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# Characterization of the influence of different power supply styles on the electromagnetic emission of ICs by using the TEM-Cell method (IEC 61967-2)

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**Abstract** - In the design process of analog and mixed analog-digital circuits some design trade-offs have to be solved. With the use of a special designed test chip this paper will show that the TEM-cell method (IEC standard 61967) could be used as a helpful instrument for these trade-off decisions.

## 1. INTRODUCTION

Increasing of the complexity, the operation frequency and the miniaturization of Integrated Circuits as well as decreasing of the power supply lead to more and more EMC problems in analog and mixed analog-digital circuits. In general ICs are able to rectify a radio frequency signal and react to demodulated signals. This often causes failures of the designed function and may be safety critical. On the other hand integrated circuits usually do not radiate significantly, but they are often the source of the radiated energy. The most effective way of solving EMC-problems is to pinpoint and reduce the actual sources of interference. In this context, it is very important to tackle EMC-problems already at IC and ASIC level.

One of the main sources for electromagnetic emission are dynamic switching currents on the supply lines. This is a well known and accepted fact [1]. These high current peaks cause voltage swings on the supply lines due to the inductances of the interconnections and the bond wires as well as the lead frames. A common method to reduce these voltage swings are the use of decoupling capacitors. In the past the decoupling capacitors are mainly placed off-chip on the printed circuit board (PCB). Another way is to place decoupling capacitors on-chip, which already will be done since several years, but there is still a lack in information about the optimal placement of the decoupling capacitors and the difference in efficiency of on-chip and off-chip decoupling capacitor placement. From the marketing strategy on-chip decoupling should be used

instead of off-chip decoupling. That is at least the position of the customers of the IC manufacturers. This is therefore also an important point of view in the IC design process.

Another important issue in the design of mixed analog-digital circuits is the power supply concept. How many different power supplies should be used for optimal design? This is normally a trade-off between functionality and possible pin count. From the functionality digital and analog grounds and supplies should be separated at least. For telecommunication designs like UMTS or data converters (ADC/DAC) with large signal-to-noise ratios (SNR) additional guard rings (active as well as passive circuits) with additional quiet grounds and supplies will be needed leading to a large number of ground and supply pins of the IC. But there is also another important trade-off if the electromagnetic compatibility of the IC have to be considered during the design process. From the EMC point of view additionally parallel pins on the same electrical potential will reduce the voltage swings (and therefore the electromagnetic emission) due to the parallel inductances. On the other hand the number of possible supply pins are normally strictly limited especially in complex mixed-signal ICs.

For the discussion of these trade-offs the use of the TEM-cell method could be one very helpful instrument for the development of design guidelines for IC design taking into account all these mentioned problems. In the present paper we will show some measurement examples of the TEM-cell method regarding these problems. For this a special test chip was designed as well as the special PCB for the TEM-cell method as described in [2].

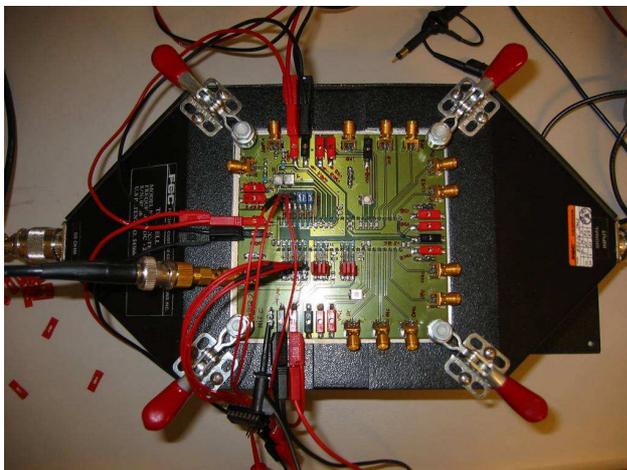
## 2. TEM-CELL METHOD (IEC 61967-2)

The TEM-cell method is used to measure the electromagnetic radiation from an IC [3], [4], which is mounted on an IC test printed circuit board (PCB) [2]. This test PCB is clamped to a mating port, which is cut in the top or bottom of a TEM- or wideband TEM- (GTEM) cell. In this case, the test PCB is not as usually in the cell, it becomes a part of the cell wall.

This test board has to be designed in a way that all connecting leads within the cell are eliminated. All the connecting leads should be located on the backside of the board outside the cell. Only the operating IC is allowed to be inside the cell.

The TEM-cell has two 50  $\Omega$  ports. One of these ports is terminated with a 50  $\Omega$  load. The other 50  $\Omega$  port of the TEM-cell (or the single 50  $\Omega$  port of the GTEM-cell) is connected to the input of a spectrum analyser to measure the RF emissions emanating from the integrated circuit and impressed onto the septum of the cell. An EMC receiver can also be used instead of a spectrum analyser.

The used test board was designed under the conditions of the IEC standard 61967 [2], [5]. The PCB is shown in **fig. 1** mounted on the described TEM-cell.



**Figure 1:** TEM-cell with used PCB

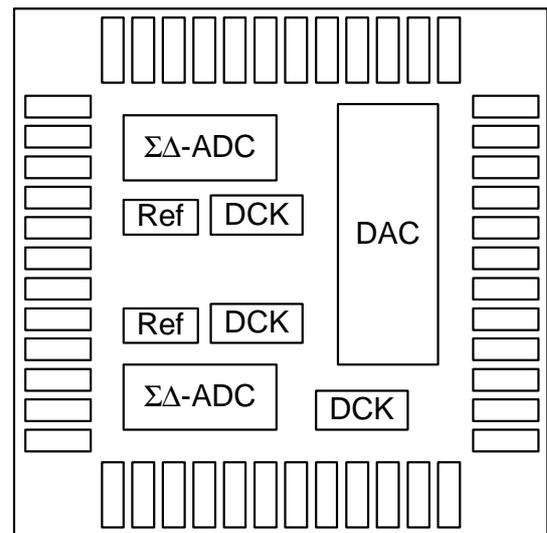
## 3. THE TEST CHIP

The main building blocks of the test chip are:

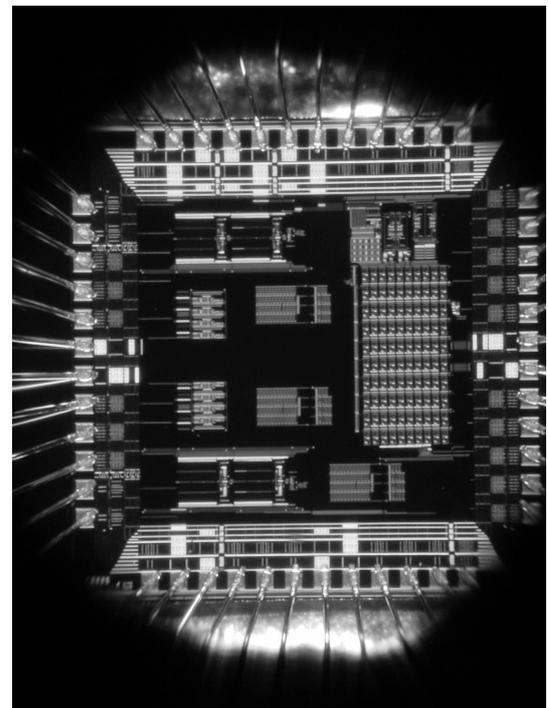
- two-stage single-bit  $\Sigma\Delta$ -ADCs
- 8 bit DAC (using current cells, 2 bit binary coded, 6 bit thermometer coded)
- DCK – on-chip decoupling capacitors
- Ref – reference blocks for the  $\Sigma\Delta$ -ADCs

The positions of the different building blocks are shown in **fig. 2** and **fig. 3**. The on-chip decoupling blocks exist of binary weighted MOSFETs (connected as capacitors) using MOSFET switches to turn on and off.

The test chip was fabricated using the austriamicrosystems 0.35 $\mu\text{m}$  CMOS technology. The nominal power supply is 3.3V for the analog and digital parts of the test chip.



**Figure 2:** schematic view of the test chip

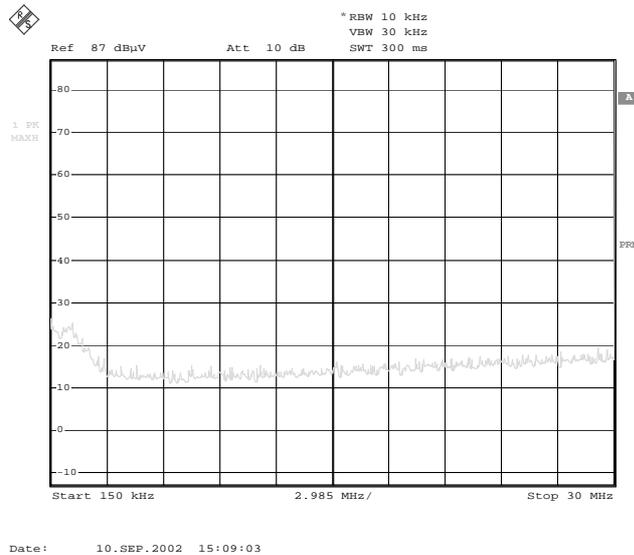


**Figure 3:** test chip

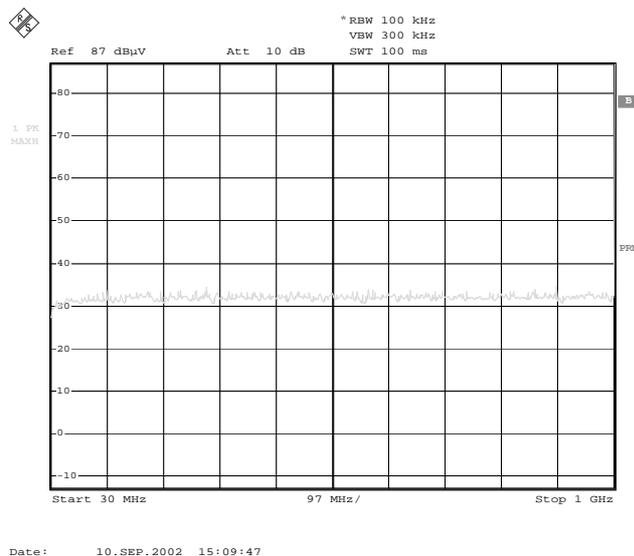
Two different versions of the test chip were designed. In the first test chip different power supplies and grounds were used for the building blocks as well as analog and digital signals. In the second test chip the different grounds are connected on-chip.

#### 4. MEASUREMENT RESULTS

**Fig. 4** and **fig. 5** show the reference measurement of the TEM-cell. For this reference measurement the TEM-cell was used with a metal plate instead of the PCB.

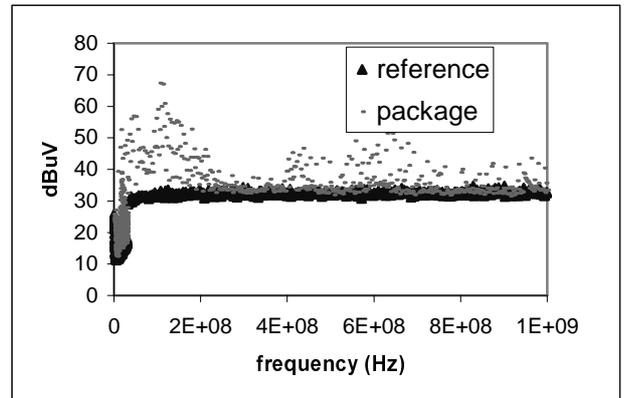


**Figure 4:** Reference measurement 150kHz-30MHz



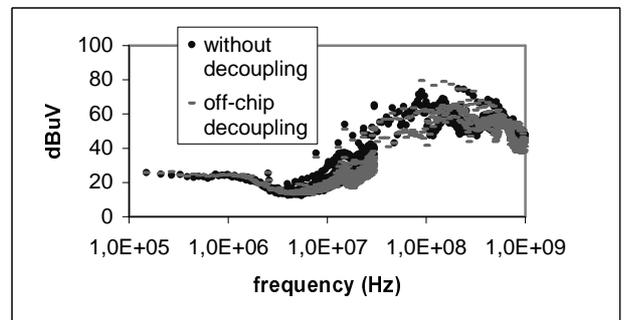
**Figure 5:** Reference measurement 30MHz-1GHz

To show the influence of the PCB a measurement of the TEM-cell with mounted PCB and a package without the silicon die is shown in **Fig. 6** compared to the reference measurement.



**Figure 6:** Comparison of the package and the reference measurement, influence of the PCB with IC package and without silicon die

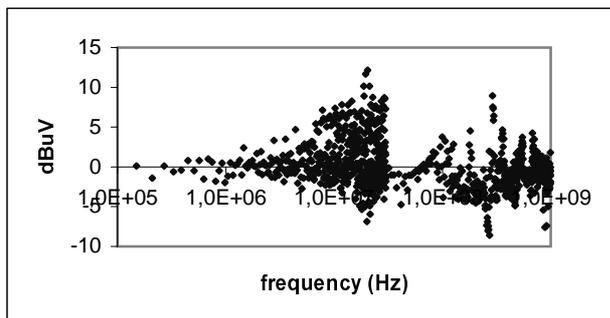
The intent of the original TEM-cell method due to the IEC standard 61967 is a quantitative measurement of the RF emissions from ICs. For this purpose the TEM-cell should be measured under EMC conditions to reduce interferences from other signals. For trade-off decisions as addressed in this paper a relative measurement method by comparison of two PCBs under the same measurement conditions are possible.



**Figure 7:** Influence of off-chip decoupling capacitances

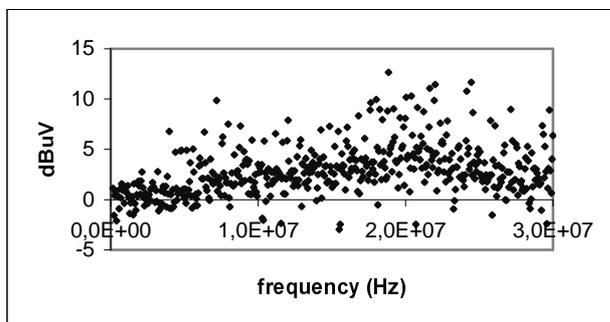
To show the influence in off-chip decoupling two different test PCBs were used one with and one without off-chip decoupling. **Fig. 7** shows that off-chip decoupling has an impact on the electromagnetic emission of an Integrated Circuit (although or especially of the fact, that only the IC is within the TEM-cell).

The difference of the two test chips regarding electromagnetic emission is shown in **fig. 8**. As shown in **fig. 8** for frequencies below 100 MHz there is an advantage in the IC version with common ground supplies and therefore more parallel pins. But above 100MHz there is an advantage in using different supply pins.

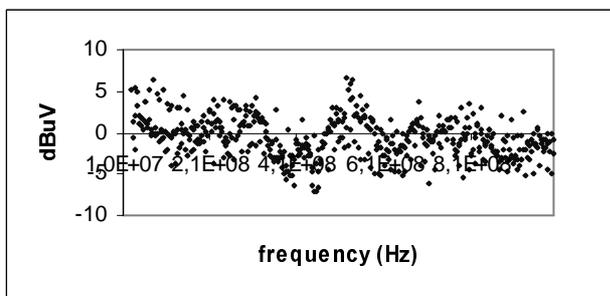


**Figure 8:** electromagnetic emission of the both test chip subtracted from each other

In **fig. 9** and **10** the influence of on-chip decoupling on the electromagnetic emission is shown compared to a chip without on-chip decoupling. In the frequency below 30 MHz on-chip decoupling reduces the electromagnetic emission (fig. 9 shown is the electromagnetic emission without decoupling minus the emission with on-chip decoupling). For frequencies above 30 MHz for this test chip there is no clear improvement. The reason for this measurement result is due to a not optimized placement and choose of the capacitance value of the decoupling blocks for higher frequencies.



**Figure 9:** influence of on-chip decoupling on the electromagnetic emission (150kHz-30MHz range)



**Figure 10:** influence of on-chip decoupling on the electromagnetic emission (30MHz-1GHz range)

## 5. CONCLUSION

The TEM-cell method could be used for characterization of different design and layout techniques for the reduction of the electromagnetic emission. The method could also be used in general to prove different circuit techniques in comparison to each other regarding their influence on the electromagnetic emission of the circuits. With the TEM-cell method the preparation of new design guidelines is possible for use in the near future.

## 6. REFERENCES

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