The Design of Current Probe in the IEC Conducted Emission Measurement above 1 GHz

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***Abstract* – A current probe based on IEC standard 61967-4 is proposed to investigate the conducted electromagnetic emission of IC above 1 GHz. The 1 Ω method in direct coupling method is revisited, and the concern for extending frequency range is discussed. The critical resistive network of 1 Ω probe is realized by a semiconductor process instead of the SMD resistors. With the advantage of reduced parasitic effect, the applicable bandwidth can be extended to 2.4 GHz. The proposed 1 Ω probe is verified to fulfill the EMI measurement of IC with operating frequency higher than 1 GHz.**

***Index Terms* — EMC, EMI, conducted emission, current probe, measurement.**

1. Introduction

The continuous miniature of the feature size in integrated circuit (IC) technology, as known as Moore's law, increases the importance of the electromagnetic compatibility (EMC) issues related to microwave engineering, signal integrity, and power integrity of IC. Scaling down the size of the devices as well as the increasing transistors amount allow IC to be operated at high-speed with low power consumption. The consequently desired high performances not only produce noise but also make the IC itself sensitive to interference. This situation leads the demand of characterizing their behaviors of emission and immunity. To investigate these problems, several measurement methods have been developed as the standards.

The technology committee of International Electrotechnical Commission (IEC) published a series of IC level test methods on electromagnetic interference [1] and electromagnetic susceptibility [2]. Depending on the transfer types of electromagnetic wave, the test methods can be further classified into radiated or conducted ones. In order to analyze the conducted RF currents/voltages, two acquisitions named 1 Ω current and 150 Ω voltage measurement are standardized as IEC 61967-4 [3], as known as the direct coupling method. The physical connection between probes and the IC under test could guarantee the measurement with high repeatability and correlation.

Comparing to the 150 Ω voltage probe, seldom works [4]-[5] were reported and met the specifications of 1Ω method. The practical problem on implementing the current probe is raised from the imperfection of the critical component,

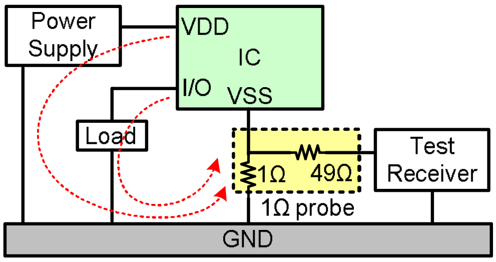

Fig. 1. Conducted emission measurement with the 1 Ω current probe.

1 Ω surface mounted device (SMD) resistor at high frequency. Therefore, its applicable frequency bandwidth becomes an issue and needs to be solved.

In this work, a novel approach is demonstrated to overcome the disadvantage of 1 Ω probe realized with SMDs. By replacing the SMD components with a 1 Ω network fabricated in a semiconductor process, the parasitic effect is reduced. Therefore, the measurement bandwidth can be expanded to 2.4 GHz. This paper is organized as follows. The 1 Ω method is revisited and the design issue is emphasized. And the novel 1 Ω probe composed of semiconductor resistors is proposed in section II. The proposed probes is examined in section III, And the measured results show the applicable bandwidth of 1 Ω probe could exceed the IEC standard with 1 GHz bandwidth.

2. Bandwidth Improvement of the 1 Ω Probe Method

The 1Ω probe is inserted between the VSS pin of the IC and the ground of PCB as shown in Fig. 1 to measure the RF sum current flows through the 1 Ω resistor. Because the return paths of an IC are mostly via the ground or power plane. Therefore, the VSS pin of IC is a great position for measuring the conducted emission current. The 1 Ω probe composes of a 1 Ω resistor and a 49 Ω resistor. This configuration satisfies the maximum power transmission by looking from test receiver side. From the VSS pin side, the 1 Ω provides a low impedance current path for IC operation.

As the miniature trend, the SMDs become the popular candidate to realize the probes. But the limited operating bandwidth of the SMD resistors comes from their packages. The parasitic effect rises as well as the increasing frequency

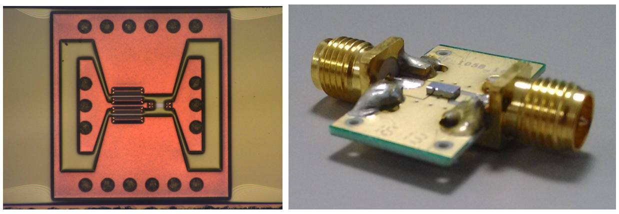

Fig. 2. Photographs of: (a) the 1Ω network in IPD technology, and (b) the current probe with flip-chip 1Ω network.

TABLE I
1 Ω Current Probe Specifications in IEC 61967-4

Frequency range	DC - 1 GHz
Output impedance	40 Ω - 60 Ω
Insertion loss	34 dB ±2 dB

and it makes the probe difficult to be realized with wider bandwidth than the IEC 1 GHz specification.

In order to minimize the parasitic of SMD resistors, the chip resistors are adopted. The semiconductor technology used in this work is the integrated passive device (IPD). It is a passive only process for wireless communication systems or RF applications. It has three metal layers with low dielectric constant material, and a NiCr layer is used for implementation of resistors. As shown in Fig. 2(a), the 1 Ω resistor is shunted to ground planes of the coplanar-waveguide (CPW) structure with a reduced inductance. And the fabricated IPD 1 Ω network chip is then flipped on a PCB with 50 Ω SMA connectors as shown in Fig. 2(b). The performance of the proposed probe will be examined in the following section.

3. Experimental Results

The IEC standard specifies the characteristics of 1 Ω current probe in detail with the measurement bandwidth of 1 GHz as listed in table I. The most critical item is the insertion loss with a calibration circuit. The measured insertion loss is referred to the sensitivity of the probe. The sensitivity is desired to exhibit a flat frequency response over the test bandwidth. A tolerance of ±2 dB from -34 dB is allowable in the IEC specification. The proposed current probe achieves an extended bandwidth of 2.4 GHz as show in Fig. 3. Besides, the impedance looking from the test receiver side should be near 50 Ω. Fig. 4 shows the output impedance complies within the limited range up to 3 GHz. With the significant improvement, the conducted emission of high speed/frequency IC can be characterized with a wider bandwidth.

4. Conclusion

The design of 1 Ω current probe to measure the conducted electromagnetic emission of IC above 1 GHz is proposed. To achieve a wider bandwidth measurement, the conventional SMD resistors of the current probe are replaced by an IPD chip with the embedded 1 Ω resistive network. The parasitic

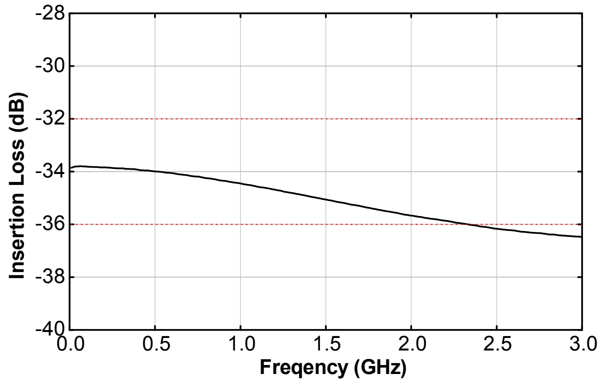

Fig. 3. Measured insertion loss of the 1Ω probe.

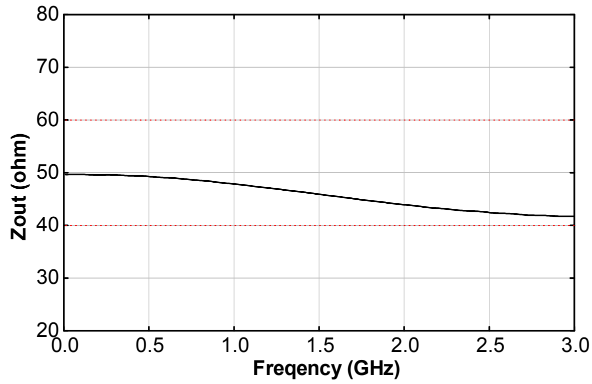

Fig. 4. Measured output impedance of the 1Ω probe

effect of chip resistor is reduced effectively compared with the SMD one with larger package. Therefore, the applicable bandwidth of current probe is sufficiently enhanced. Referring to the IEC 61967-4, the proposed 1 Ω current probe is verified and the experimental results show the capability of investigating the interference of IC up to 2.4 GHz.

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