

Educating Electromagnetic Effects using Printed Circuit Board Demos

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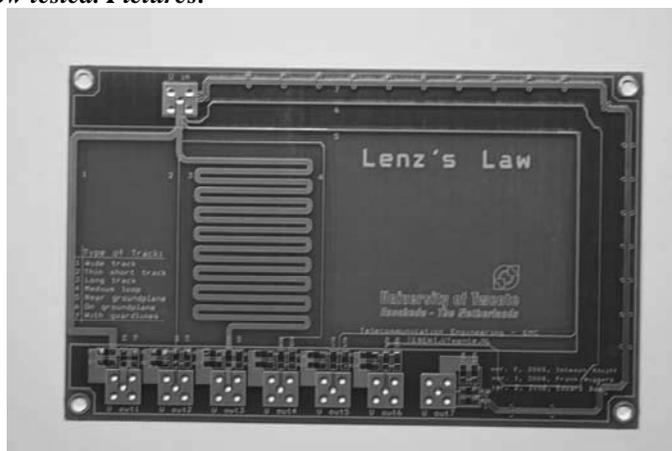
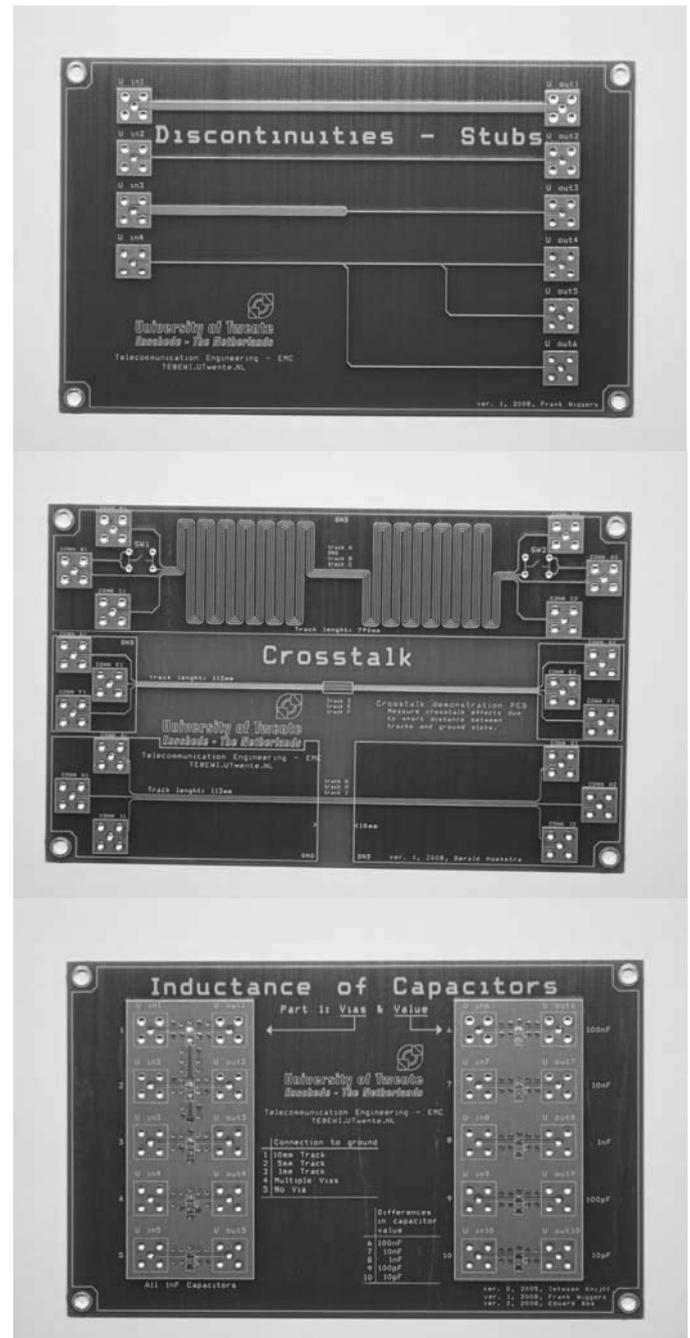
Abstract— Electromagnetic fields are considered by many students as a difficult subject. Unwanted electromagnetic fields are even tougher for students. We have developed many experiments as demonstrations (demos) to show the effect of electromagnetic fields in real life products. This paper gives an overview of these demos.

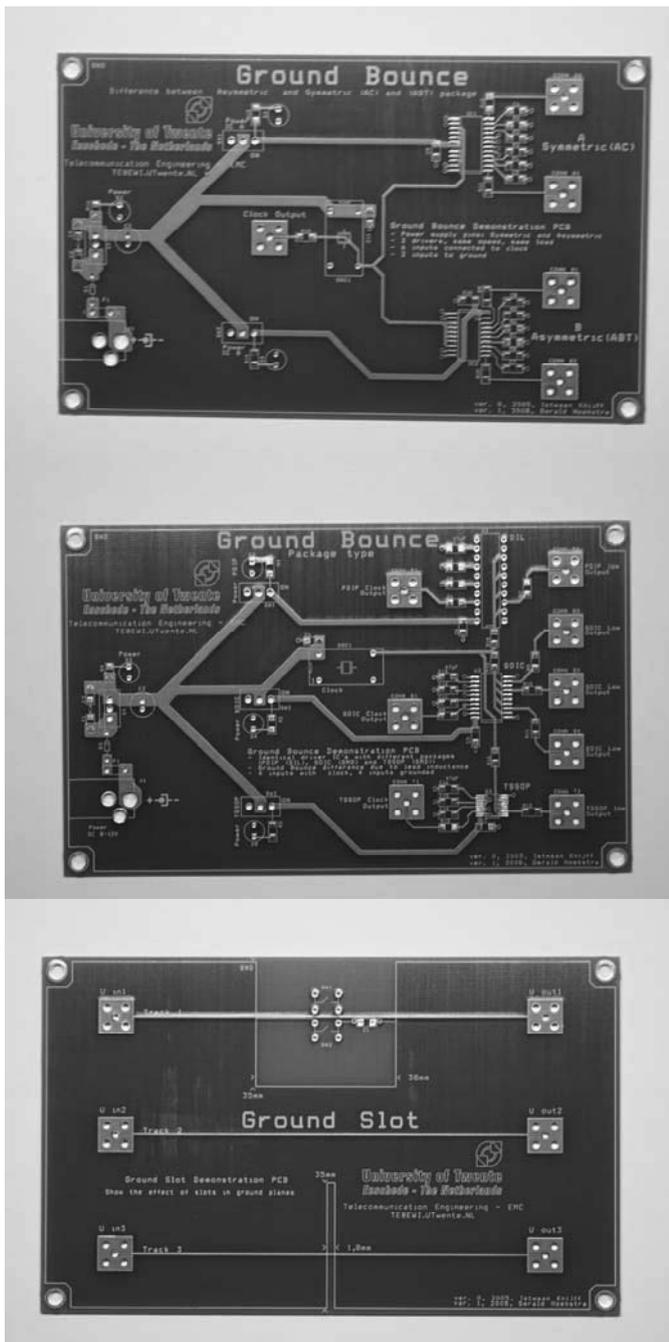
I. INTRODUCTION

Demos are often used in electromagnetic (field) courses. We have developed many types of demos and used also demos developed by others, such as those described in the IEEE EMC Education Manual [1], or the demo developed within the ASEAN-EU University Network Program [2], or within PATO [3]. We had two main drawbacks: we could easily show the fundamental aspects such as Lenz Law, or crosstalk, in an idealized world, but this was not taken for granted by practicing engineers: these engineers needed a link to their own world. Especially people involved in signal and power integrity issues, ground bounce and interconnects. Their world is often a printed circuit board. The other drawback was that huge size of many of the demos. Transportation of such demos is therefore a problem. Therefore we decided to develop a series of demos on Eurocard (100x160mm) printed circuit boards (PCB)[4]. Test equipment consists of a basic generator, a dual channel oscilloscope, and, if available, a basic spectrum analyzer. The detailed description of the demo PCBs are available on a website, for free.

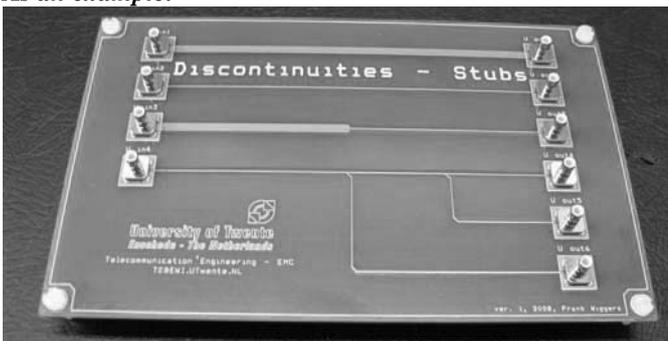
The demo kit was presented at the Euro EMC conference [5] and many, many people were interested. Therefore a new generation was developed.

To the reviewers: the boards have been produced. And are now tested. Pictures:





*These boards have been delivered some weeks ago, and now assembling:
As an example:*



The objectives, experiments and results will be described in the final paper. In the remaining part of this paper the prototype series will be described.

II. DESCRIPTION OF DEMO PCBs

A picture of the prototype kit is shown in Figure 1. This kit contains demos for showing the effect of:

- Lenz 1 – foldable
- Lenz 2 – fixed loops
- Proximity
- Ground Slot 1 – active
- Ground Slot 2 – passive
- Via Bypass
- Symmetry – signal
- Symmetry – power
- Inductance of Capacitors
- Grounding or floating heat sink
- Ground Bounce – DIL vs. SMD
- Ground Bounce – power layout



Fig 1: The demo PCB kit

A short description of every demo is available, giving:

- Description
- Expected result
- Practical result
- Explanation
- Lesson learned

The demos are also used in a practical training, and then students have to measure the effects, give an explanation themselves and draw conclusions from the experiments. We use different questionnaires for this hands-on training.

As an example, two demos are described in detail in this paper: the “Lenz, fixed loops” and the “Ground bounce” demo.

A. Lenz, fixed loops.

1) Description

Four signal tracks with the same load, but different lay-out and width. The Loop4 is the widest, and thus has the lowest resistance. (But it is the largest loop, and thus high inductance.....)

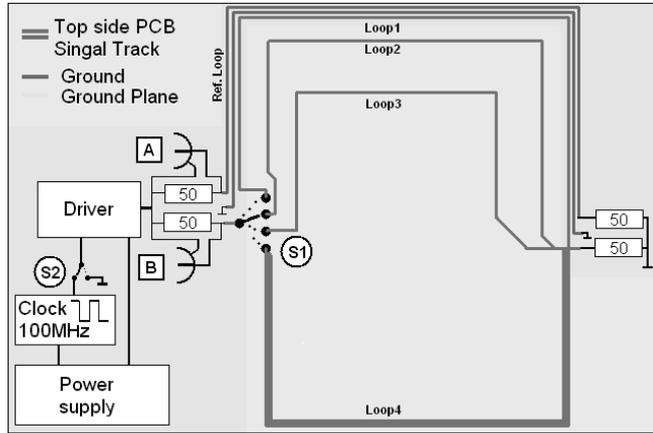


Fig. 2: The Lenz' Law experiment

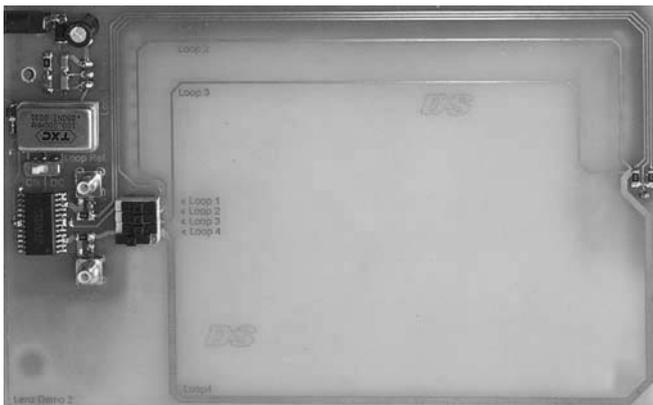


Fig. 3: The Lenz' Law experiment, the PCB

2) Expected result (students)

The signal travels best via the lowest resistance path.

3) Practical result

The signal is switched between all four tracks. Track 1 matches the original signal best, thus nearly all current flows in the loop with highest resistance (dark blue). The other loop show lower amplitude, thus less current (light blue).

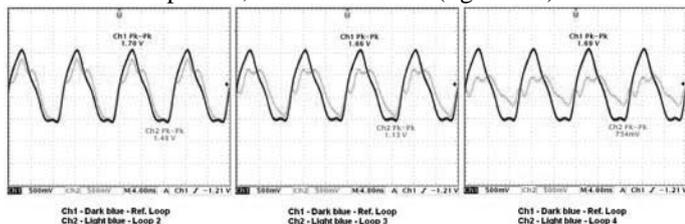


Fig. 4: The Lenz' Law experiment, the measurement result. Left loop 2, then loop 3 and right loop 4.

4) Explanation

A return path via the ground plane is available only below signal track 1 (top). Therefore a large current loop is created in the bottom three signal paths. At 100 MHz, this is a large inductance which adds to the total path impedance. Actually the narrowest and longest track is best because it has the lowest inductance.

5) Lesson Learned

Impedance is not only resistive, but also includes inductance. Be aware of loops in your design: keep signal track and ground plane close.

B. Ground bounce

1) Description

Two demos, one with different packages: DIL and SMD. The other with the same package, but with different pins used for power: edge or center pin. The drawing of the latter is shown in Figure 5. The picture of the experiment is presented in Figure 6.

2) Expected result

No difference in behavior: the components have equal specifications.

3) Practical result

Two effects are considered:

1. The ground bounce differences between two package types: the DIL package shows much more ground bounce.
2. The ground bounce differences as function as the pin location: it is reduced for outputs pins close to the IC's ground pin as shown in Figure 7.

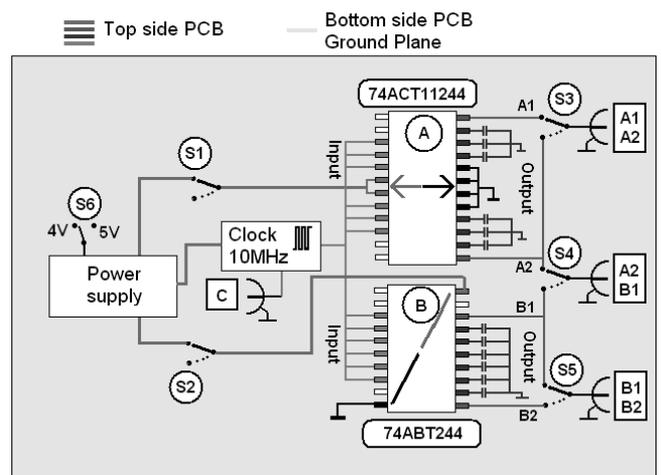


Fig. 5: Ground bounce in a package with edge pin and center pin power supply

