The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2017-2018

ELECTROMECHANICAL DEVICES

Time allowed ONE Hour THIRTY Minutes

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer ALL questions

Only silent, self contained calculators with a Single-Line Display or Dual-Line Display are permitted in this examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn examination paper over until instructed to do so

ADDITIONAL MATERIAL: Formula sheet (3 pages)

INFORMATION FOR INVIGILATORS:

Question papers should be collected in at the end of the exam – do not allow candidates to take copies from the exam room.

Turn Over

SECTION A
Answer ALL the questions

1. Calculate the equivalent resistance of the resistance network shown in Fig. Q.1, and hence calculate the current drawn from the power supply and the power dissipated in the network. [4]

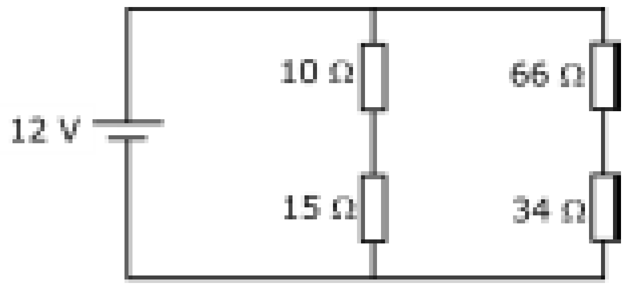

Fig. Q.1

2. A load consisting of a 30 Ω resistor in series with a 100 μF capacitor is connected across a 110 V 60 Hz single phase supply. Calculate the complex impedance of the load in Cartesian and polar form and hence calculate the magnitude and phase angle of the current. [6]

3. A squirrel-cage induction motor is stated by the manufacturer to have a rated power output of 2.5 kW at 950 rev min^{-1} when running from a 50 Hz supply

   (a) Calculate its torque at rated speed. [2]

   (b) State the approximate speed at which the motor will run when it is providing no torque i.e. when it is running without load. [1]

   (c) Calculate its speed (using the linear model) when driving a load requiring a torque of 20 Nm. [3]

4. A strain gauge with a nominal value of 350 Ω and a gauge factor of 2.2 is subjected to a tensile strain of 800 microstrain. By how much will its resistance change? [3]

5. An inexperienced designer has created the circuit shown in Fig. Q.5. consisting of a NAND gate followed by an AND gate. It receives a series of pulses on input A and is intended to output pulses on output D only when B is low (digital 0).

(a) Draw a timing diagram showing the states of A, C and D the when input A is receiving a train of pulses and input B is low (digital 0). [3]

(b) Draw a timing diagram showing the states of A, C and D the when input A is receiving a train of pulses and input B is high (digital 1), and hence explain briefly why the output is not as expected, including giving the name of this unexpected behaviour. [5]

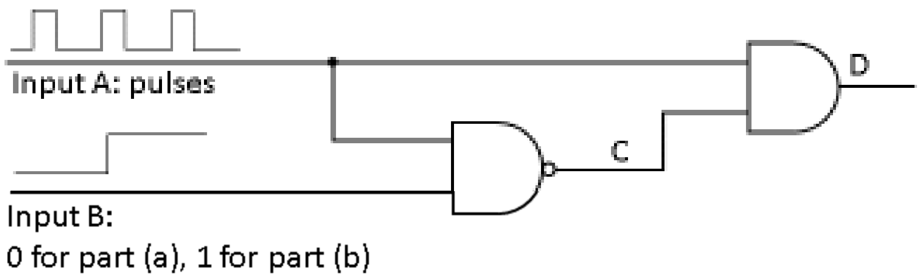

Fig. Q.5

6. An analog-to-digital converter (ADC) is required to digitise a signal in the range 0-10 V with a resolution of 0.005 V. Determine how many bits of precision the ADC must have in order to achieve this resolution. [3]

SECTION B
Answer ALL the questions

7. (a) An industrial load runs from a 415 V 50 Hz three-phase supply. It is star-connected and each phase of the load consists of a 50 Ω resistor in series with a 200 mH inductor.

i) Calculate the phase voltage (i.e. the line-to-neutral voltage). [2]

ii) Calculate impedance of the each phase of the load in either Cartesian or polar form. [4]

iii) Calculate the magnitude and phase of the line current. [4]

iv) Calculate the power factor. [2]

v) Calculate the total power dissipated by the load. [3]

(b) A star-connected three-phase squirrel-cage induction motor with two pairs of poles per phase, running from the same supply as in (a), has a rotor resistance of 10 Ω and a standstill rotor reactance of 50 Ω referred to the stator windings.

i) Calculate the value of slip at which pullout occurs, and explain what this means, illustrating your answer with a sketch of the torque-speed curve of a typical induction motor. [5]

ii) Calculate the torque when the motor is running at its rated speed of 1440 rev min^{-1} using the theoretically-based model based on the motor's electrical parameters, and hence calculated its rated power output. [9]

(c) A loudspeaker has an impedance of magnitude 3 Ω and is to be driven from a signal generator which is designed to be connected to a load with an impedance of magnitude 50 Ω.

Calculate the turns ratio of the ideal transformer which will give the best match of the signal generator to the loudspeaker, i.e. which will make the impedance of the load appear to be 50 Ω when referred to the transformer primary. [6]

8. (a) Write down the truth table of an AND gate, OR gate, XOR gate and a JK flip-flop. [4]

(b) Draw a diagram showing how a set of J-K flip-flops can be used to energise the windings of a switched reluctance motor in sequence, so that the motor moves around by one increment for each pulse received on the clock input. You may assume that the outputs of the J-K flip-flops are able to operate the windings directly (though in practice some further circuitry would be needed to make the signals sufficiently powerful). [5]

(c) Draw a circuit diagram of a push pull pair showing how a digital logic signal can be used to operate (i.e. switch on and off) a large solenoid. When the solenoid is turned off quickly, it could damage the push-pull pair circuit. Write down the equation describing this phenomenon. Add an extra component to your circuit diagram which would protect the circuit from this effect. [8]

(d) Draw the diagram for an operational amplifier, and label the inverting terminal, the non-inverting terminal, the output, the input resistance, the output resistance. Then write down the equation relating the voltage at the inverting terminal, non inverting terminal and the output. Using a diagram explain the difference between the open loop gain of an op-amp and the closed loop gain. [8]

(e) The circuit shown in Figure Q.8 (e) is to be used to average the results of three sensors. Demonstrate that the output voltage V_{OUT} is equal to the average of the input voltages V_1, V_2 and V_3 but of opposite sign provided the open-loop gain of the op-amp is infinite.

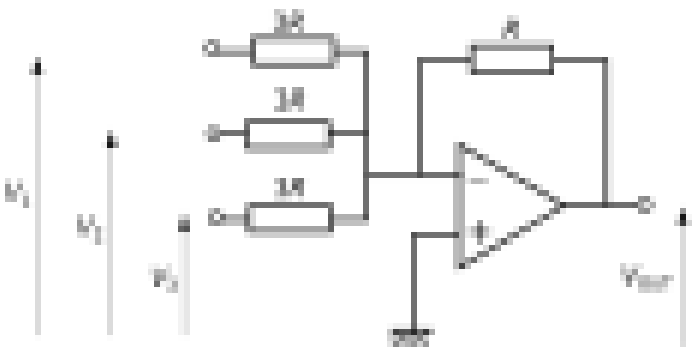

Fig. Q.8 (e)

[10]

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