EEE223

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EEE223 Assignment 3

Hamish Sams

April 26, 2018

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1 Question 1

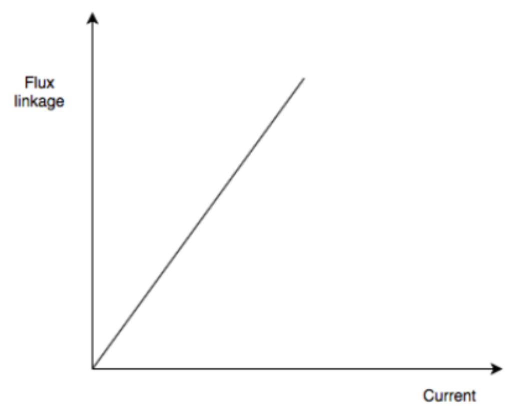

Figure 1: Graph of linear flux linkage against current(non saturated)

The energy stored in the circuit is defined as the area underneath the graph and therefore the integral of current with respect to flux linkage.

$$E = \int_0^{I_p} I d\Psi \tag{1}$$

Given that $\Psi = LI$
and therefore $d\Psi = LdI$ if the inductance is constant.
therefore:

$$E = \int_0^{I_p} ILdI = \frac{1}{2}LI^2 \tag{2}$$

Hence

$$E = \frac{1}{2}LI^2 \tag{3}$$

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2 Question 2

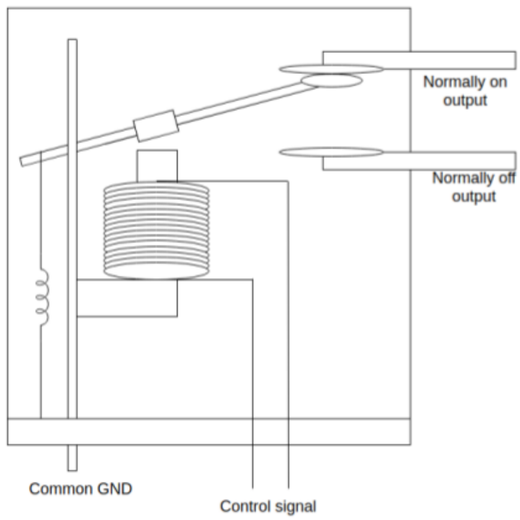

Figure 2: Simple diagram of relay circuit.

This relay functions by controlling the current through an inductor to attract an iron arm which changes the contact of the arm between contacts. The arm will return to its original position after the inductor current is turn off by the force of a spring on the arm.

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3 Question 3

Assuming a 1N force applied by the spring and the spring and coil are at equal lengths along the rotating arm a 1N force is required to equal the pull. Force on the armature is given by

$$F = \frac{1}{2}I^2\frac{dL}{dx} \tag{4}$$

it can also be shown that the inductance of the core is given by:

$$L = \frac{N^2\mu_0 A}{x} \tag{5}$$

Differentiating this with respect to x and substituting in we get that the force towards the core is given by:

$$F = \frac{1}{2}I^2\frac{N^2\mu_0 A}{x^2} \tag{6}$$

Given the values of F,N,μ,A and x we can rearrange to get a current I of 0.53A (this is a minimum) for x = 5mm and I = 0.21 to re-open the contact (this is a maximum) for x = 2mm

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4 Question 4

The values are not equal because when the relay is shut the magnetic reluctance is much smaller as the airgap is more than halved which is by far the main source of reluctance compared to the core.

As the reluctance is smaller more flux can flow for the same mmf in the same area therefore a larger flux density equating to a larger force. This means if the contact is open and is in equilibrium if the contact moves closer at all the reluctance will reduce increasing the force pulling the contact and vice versa for closing meaning its near impossible for the relay to be in an equilibrium state using a DC signal.

5 Question 5

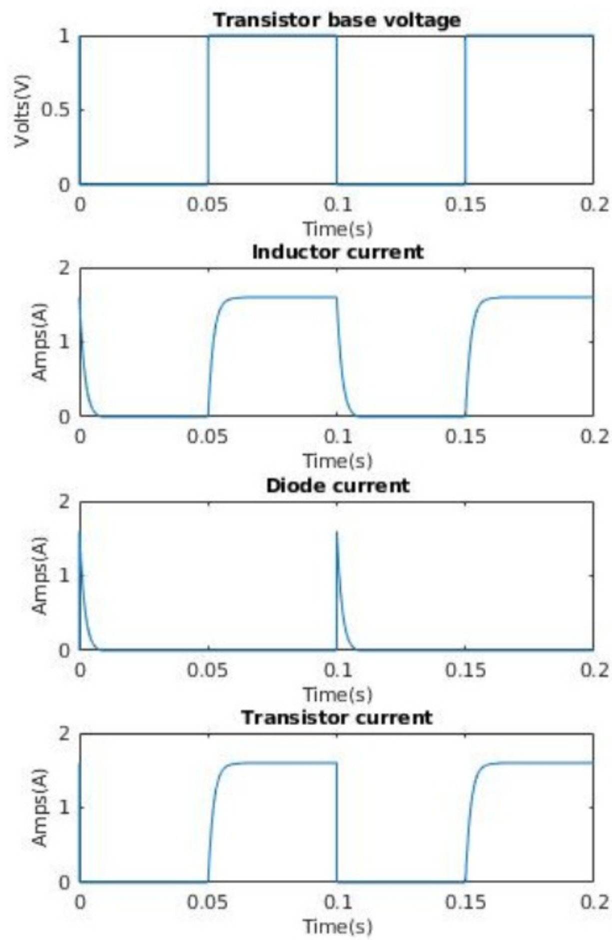

Figure 3: Currents within the relay circuit operating at 10Hz.

6 Question 6

Response is determined by the electrical delay added with the mechanical delay.
Electrical delay: time for inductor current to get to 0.5A.

$$I = I_0(1 - e^{-t\frac{R}{L}}) \tag{7}$$

Where I_0 is the steady state current ($I_0 = \frac{V}{R}$) we can therefore put all of our values in and re-arrange for t to give $t = \frac{-L}{R} \cdot ln(1 - \frac{I}{I_0}) = 0.75ms$

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7 Question 7

This time the current must drop from its value down to 0.2A to turn off and so instead we use the discharging equation:

$$I = I_0 e^{-t\frac{R}{L}} \tag{8}$$

once again using the circuit values (charging resistance is same as discharging assuming 0 diode resistance) and required current, re-arranging to give:

$$t = \frac{-L}{R} \cdot ln(\frac{I}{I_0}) \tag{9}$$

giving the value $t = 4.16mS$

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8 Question 8

Using equation 8 but this time re-arranging for R and using a value of $t = 0.2$ we can see that $R = 62.4\Omega$ not forgetting to remove 30Ω due to R to get $R_s = 32.4\Omega$

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9 Question 9

At the moment the transistor turn off 1.6A(I_0) is flowing through the circuit (the inductor diode loop) we know the voltage at the top node is 48V and that 1.6A is flowing upwards through R2 therefore a voltage increase of 1.6*R2 volts on the resistors bottom creating a peak voltage of $V_p = 39 * 1.6 + 48 = 110.4V$

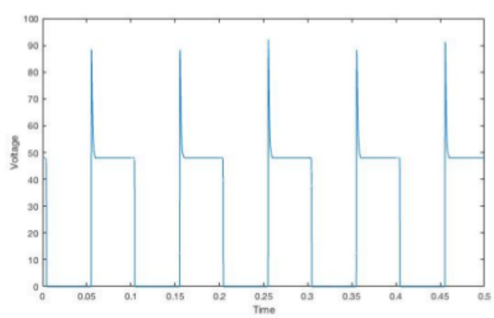

Figure 4: Graph of V_{ce} over time

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GRADEMARK REPORT

FINAL GRADE

85/100

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

RUBRIC: MARKSCHEME	4.25 / 5

Q1-1 (5%)	5 / 5
INCORRECT (0)	Failed to identify that psi=Li
CORRECT (5)	Identify that psi=Li, due to non-saturation assumption

Q1-2 (5%)	5 / 5
INCORRECT (0)	Failed to solve integral to find 0.5Li^2
CORRECT (5)	Successfully solve integral to find 0.5Li^2

Q2-1 (5%)	5 / 5
INCORRECT (0)	Failed to show coil around soft iron core
CORRECT (5)	Show coil around soft iron core

Q2-2 (5%)	5 / 5
INCORRECT (0)	Failed to show armature in magnetic path with spring return
CORRECT (5)	Show armature in magnetic path with spring return

Q3-1 (5%)	5 / 5
INCORRECT (0)	Failed to identify expression F=(mu0 A N^2 I^2)/(2 x^2)
CORRECT (5)	Successfully identify expression F=(mu0 A N^2 I^2)/(2 x^2)

Q3-2 (5%)	5 / 5
INCORRECT (0)	Failed to find current to close relay successfully
CORRECT	Current to close relay found at 0.526A

(5)

Q3-3 (5%)	5 / 5
INCORRECT (0)	Failed to find current to release relay successfully
CORRECT (5)	Current to release relay found at 0.210A

Q4-1 (5%)	5 / 5
INCORRECT (0)	Fail to identify lower reluctance when smaller air gap
CORRECT (5)	Identify lower reluctance when smaller air gap

Q4-2 (5%)	0 / 5
INCORRECT (0)	Fail to identify different reluctance permitting different current to maintain field strength
CORRECT (5)	Identify different reluctance permitting different current to maintain field strength

Q4-3 (5%)	0 / 5
INCORRECT (0)	Fail to identify hysteresis as a key benefit
CORRECT (5)	Identify hysteresis as key benefit and discuss in some way

Q5-1 (5%)	5 / 5
INCORRECT (0)	Fail to correctly show relay current
CORRECT (5)	Relay current (IL) correct (exponential up, exponential down)

Q5-2 (5%)	5 / 5
INCORRECT (0)	Fail to correctly show collector current
CORRECT	Collector current (IC) correct (exponential up, straight down)

(5)

Q5-3 (5%) 5 / 5

INCORRECT (0)	Fail to correctly show diode current
CORRECT (5)	Diode current (ID) correct (difference between the two)

Q6 (5%) 5 / 5

INCORRECT (0)	Fail to get correct time period
CORRECT (5)	Correct time period of 750us

Q7 (5%) 5 / 5

INCORRECT (0)	Fail to get correct time period
CORRECT (5)	Correct time period of 4.16ms

Q8-1 (5%) 5 / 5

INCORRECT (0)	Failed to make credible attempt
CORRECT (5)	Credible attempt made, e.g. 0.2=1.6 exp(t(R+Rs)/L), t=2ms

Q8-2 (5%) 5 / 5

INCORRECT (0)	Failed to get correct resistor value
CORRECT (5)	Correct resistor value of 32.4Ohms

Q9-1 (5%) 0 / 5

INCORRECT (0)	Fail to correctly identify peak voltage
CORRECT	Identify correct peak voltage of 110.4V. Propose device voltage rating greater than or

(5)	equal to this this.

Q9-2 (5%) 5 / 5

INCORRECT (0)	Failed to show exponential decay of Vce
CORRECT (5)	Exponential decay from peak to 48V shown

Q9-3 (5%) 5 / 5

INCORRECT (0)	Did not show one complete cycle
CORRECT (5)	Display at least one complete cycle and voltage when switch off at 0V