EEE229 – Assignment 2

1 Introduction

This document covers the structure and calculations for a simple relay and a relay driver circuit based upon the notes from module EEE229. The two sections are intended to be combined to produce a full system for switching a relay. Both sections will be analysed via answers to the questions given in the Assignment 2 Worksheet.

2 Q1 – Linear, Non-saturated Magnetic System Energy

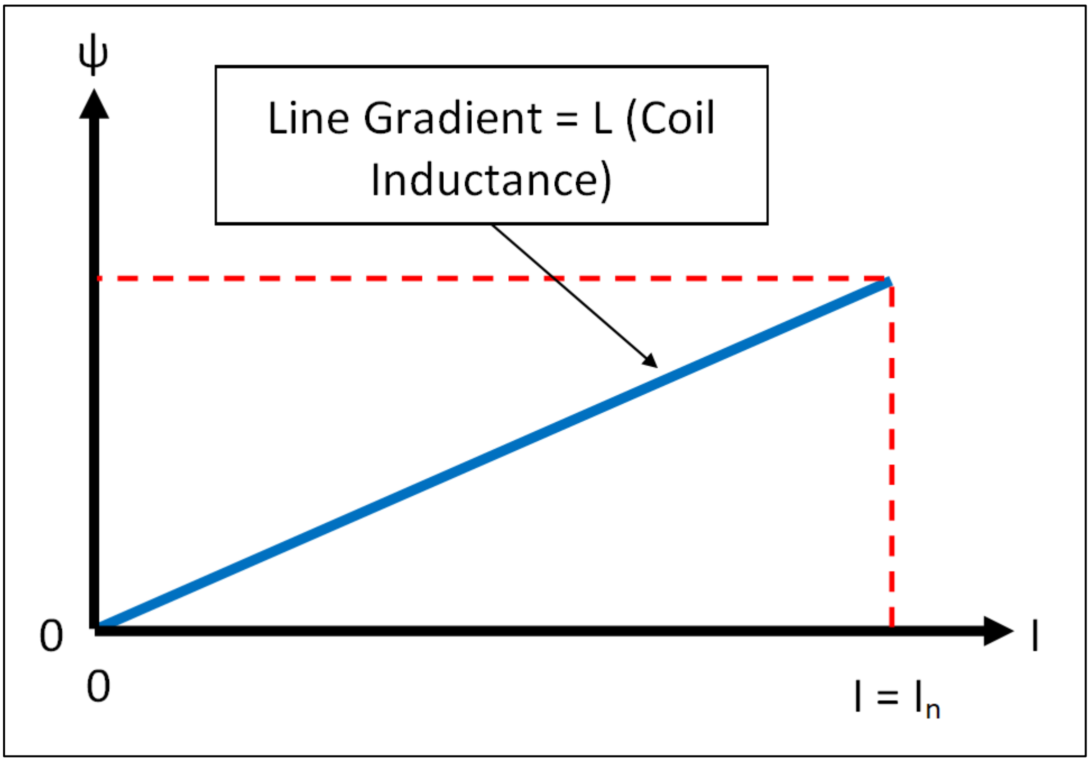

Figure 2.1: Flux Linkage vs Current for a Magnetic System

The energy in a Magnetic system is often represented by a Flux Linkage vs Current graph, as shown in **Figure 2.1**. Stored magnetic energy in a system is given by:

$$W = \int_0^{I_n} I \, d\psi$$

As shown in **Figure 2.1**, the Inductance of a Linear Magnetic system is constant. Therefore, we can show that:

$$\psi = LI \qquad \therefore d\psi = LdI$$

Consequently, we can calculate the energy stored within the Magnetic system:

$$W = \int_0^{I_n} IL \, dI$$

$$W = L\int_0^{I_n} I\,dI$$

$$W = L\left[\frac{1}{2}I^2\right]_0^{I_n}$$

$$W = \frac{1}{2}L(I_n)^2$$

3 Q2 – Typical Electromagnetic Relay

Figure 3.1 shows a typical simple Electromagnetic Relay structure. When no current is flowing through the coil no magnetic field is generated around the coil; thus, the only force exerted on the armature is that from the spring. This causes the armature to be in it's returned position, depending on the relay contacts this could mean circuit closed or open. When the coil is energised its magnetic field actively attracts the armature through reduction of the airgap. Consequently, the armature opens or closes the electrical circuit respectively.

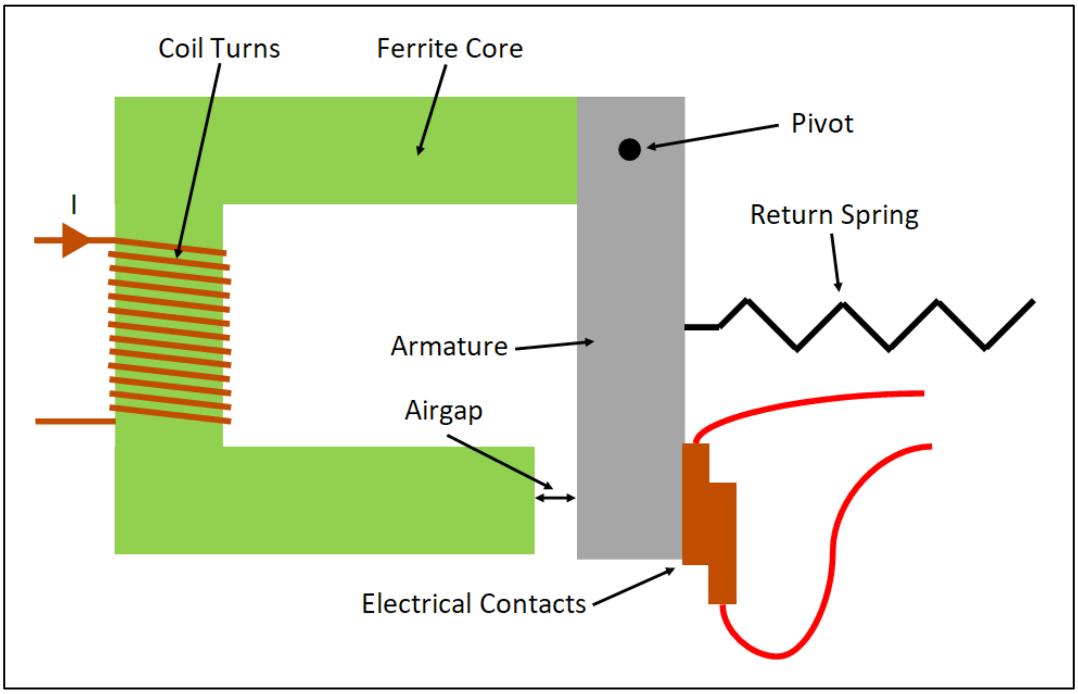

Figure 3.1: Simple Electromagnetic Relay Structure

4 Q3 – Relay Current Calculations

The current through the coil of a simple relay is given by the following equation:

$$I = \sqrt{\frac{2x^2F}{\mu_0 AN^2}}$$

The following values are given for the relay:

$$N = 1200\ \ A = 100mm^2\ \ x = 5mm\ (When\ open)$$

$$x = 2mm\ (When\ closed)\ \ F = 1N\ \ \mu_0 = 4\pi \times 10^{-7}$$

Therefore, we can use the equation for the force to calculate the value of current in the coil when the relay closes and when it opens. These values are as follows:

I when Relay Closes ≥ 0.526A **I when Relay Opens ≤** 0.210A

5 Q4 - Explanation for difference in Current Levels

As can be seen in **Q3**, there is a difference in the current levels for closing and opening the relay armature. This can be explained by analysing the reluctance of the circuit.

When the relay armature is open and the coil is switched on in order to close it, the magnetic circuit has an airgap of 5mm. This large airgap produces a larger dominant reluctance and by extension a larger current requirement in the coil (this can be observed in the current equation from Q3).

Inversely, when the relay contact is closed and the coil is being switched off to open it, there is a smaller airgap of 2mm. This produces a much lower magnetic reluctance and thus a lower coil current requirement to keep the armature closed.

This is beneficial as there is a response like a Schmitt Trigger built into the relay. Essentially, when the relay is switched on it is very unlikely to immediately switch off again and vice versa. Ultimately, there is no area of instability where the coil current causes the armature to oscillate between open and closed, it will always fix at one state.

6 Relay Driver Specifications

The following are the given set of specifications for the Relay Driver circuit:

Coil Resistance (R) = 30Ω **Coil Inductance (L) =** 0.06 H

Switch on Current = 0.5A **Switch off Current** = 0.2A

7 Q6 – Relay Response Delay Time