Lab# 5 Inductive circuits

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Objectives:
- Measure current and voltage in an inductive circuit
- Measure overvoltage in an inductive circuit
- Measure τ constant and 5 τ period.

Material: Mindi simulator

To hand in to Team Assignment

1- This document with the answers and measures. Copy-paste screenshots when required.
2- You provide comments to all screenshots
3- Upload the wxsch project file for all parts

Lab work

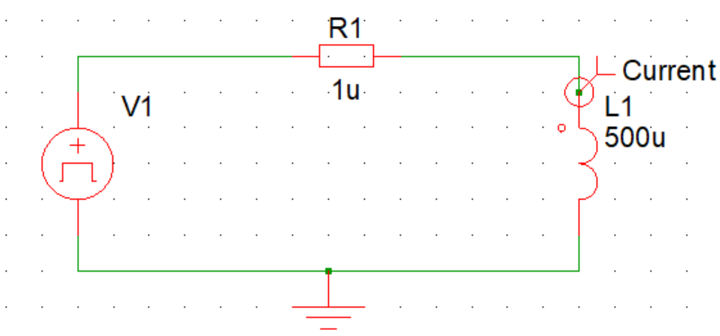
Part 1: Inductor current and voltage in a DC circuit

This part demonstrates that the rate of change of the current in an inductor is proportional to the voltage drop across it and inverse proportional to the inductor value in Henrys.

L circuit

Wire the following circuit. Even though the circuit does not contain resistor, for technical reasons, a fractional resistor must be connected in series with the inductor.

R1 of about 0 Ω (1μΩ) V1 = 5 V L1 = 500 uH



Set the simulator analysis to:
- Transient
- Stop time to 3mS

Set V1 waveform generator to:
- Frequency: 100Hz
- Pulse: 10V
- Wave Shape: square

Fill up the following measure table

Table 1 Rate of change of the current

	Rate of change of the current **Δi /Δt** (A/mS)
Theoretical	$Rate\ of\ change = \frac{\Delta i}{\Delta t} = \frac{10V}{500\mu H} = 20kA/S$ 20kA/S = 20A/mS
Measured	$Measured = \frac{20A - 10A}{1mS - 0.5mS} = 20A/mS$

Large inductor

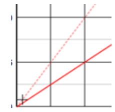
Now double the inductor value.

Fill up the following measure table

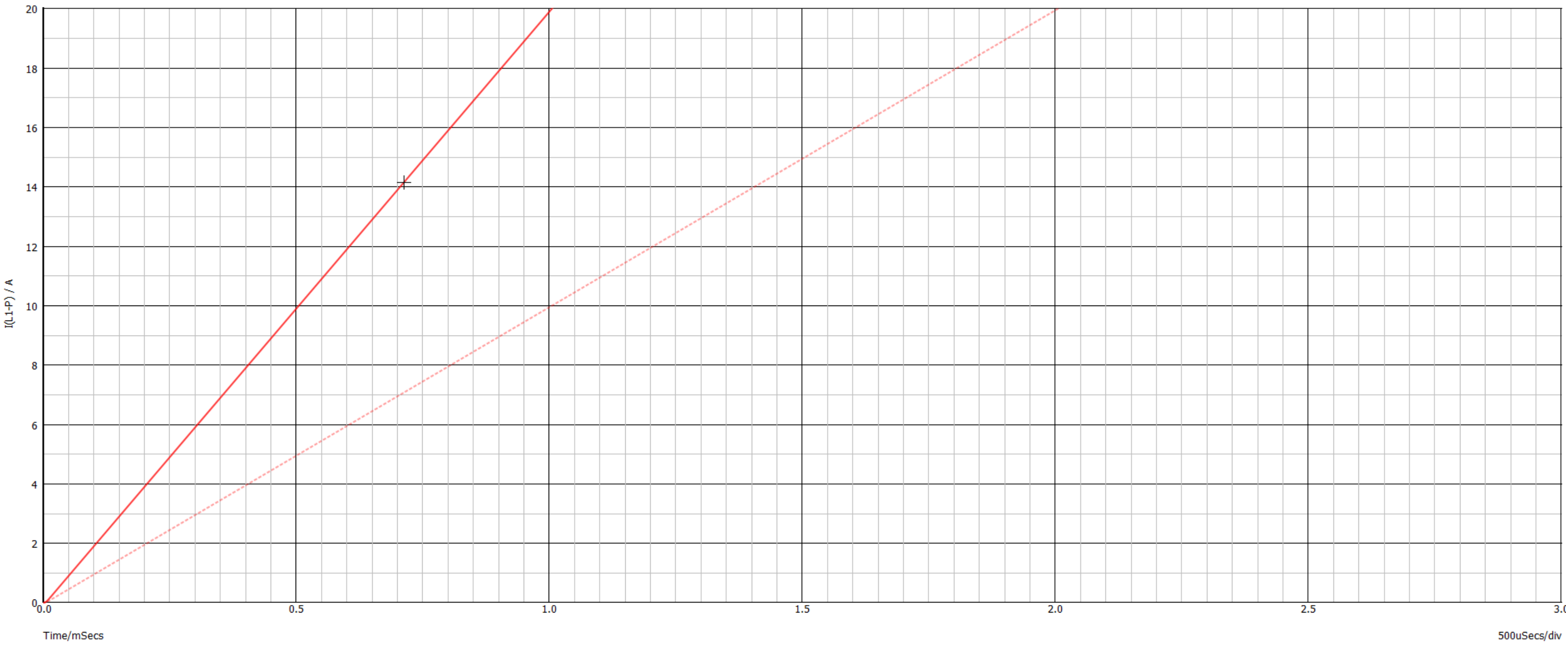
Table 2 Rate of change of the current with a larger inductor value

	Rate of change of the current **Δi /Δt** (A/mS)
Theoretical	$Rate\ of\ change = \frac{\Delta i}{\Delta t} = \frac{10V}{1mH} = 10kA/S$ 10kA/S = 10A/mS
Measured	$Measured = \frac{10A - 5A}{1mS - 0.5mS} = 10A/mS$

Take a screenshot of the current. For easy comparison, the screenshot must contain **both waveforms** - 500uH and 1mH - on the same curve.



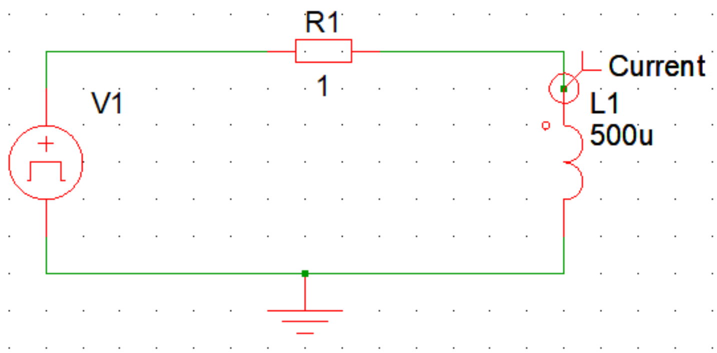
The axis ranges must be as follows: from 0A to 20A



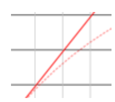
Screenshot for RL circuit for part 1 - tables 1 and 2. Solid red line: L = 500uH and dotted red line: L = 1mH.

RL circuit

Since a real coil is a RL circuit, the current cannot increase indefinitely because the resistor limits the current.
To simulate a real coil, add a 1 Ω resistor in series with the inductor



Take a screenshot of the current. For easy comparison, the screenshot must contain **both waveforms** – 1 Ω and 1uΩ - on the same curve.



The axis ranges must be as follows: from 0A to 8A

Characterize your circuit by filling up the following measure table:

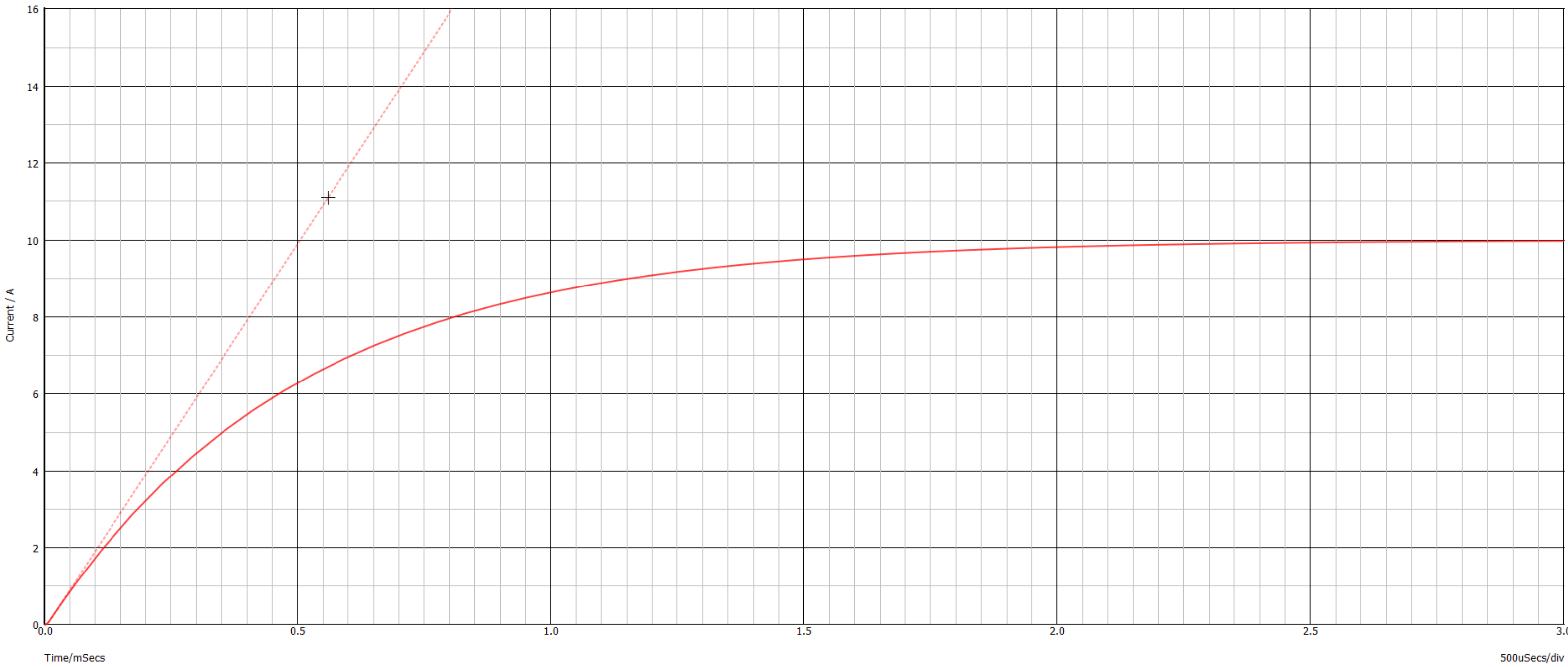
Table 3 Characteristics of a RL circuit

	Initial rate of change of the current **Δi /Δt** (A/mS)	Final rate of change of the current **Δi /Δt** (A/mS)	I max	τ (uS) at 63 %	5τ (uS) at 99 %
Theoretical	$\frac{\Delta i}{\Delta t} = \frac{10V}{500\mu H} = 20kA/S$ 20kA/s = 20A/mS	$\frac{\Delta i}{\Delta t} = 0A/S$	$I = \frac{10V}{1\Omega} = 10A$	$\tau = \frac{500\mu H}{1\Omega} = 500\mu S$	$5\tau = 5 * 500\mu S = 2.5mS$
Measured	20A/mS	$0A/mS$	9.97A	6.28A @ ~500uS	9.93A @ ~2.5mS

Notes:

τ is the amount of time it takes for the current to reach 63% of its max value.

5τ is the amount of time it takes for the current to reach 99% of its max value.



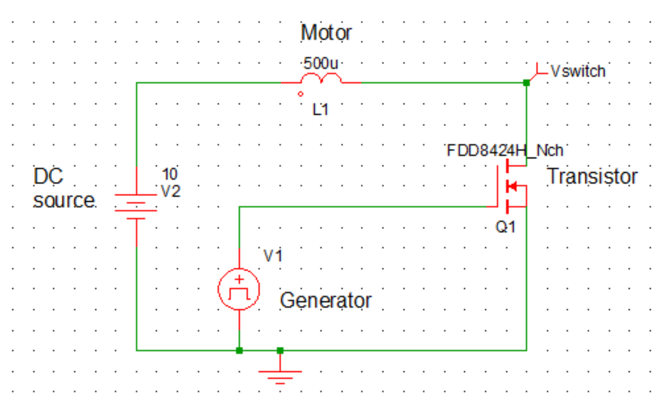
Screenshot for RL circuit for part 3. <u>Dotted red line</u>: R = 1uΩ (no current limit) and <u>solid red line</u>: R = 1Ω (with current limit).

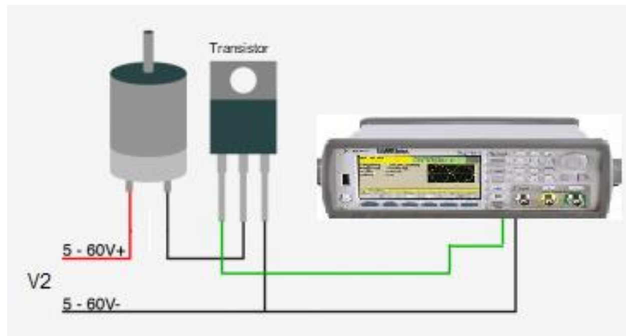
Part 2: Over voltage spike in a motor control circuit

As a load, a motor is a coil and this part demonstrates over voltage in a motor when there is no suppression component.
Also, when a freewheeling diode is added to the circuit, it will suppress the voltage spikes.

Without freewheeling diode

Wire the following motor control circuit. The MOSFET transistor coupled with the waveform generator act as a switch that turns ON and OFF at a specific frequency.





Set the simulator analysis to:

- Transient
- Stop time to 15mS

Set V1 waveform generator to:

- Frequency: 200Hz
- Duty: 6%
- Pulse: 5V
- Wave Shape: pulse

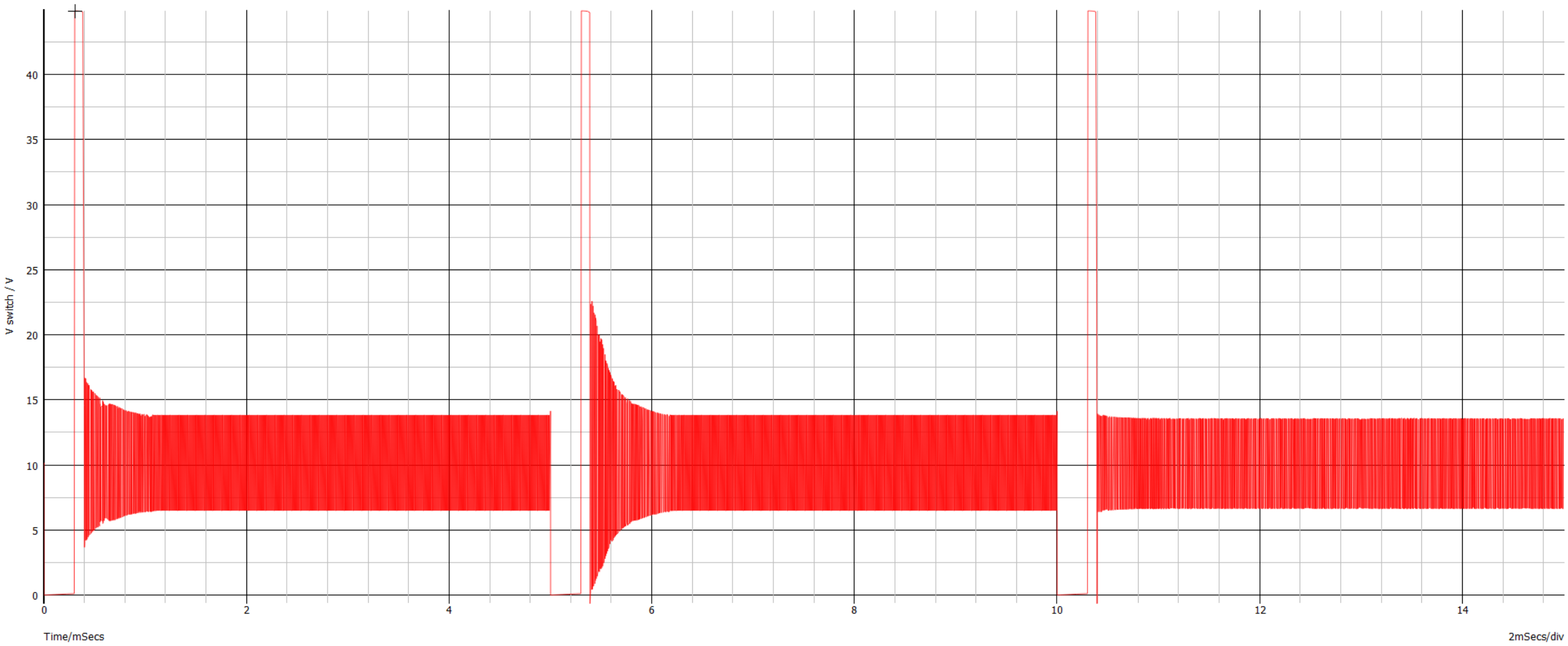
Run the simulator and measure the voltage spike at the switch:

Table 4 voltage spike without freewheeling diode

	V switch spike(V)
Measured	44.88V

Is there a voltage spike at the switch? Explain

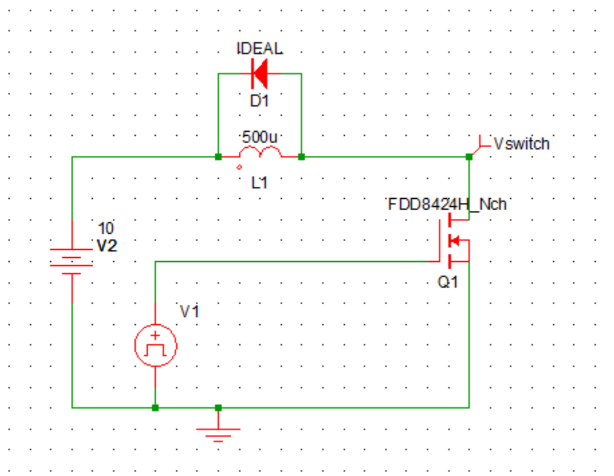
There is a large voltage spike at the switch because there is no freewheeling diode preventing the large spikes from occurring when the motor turns off. See screenshots below.



Screenshot for part 2 when there is no freewheeling diode connected in parallel across the motor. There are noticeable large spikes that occur when the motor turns off.

Spike suppression freewheeling diode

To prevent voltage spikes, an anti-parallel freewheeling diode must be added in parallel with the motor:



Run the simulator and measure the new voltage at the switch:

Table 5 voltage at the switch without freewheeling diode

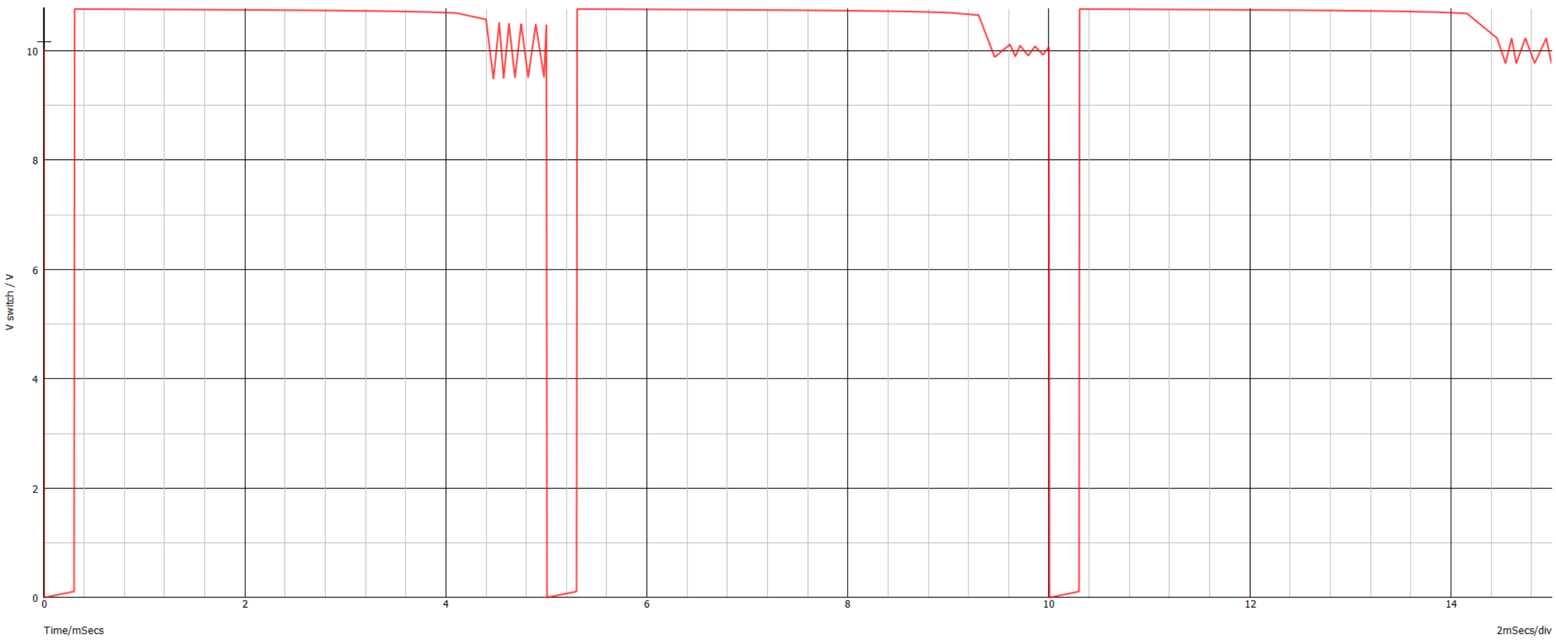
	V switch OFF (V)	V switch ON (V)
Theoretical	10V + 0.7V = 10.7V	0V
Measured	10.8V	54.34mV

Is there still a voltage spike at the switch? Explain

With the freewheeling diode connected parallel across the motor, there is no more large spikes at the switch when the motor turns off. This is because the freewheeling diode prevents these large spikes from occurring. See screenshot below.

What is the voltage drop across the diode when Q1 turns off?

When Q1 turns off, the voltage drop across the diode (that's connected in parallel with the inductor) becomes forward-biased with 0.7V drop across it.



Screenshot for part 2 when there is a freewheeling diode connected in parallel across the motor. There are now no more noticeable large spikes that occur when the motor turns off.

To approve

After lab questions

Q1.1- Explain the purpose of a freewheeling diode.

The freewheel diodes are usually connected across inductive coils (such as motors) to prevent large voltage spikes from occurring when power is cut to those devices.

Q1.2- Give a few examples of systems containing inductors and coils in your everyday life.

As mentioned above, an example of a system containing inductors and coils are circuits with motors. Other examples are solenoid circuits, tuning circuits and switch-mode power supply circuits (SMPS).

Q2- In part2, what is the purpose of the MOSFET transistor? Explain

The purpose of the MOSFET transistor was to act like a switch (similar to BJT acting like switch) where the voltage from the signal generator (depending on the cycle) would determine if the motor will be on or off (unlike with BJT where the current applied to the base of the transistor determines if the motor will be on or off). In this case, if during ON cycle: apply 5V to gate of MOSFET -> motor on or if during OFF cycle: apply 0V to gate of MOSFET -> motor off.

Q3- In part2, do you think the coil can damage the MOSFET transistor? Explain

If there is no freewheel diode, then there is a strong chance that the MOSFET can be easily damaged because more than likely, the voltage that the spike will create when the coil turns off will be much greater than the rated breakdown voltage of the MOSFET causing it to fail. If there is a freewheel diode, as discussed before, the spikes will no longer occur, therefore there should be no damage that will occur with the MOSFET.

Q4- Does a motor contain a coil? If yes, do you think it has a large inductance?

Motors do contain a coil (as shown in Part 2 above). Because a motor has many windings for it's coils, I believe that it has a large inductance.

If a switch is in series with a motor and a source, do you think the switch can wear out faster than other types of load (light bulb for example).

If the switch does not have a freewheeling diode to protect it, then it can be damaged much faster than other loads. The effects of having the freewheeling diode versus not having one are discussed above and shown in Part 2 and apply to switches and other devices connected to motors and other related coils and inductors.

Is it possible to reduce the deterioration of the switch? Explain

As shown before, with a freewheeling diode present, large voltage spikes are no longer an issue therefore they protect the devices that they are connected to. The obvious solution to prevent the switch from deteriorating is by having a freewheeling diode connected across the switch so that the large voltage spikes don't damage the switch.