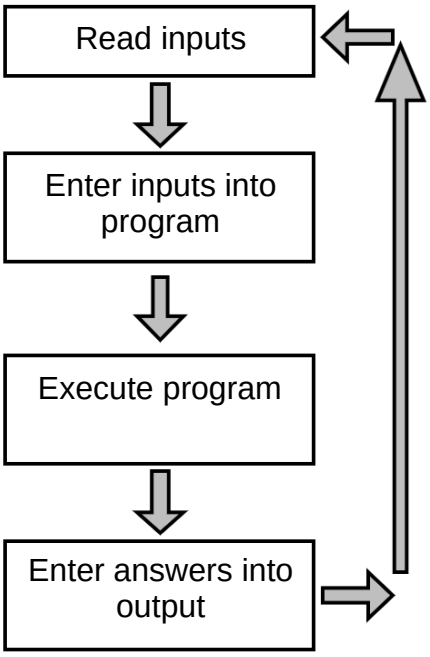
QUESTION 6 MICROCONTROLLERS

6.1



Marking note
- 1 mark is awarded per label.
- The 6th mark is awarded if the learner has all labels correct and the sketch is also drawn correctly.
- The positioning of the components may differ from that of the memo.

6.2



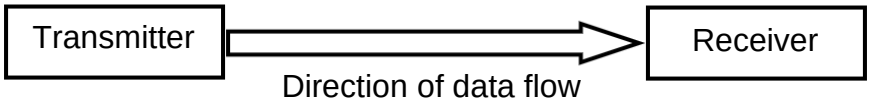
Marking note
- 1 mark is awarded per block placed in correct position.
- 1 mark for all the arrowheads together if they are in correct direction.

6.3 It is a low-power computer without a keyboard, screen or hard disk that is placed in microchip format on an integrated circuit.

6.4
- Memory data register
- Memory address register
- Counter register
- Control register
- Current-instruction register

6.5 It receives analogue data and converts the data into digital format which is then made available to the microcontroller to do further calculations.

6.6



6.7 Half-duplex
Full duplex/duplex

6.8 Takes up a lot of space on the logic chip for the parallel paths.
Makes manufacturing the logic chip more complex.

6.9 Synchronous communication uses data blocks or bytes that are sent as one long continuous stream of data. A clock pulse is used to synchronise the transmitter and receiver of the system.
Asynchronous communication converts the data into bit format and sends the data in bit format after the receiver has acknowledged the data format. No clock pulse is used, the system is switched on by a start bit and switched off by an end bit.

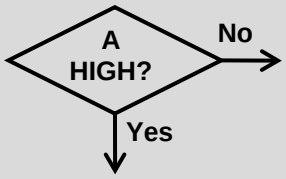
6.10
- Serial Communication Interface (SCI)
- Universal Asynchronous Receiver/Transmitter (UART)
- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I2C)

6.11 In legal data flow the data lines will follow one another after a specific action and they will not cross one another or move against the other flow.
In illegal data flow the data lines will just end without reaching a function. The data lines may also move against the flow of other lines or the data lines may cross other data lines.

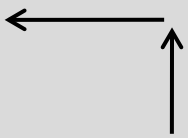
6.12 The flow chart ensures that pressing the switch is seen as only one pulse by the microcontroller. If the method is not used, the CPU will move uncontrolled through the repeat function and the counter will make error counts for the period that the switch is kept in. If the user keeps in the pulse switch, the CPU will not go to the next step before the pulse switch is released. Therefore, the counter will move on only one count each time the pulse switch is pressed.

6.13

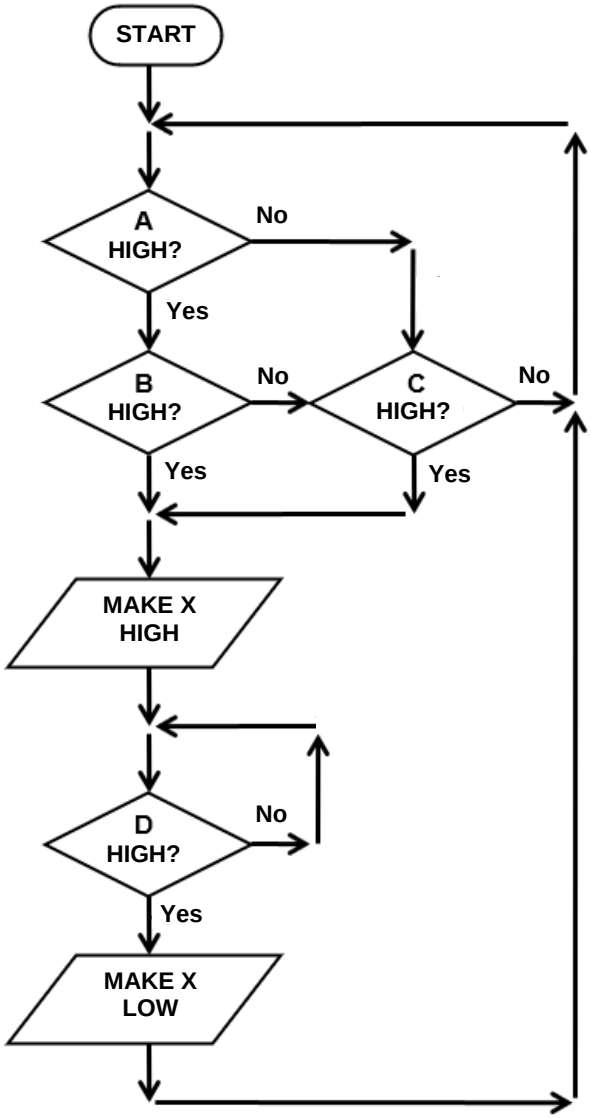
MARKING NOTE



1 mark is awarded per block with correct entry, output arrows and labels if applicable.



Data flow-back arrows are marked correct as a single unit if they are indicated correctly.



Total: 200 marks