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MSS Lab **Part A: Lumped Element Simulation (Saber)** **Exercise 4: Simple Mechatronic Circuit**		Prof. Dr.-Ing. G.Schmitz **Flugzeug- Elektrik und Elektronik**
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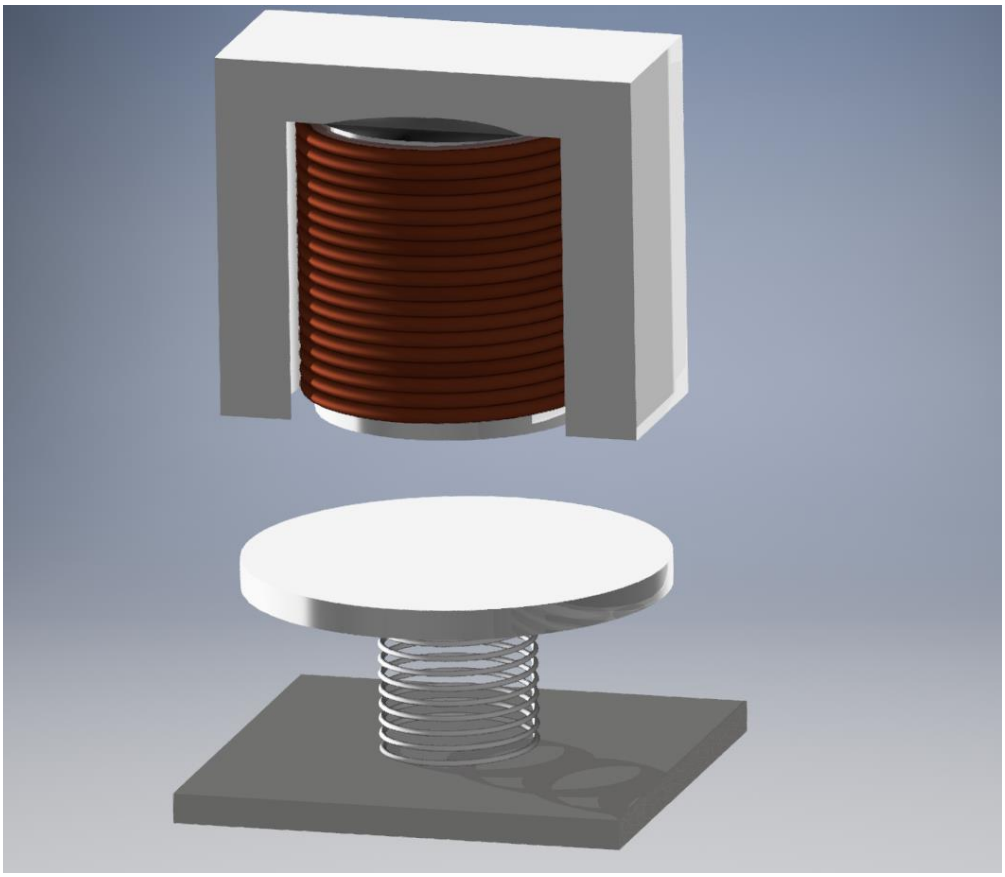


1 Introduction

In this lab we want to get familiar with characteristic curves of transistors and some basic circuits with and without mechanical components. During this lab we also want to learn the basics of plotting x-y diagrams and making calculations with the curves.

2 Execution of the exercises

In the exercise you will first design a simple transistor circuit and analyze it using the "Transient Analysis Function". After this you will try to design basic circuits for switching and amplification.

2.1 Simulation of a coil with a transistor driver

2.1.1 Simulation of a coil driver without freewheeling

Design a circuit where a magnetic actuator is switched by a trasistor power stage containing:

- one Darlington- Transistor (Typ 2N6388, SABER- Name: q2n6388),
- a voltage source with 12V (SABER- Name: Voltage Source, Constant Ideal),
- a pulssource as Input signal (SABER- Name: Voltage Source, Pulse),
  using the following parameters:

Meaning	Sabername	Proposed value
Initial Voltage Level	initial	0
Puls Voltage Level	pulse	10
Risetime	tr	1m
Falltime	tf	1m
Delay before the first pulse	delay	0.1
Pulswidth	width	0.5
Time between repeating the pulses	period	- (*opt*)

- a coil with an inductance of 100mH and a resistance of 2Ω
- a base resistor for the transistor of 10kΩ

As simulation parameters for the Transient Analysis you should use: Tend: 2 (i.e. 2 seconds), Time Step 0.01 (i.e. 10ms).

Display the values for the Input Voltage (Pulse source), the Coil Current and the Coil Voltage versus time. What do you observe regarding the Coil Voltage?

2.1.2 Simulation with freewheeling

Ammend the cicuit by a freewheeling diode and compare the results to 2.1.1.

2.1.3 Simulation with freewheeling diode and resistor

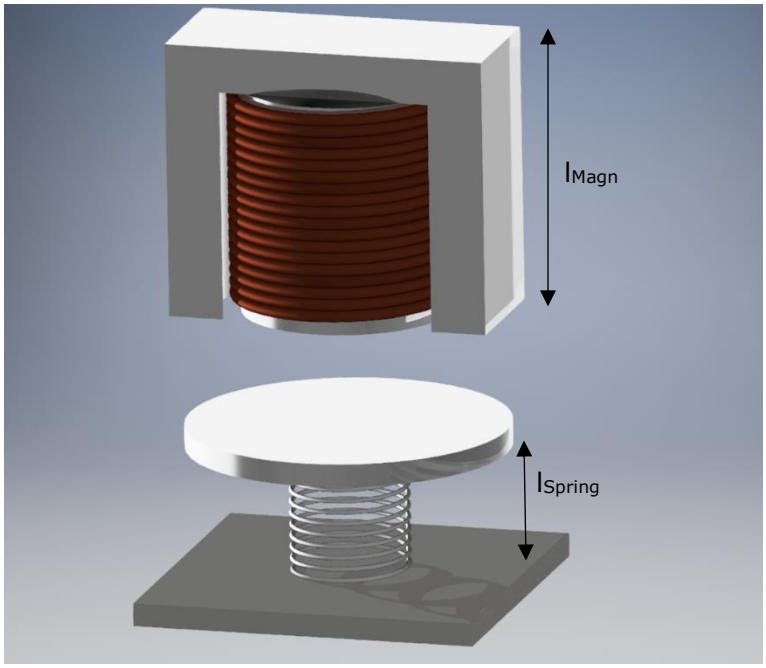
Now add a resistor to the freewheeling path and compare the results to 2.1.2.

2.1.4 Simulation with freewheeling diode and Zenerdiode

Now use a Zenerdiode (e.g. 40V) instead of the resistor and compare the results to results with different values for the resistor (saber-model: zd, parameter ‚vzt' in „saber model" ist he Zenervoltage. The inner resistance ‚rzt' should be reduced to 0,01 Ohm) .

2.2 Simulation of a simple mechatronic System

Now replace the coil by an electromagnet. On the mechanical „side" of the magnet you have to add the mass of the armature (including the reduced mass of the spring), a spring and a damping. Moreover, you will need a fixpoint for the spring, which has to be set to a certain distance to the magnet.



A proposal for the components and parameters is as follows:

- The Pulse voltage source should be set to delay = 50m and width = 200m.
- Set the time of simulation (Tend) to 500m and the Time Step to 1u.

- Spacer 10mm (for the fixpoint of the spring)

spring (spring_t, "t" stands for "translational" to discriminate from rotational springs): length: 5mm (l_{Spring} = ‘initial deformation'), Applying a „weight" of 100 grams the spring should extend an amount of 1mm; Calculate the spring constant in N/m (approximate the result).

- Mass of the armature: 50g (Remember, that all parameters are entered in the mks- System!)
- Damper (damper_t): 2 N/m/s i.e. a damping whichs depends on the velocity. Here we choose a small value so that the oscillation of the spring mass system can be well seen.

- Magnet (el_magnt):
  Parameter:

Meaning	Sabername	Proposed value
Inductance with armature attracted	lmax	10m
Variation of inductivity while armature departs (important also for the correlation between current and force)	lcoef	200
Position of the pole surface	x0 (l_{Magn} in picture)	0
Stiffness of the spring	kstop	20000k

The Armature in the picture is regarded as having a thickness of zero.

The following section is only for your information. You don't have to do simulations or calculations to get the curves!!

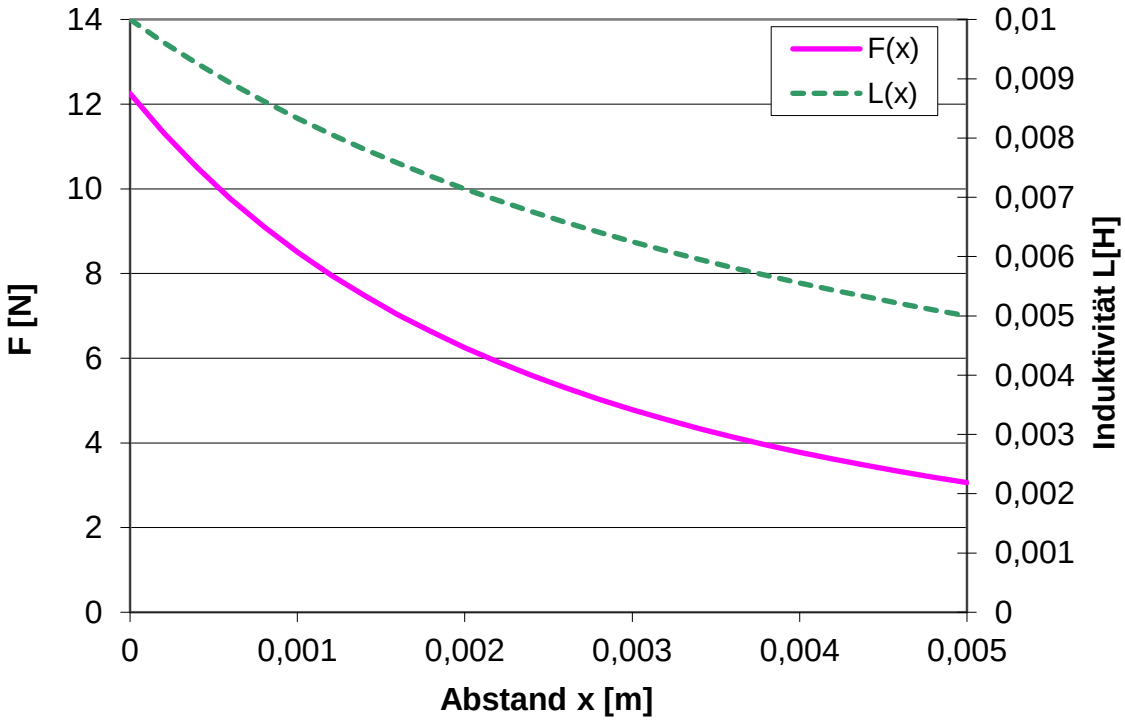
Note about the formulas used in the model:

For the regular operation of the magnet the distance x (x = pos1 - pos2) has to be larger than the position x_0. The force of the magnet is given by:

$$F_{magn} = -\frac{1}{2}\left(\frac{l_{coef}}{l_{max}}\right)\cdot(L(x)*i)^2$$ with the inductivity depending on the distance x:

$$L(x) = \frac{l_{max}}{1 + l_{coef}\cdot(x - x_0)}$$

Yielding the following curve for the inductivity and the force versus the distance:



- The behaviour of the armature impacting on the pole surface is depending on the „stiffness" of the pole surface. So the stiffness i.e. the spring constant should be chosen quite high, because compressing the pole surface really requires a lot of force. For the region of negative x- values (x = pos1 - pos2) with x<x0 the force is calculated using the formula for a spring: $F = -kstop\cdot(x - x_0)$