The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2020-2021

ELECTROMECHANICAL DEVICES

Time allowed TWO hours plus 30 minutes upload period

Open-book take-home examination

Answer ALL questions

You must submit a single pdf document, produced in accordance with the guidelines provided on take-home examinations, that contains all of the work that you wish to have marked for this open-book examination. Your submission file should be named in the format '[Student ID]_MMME2051.pdf'.

Write your student ID number at the top of each page of your answers.

This work must be carried out and submitted as described on the Moodle page for this module. All work must be submitted via Moodle by the submission deadline. **Work submitted after the deadline will not be accepted without a valid EC.**

No academic enquiries will be answered by staff and no amendments to papers will be issued during the examination. If you believe there is a misprint, note it in your submission but answer the question as written.
Contact your Module Teams Channel or SS-AssessEng-UPE@exmail.nottingham.ac.uk for support as indicated in your training.

Plagiarism, false authorship and collusion are serious academic offences as defined in the University's Academic Misconduct Policy and will be dealt with in accordance with the University's Academic Misconduct Procedures. The work submitted by students must be their own and you must declare that you understand the meaning of academic misconduct and have not engaged in it during the production of your work.

SECTION A

1. You are designing a circuit to add two two-bit binary numbers together, A and B. The result will be stored in the output bits Q_1,Q_2 and Q_3. Write out the truth table for this circuit. The inputs in the truth table must be ordered starting with the lowest binary number in the first row and the highest binary number in the final row. Make sure the MSB is on the left, and the LSB is on the right when you write your binary numbers. [5]

2. An inverting amplifier circuit has a feedback resistor of value 10k Ohms and an input resistance of 1k Ohms, and an open loop gain of $5x10^3$ at 50 Hz. Calculate the closed loop gain of the circuit, showing the equation you use to calculate the result. Why are Op-Amps generally not used in their open-loop configuration (*do not write more than 20 words*)? [5]

3. You are designing an analog to digital converter (D2A) using an R2R ladder and a comparator. You will be measuring the voltage range between -5V and +5V, you want to have a resolution of $1x10^{-3}$ V. How many IO lines would you need to connect your D2A convert to a computer? Give one reason why you would use a flash converter over a converter with an R2R ladder. [5]

4. Calculate the equivalent resistance of the resistance network shown in Fig. Q.4, the current *I* and the power dissipated in the network. [5]

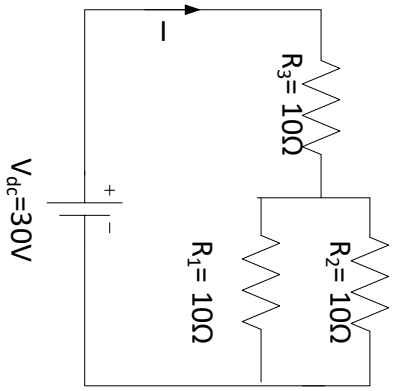

Fig. Q.4

5. A coil having an inductance of 100 mH and resistance of 200 Ω is connected to a 115 V 400 Hz AC supply as shown in Fig. Q5. Determine:

(a) The impedance *Z* of the RL circuit. [1]

(b) The power factor of the coil. [2]

(c) The current RMS value taken from the supply. [1]

(d) The power dissipated as heat in the coil. [1]

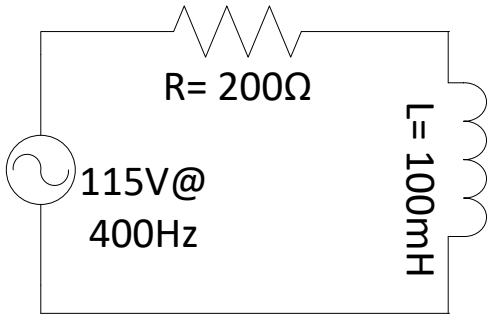

Fig. Q.5

6. In Fig Q.6, an alternating voltage supply V_{ac} of 240V @ 50Hz is connected to a transformer primary winding, which has 1000 turns. The transformer secondary winding has 100 turns. A load resistor, R_L= 2Ω, is connected to the secondary winding. (The transformer can be viewed as an ideal transformer)

(a) What are the secondary voltages and the current? [2]

(b) What is the primary current? [1]

(c) What is the equivalent resistance seen by the power supply? [2]

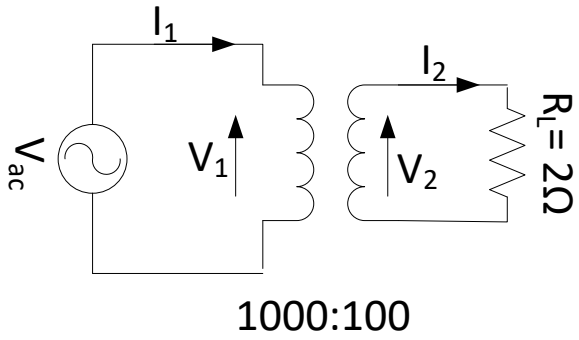

Fig. Q.6

SECTION B

7. You are a lead engineer designing a new computer for an aircraft. You have been asked to contribute to various parts of the computer design. Your first job is to design the power supply to the computer.

(a) Draw the circuit diagram for a full wave bridge rectifier, including the smoothing capacitor and a load resistor representing the computer. Draw the input waveform and the output waveform to the bridge rectifier for a 10V RMS input voltage, labeling the magnitudes of the voltage waveform. Give one advantage of a full wave rectifier and one advantage of a half wave rectifier. Mark on your diagram (use color if you would like to) the path the current takes through the bridge rectifier when the AC is both positive and negative. On the output waveform add another line representing the effect of the diode losses. [10]

(b) When running, the computer will draw 1 Amp from the power supply, the mains frequency is 50 Hz, choose a capacitor for the power supply which would give a ripple voltage of 0.1 mV. Do you think this is a reasonable value? What other components could you use to reduce the ripple? [3]

(c) If at the peak of the charging cycle, your computer is drawing 1 Amp from the power supply and the forward voltage drop over each diode is 0.6V, how much power will be lost in the bridge rectifier? [2]

(d) As part of the computer design, you are asked to design a unit which will identify the prime numbers 2, 3 ,5 ,7. Write out a truth table for the circuit which will do this. This circuit should have a single output bit Q. Q must be 1 when the number is prime and 0 when the number is not prime. The truth table must be ordered with the lowest value input at the top of the truth table and the highest value input at the bottom of the table. The least significant bit on the right of the table and the most significant bit on the left. Write out the Boolean expression representing your truth table. [5]

(e) Simplify the expression you derived in part d using Boolean simplification, showing your working. No marks will be given if there is no working. [5]

(f) The computer must drive a relay which will be used to activate the landing gear of the computer, the current drawn by the relay is too high to be driven by the computer directly. You decided to use a push pull pair in combination with a MOSFET to drive the relay. Draw out the full circuit diagram for your relay driver circuit. The circuit must include the relay, a back EMF protection diode, the transistors and the signal from the computer. Also draw on the circuit arrows showing how charge enters and leaves the gate of the MOSFET. Also state why a push pull pair would be used to drive the MOSFET. [5]

(g) You are now asked to design a part of the circuit to lower the undercarriage of the aircraft. The design brief states that there should be a button in the cockpit which when pressed and held down for more than five seconds, will open a relay which will in turn will release the undercarriage. Draw a circuit using a Darlington pair which will perform this action. The time constant of the circuit you design is 10 seconds, how long will the switch have to be depressed to activate the undercarriage? [5]

8. A three-phase AC, star-connected squirrel-cage induction motor with 4 poles per phase runs from a 415V (rms, line-to-line) 50 Hz supply. The motor's full-load (rated) speed is 1445 rev/min. The rotor of the motor has a resistance of 2 Ω and a standstill reactance of 10 Ω referred to the stator windings. Use the theoretical model of the induction motor which is based on its electrical characteristics rather than the linearised empirical model.

(a) What is the synchronous speed of the motor? [3]

(b) What is the rms phase voltage of the motor's stator? [3]

(c) What is the slip at the motor's rated speed, and hence what are the full-load torque and power? [8]

(d) What is the starting torque i.e. the torque when the rotor is completely stalled and not rotating? Compare the starting torque with the rated torque, which one is bigger? Draw a simple practical torque-speed curve. [8]

(e) When it is supplied at the rated frequency and voltage and is running at its rated speed, the motor draws a phase (or line) current of 6.5A at a power factor of 0.68 lagging. What power is being drawn from the power supply, and hence what is the motor's efficiency? [5]

(f) Explain the physical principle of a three-phase squirrel-cage induction motor, including a description of the roles of the three-phase supply and the squirrel cage. You are encouraged to illustrate your explanation with sketches but you do not need to quote any equations. [8]