

EMC

Laboratory exercise 3

Passive components

Biomedical Engineering
LTH



Laboratory exercise 3: passive components

This exercise deals with the frequency properties of passive components. The measurements are made using a spectrum analyzer (with built-in tracking generator), and with an impedance analyzer.

Readings

Williams, "EMC for product designers, Ed. 5" pp 406-417.

Slides from lecture on passive components.

You should understand and be able to explain

- The quality factor (Q-value) of a coil and the loss factor (dissipation factor, D-value) of a capacitor.
- How a ferrite can reduce interference. What properties of the material which are used.
- How a three-terminal capacitor is configured.
- The equivalent circuit diagrams of resistors, capacitors and coils, and the frequency response of these components.
- Parasitic inductive and capacitive effects in passive components.

Laboratory report

In the report, the results and conclusions of the measurements are to be presented (description of methods or list of equipment are not necessary). The report is written in groups (or individually if you do the laboratory exercise on your own) and is to be 2-4 pages long, in addition to a cover page (where your name(s), the name of the exercise and the tutor's name are listed). Academic accuracy concerning references is assumed. The report is submitted to the tutor via Canvas one week after the laboratory exercise.

To bring to the laboratory exercise

One person in the group should bring a USB-stick in order to save the results of the measurements for the laboratory report (the computer in the lab does not have an Internet connection).

Equipment

Siglent SSA 3021X spectrum analyzer with built-in tracking generator 9 kHz – 2.1 GHz.

HP 4194A impedance analyzer with computer controlling (LabView)

Hioki IM7581 impedance analyzer 100 kHz – 300 MHz

Ferrites

- FB-43-101
- FB-61-101
- FB-75-101

EMI-filter

- Murata 222 (2,2nF)
- T-filter using discrete components

Coils

- 15 μ H
- 47 μ H
- 220 μ H

Capacitors

- 4,7 nF polyester (mylar)
- 4,7 nF ceramic

- 4,7 nF mica
- 47 nF polyester (mylar)

Resistors

- 3,3 Ω
- 100 Ω
- 10 k Ω

Part 1: the frequency properties of passive components

Please note!

Discharge yourself to ground in the beginning of the laboratory exercise before touching the input connector of the spectrum analyzer!

Siglent SSA 3021X

When you have turned the spectrum analyzer on, adjust for a frequency range up to 1 GHz and perform the measurements as described below. Depending on the results and the specifications of the components (devices under test), chose a suitable frequency span for the actual measurements. The tracking generator is activated using the button marked “TG”.

1. Study the attenuation of a ferrite bead when it is applied to a wire. There are three different ferrite materials. In which frequency ranges are they active? Why? What happens if two or more beads are applied? Do you see any relationship between the relative permeability of the ferrite material (see data sheets), and what frequencies are attenuated.
2. Study the attenuation of an EMI-filter, type Murata, 2.2 nF. Compare to a similar one consisting of discrete components, 2.2 nF, 2 x 470nH.
3. Suggest some own designs and study the effects using a prototype board. Consider what frequencies are affected, and what frequency range is suitable for the measurements. Does the actual frequency properties of your filter correspond to the theoretical ones, if not: why?
Hint: feel free to try the filter simulator at (for example) <http://sim.okawa-denshi.jp/en/Fkeisan.htm>

Part 2: impedance analysis of R, L and C

HP impedance analyzer with computer control

The components which you are to examine are to be clamped to the test fixture, which is attached to the impedance analyzer. As you start the measurement procedure, the impedance analyzer performs a four-terminal measurement, meaning that current is conducted through the component while voltage and phase-shift between current and voltage is being measured.

For the HP-impedance analyzer:

The LabView-program in the computer controls the impedance analyzer and retrieves the results which are plotted on the computer. The measurement is started by clicking on the icon with the arrow pointing right. The results of the measurements are then saved as Matlab-files. Please note that each measurement generates three different files, which have to be saved under different names. When the software has started a measurement, the keypad of the impedance analyzer will lock. To reactivate the keypad, press "LCL" (Local) on the impedance analyzer.

The Hioki-impedance analyzer is run on the touch screen (or possibly with other software).

Please note that the values of the components in the following assignments may be changed at the lab session.

4. Measure the frequency behavior of metal film resistors of 3.3 Ω , 100 Ω and 10 k Ω . What properties do the components show at higher frequencies? How much is the change in percentage? Why are the impedances altered?
5. Measure the frequency behavior of a 4.7 nF and a 47 nF polyester (mylar) capacitor. What are the resonance frequencies and the impedance at those? Compare with a 4.7 nF ceramic capacitor and a 4.7 nF mica capacitor. Measure and compare the loss factors D^1 at 1 MHz, 5 MHz, and 10 MHz for the 4.7 nF capacitors. Conclusions? Which of the capacitors is the 'best' one?
6. Measure the frequency behavior of a 15 μH , 47 μH and a 220 μH inductance (the latter one can easily be mistaken for a resistor). What are the resonance frequencies and the impedance at those? How is the resonance frequency calculated for an LC-circuit? Does the ratio between the resonance frequencies seem to be correct?

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¹ The loss factor is denoted as the D-factor as an abbreviation of *Dissipation factor*, hence the D. The D-factor is the inverse of Q, i.e. $D=1/Q$. ESR = Equivalent Series Resistance.