EEE223 Assignment 3

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1 Question 1

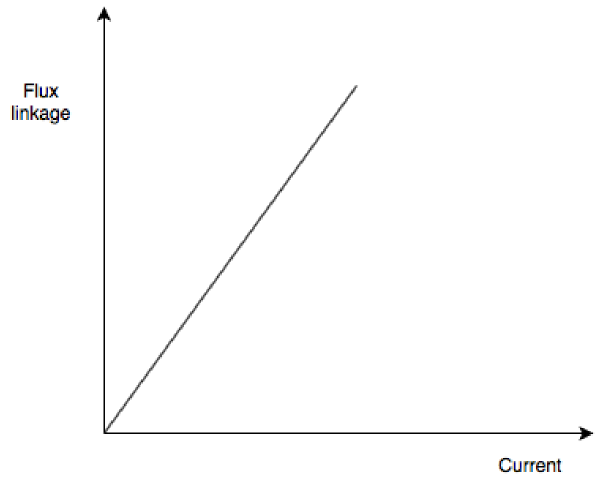

Figure 1: Graph of linear flux linkage against current(non saturated)

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.

$$E = \int_0^{I_p} I d\Psi \quad (1)$$

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

$$E = \int_0^{I_p} ILdI = \frac{1}{2}LI^2 \quad (2)$$

Hence

$$E = \frac{1}{2}LI^2 \quad (3)$$

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2 Question 2

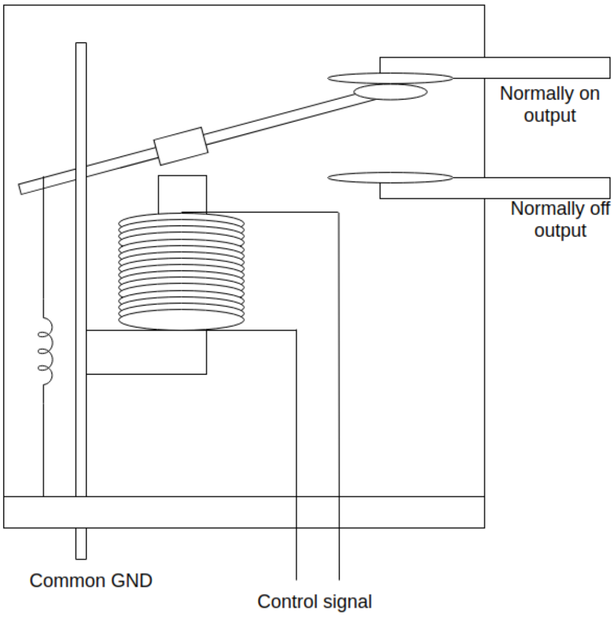

Figure 2: Simple diagram of relay circuit.

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

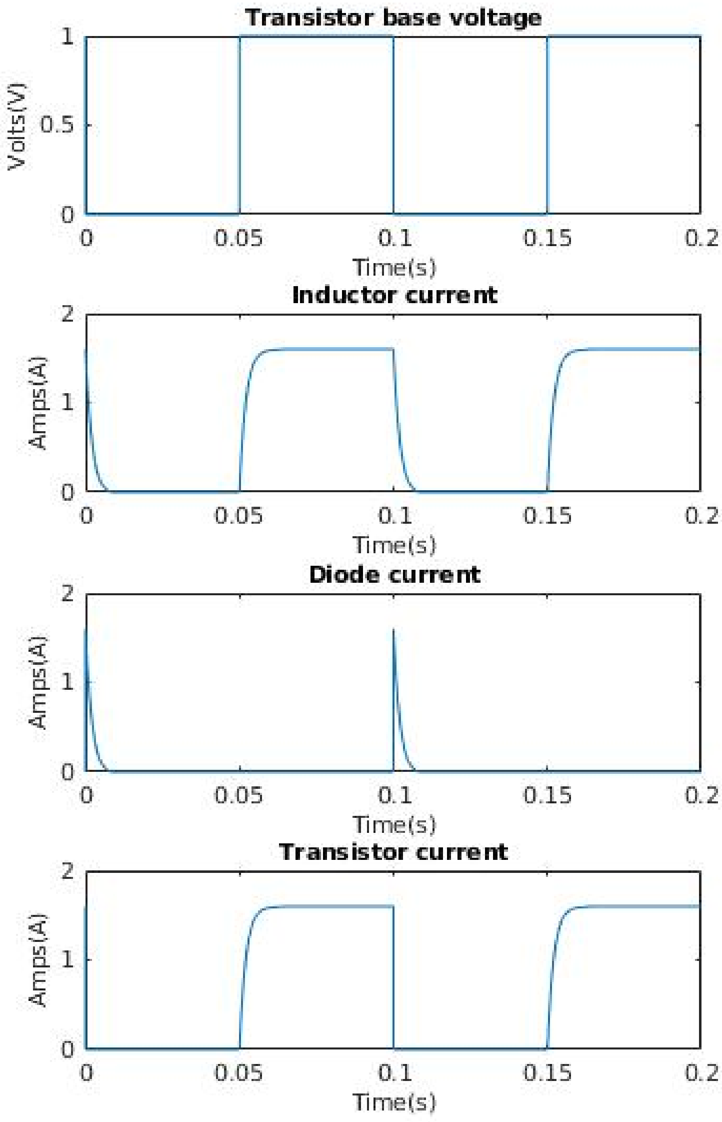

Figure 3: Currents within the relay circuit operating at 10Hz.

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 $V_p = 39 * 1.6 + 48 = 110.4V$