The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2018-2019

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.

1. The inductor network shown in Fig. Q.1 is connected to a 60 Hz 20 V (rms) supply. Calculate the equivalent inductance of the network, the inductive reactance, and the magnitude and phase angle of the current. Assume there is no mutual inductance. [5]

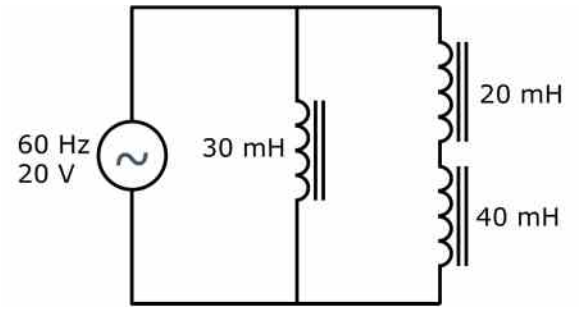

Fig. Q.1

2. A permanent magnet DC motor is stated to provide its rated torque of 0.12 Nm when it is drawing a current of 5 A. At what no-load speed (in rev min^{-1}) will it run if it is connected to a 12 V supply, neglecting friction? If it rotates at 4000 rev min^{-1} when it is supplying its rated torque while being driven from a 12 V supply and drawing 5 A, what is its armature resistance? [5]

3. An electromagnetic actuator has 3000 turns of wire and has pole pieces of area 1.1×10^{-4} m^2. When the pole pieces are 0.01 m apart, what force does the actuator provide when a current of 1.5 A is flowing in the actuator? Assume that the flux density is uniform within the air gap and neglect the reluctance of any other parts of the magnetic circuit. [5]

4. A digital device needs to be activated when the numerical value carried on a set of four digital lines takes one of the four following values: 1000, 1001, 1010 or 1011. Design a digital logic circuit that will output a "high" (1) digital signal when the four lines carry one of these numbers and will output a "low" (0) signal otherwise. [4]

5. Derive an expression for the output voltage V_{out} of the circuit shown in Fig. Q.5 in terms of the input voltage V_{in}, the op-amp gain A and the values of the resistors R_1 and R_f. You may make the usual assumptions of infinite input impedance, zero output impedance and $V_{out}=Av$. Hence simplify your expression for the case where A is very large. [6]

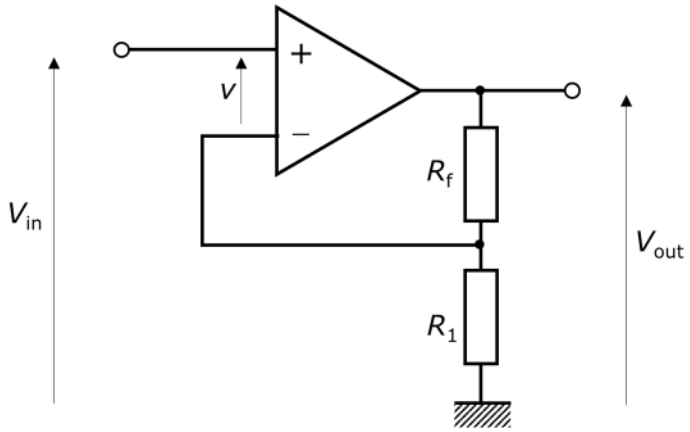

Fig. Q.5.

6. Explain the operation of a flash ADC, illustrating your answer with a circuit diagram. [5]

7. (a) A 400 V rms (line-to-line voltage) 50 Hz three phase power supply is star-connected to an induction motor which draws a current of 78 A at a phase angle of 50° lagging. Calculate the total active power drawn by the motor. [5]

(b) The star-connected induction motor described above has a rotor resistance of 15 Ω and a rotor standstill reactance of 75 Ω referred to the stator windings. There are three pairs of poles per phase. Calculate the phase voltage, the slip and the torque when the motor is driving a load at 955 rev min^{-1}. Hence calculate the power supplied by the motor and its efficiency. [12]

Continued on next page

(c) Each phase of the above power supply (relative to neutral) is provided from a separate transformer which steps an 11 kV (11 000 V) supply down to the phase voltage (as calculated by you in b). Noting once again that the transformer supplies 78 A at a phase angle of 50° lagging to each phase of the motor, what current will be drawn by the 11 kV winding of the transformer, and hence what will the apparent power (VA) rating of this transformer need to be? (Note: only consider a single transformer here, and do not consider how the connections of the primary winding of this transformer relate to those of the other two transformers in the system). [9]

(d) It is now desired to be able to vary the speed of the motor so that it runs significantly faster or slower than the 955 rev min^{-1} stated earlier. Explain what determines the approximate speed of an induction motor when run directly from the mains supply, and hence explain what additional electronic hardware would be required to vary the speed of the motor over a wide range. Sketch the torque-speed characteristics that describe its behaviour when driven from this additional electronic hardware. [9]

8. (a) You are an engineer designing a computer for a flight control system, key components of this system are OR gates, AND gates, XOR gates, NOT gates and JK flip-flops.

i) Write down the truth table for these components and the circuit symbol of each component. [5]

ii) Part of the computer uses 8 bit numbers to perform mathematics. Write down the 8-bit binary codes for the decimal numbers 64, 100 and 120. [3]

iii) The computer must be connected to a shaft-encoder measuring <u>relative</u> shaft position with a resolution of <1°. How many optical sensors would need to be used to achieve this level of accuracy? [2]

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(b) i) As part of the design for the computer you have to design a chip to add a two digit binary number to a one digit binary number. The chip has two input wires (A1,A0) representing the two bit binary number and one input wire representing the one bit binary number (B0). The chip has three output wires representing the answer (O2,O1,O0). Write down the truth table for this chip. For the output the most significant bit must be stored in O2 while the least significant bit stored in O0, for the input the most significant bit must be stored in A1 and the least significant bit stored in A0. [4]

ii) Draw the complete circuit diagram for this adding unit. You should allow a complete page of your exam booklet for the answer to this question part as it will take up a lot of space. [5]

iii) After having designed the chip, you are doing some boolean algebra to check your design is fully minimized. For example, fully minimize the following expression using boolean algebra:

$$(x+z)(x+y)(\overline{z}+y)$$

[4]

9. (a) You need to design a power supply. It must include a voltage regulator, smoothing capacitors, a load and the bridge rectifier. Draw the circuit diagram for the power supply incorporating these features. [5]

(b) Part of the power supply specification is that it should not deliver power to its output until a few seconds after the on-button has been depressed. To achieve this you decide to use a Darlington pair based timer, you connect the Darlington pair to a relay, which will in turn be used to power on the computers main circuits.

i) Draw a circuit diagram of a Darlington pair based timer circuit which could be used for this. The circuit diagram must include a switch and a relay. [5]

ii) The transistors in the circuit have β values of 10 and 8. What is the overall gain of the Darlington pair? [2]

END