Discrete 1Ω Probe by Using Flip-Chip IPD Resistor and Amplifier for Inspecting EMI of a Packaged IC

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***Abstract*—A 1Ω probe for EMI test is implemented by using a flip-chip integrated passive device (IPD) resistor and a commercial amplifier. Comparing with the conventional 1Ω probe composed of only the passive resistors (a 1-Ω plus a 49-Ω resistor), the proposed 1Ω probe exhibits better gain and noise performance. With the improved sensitivity, it could be helpful for detecting the suspicious EMI of a packaged IC.**

***Keywords*—Active current probe, CMOS, Conducted emission, Electromagnetic emission (EME), IC.**

I. Introduction

More and more manufacturers of electronic equipment request IC vendors to provide the EMC information of ICs. The EMC evaluation at IC level becomes essential because finding the root cause of the specification violation for a product is time-consuming. All elements in the system, including IC, packages, traces, components, connectors, PCB, and case, are suspicious. Via the measurement at IC level, the EMC performance could be compared between different versions of designs at different levels (IC, PCBs, modules, or system). Therefore, International Electrotechnical Commission (IEC) released several measurement standards [1]-[2] to evaluate IC level electromagnetic interference (EMI) and electromagnetic susceptibility (EMS). Among the standards, the easy-to-use 1Ω probe method is popular [3]-[4].

The most important step to obtain reliable measured results by using the direct coupling method is to implement the probes with certification. In the early period, it was difficult to make the 1Ω current probe meet the specifications in the standard. The parasitic issue that dominates the response is solved by shunting multiple lumped resistors [5], and the current probe is built to comply with the 1 GHz bandwidth of IEC standard. Furthermore, the on-chip 1Ω and 150Ω probes implemented by the IPD technology [6] show the capability of conducted emission measurement is significantly extended up to 15 GHz. Successfully, the bandwidth of emission measurement has been expanded to fulfill the evaluation of modern high speed ICs operating in the several GHz range.

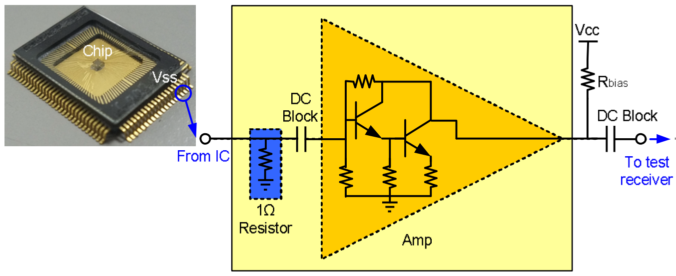

Fig. 1. Proposed 1Ω probe with gain and *NF* improvements for IC EMI test.

The rest issue of the 1Ω current probe is the high insertion loss of 34 dB. The high loss nature of the probe causing by the passive components degrades the sensitivity of the probe. In this work, an active 1Ω probe is proposed to provide extra gain than the traditional passive probe for detecting the potential interference in the modern high speed ICs.

II. Analysis of Different 1Ω Probe Topologies

Based on the IEC standard, the insertion loss (S_{21}) of 1Ω probe is about 34.2 dB with its noise figure (*NF*) equals to 34.2 dB. In order to improve the loss, the most straightforward idea is to add an amplifier with gain at the output of the probe. For performance comparison, an ideal amplifier is assumed to have the gain of 20 dB, *NF* of 2 dB, and the perfect match of 50 Ω at input and output. As the result, the overall S_{21} can be reduced to 14.2 dB. But from the viewpoint of the *NF*, the overall *NF* will deteriorate to 36.2 dB. The way to reduce the *NF* is proposed to modify the topology by cascading the amplifier directly behind the 1-Ω resistor as shown in Fig. 1. Because of the removal of the passive 49-Ω resistor, the proposed topology exhibits the improved performance on S_{21} and *NF* at the same

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TABLE I. CALCULATED RESULTS OF DIFFERENT 1Ω PROBE TOPOLOGIES

Specifications	**Passive 1Ω Probe**	**Passive 1Ω Probe + 20 dB Amp.**	**Proposed Probe**
Insertion loss (S_{21})	34.2 dB	14.2 dB	8.3 dB
Noise figure (*NF*)	34.2 dB	36.2 dB	26.5 dB

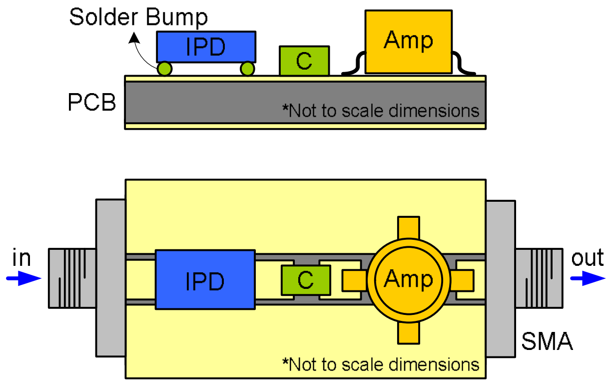

Fig. 2. Side view and top view of the proposed 1Ω probe.

time as shown in Table I. The S_{21} and *NF* show 25.9 dB and 7.7 dB improvements than the conventional probe, respectively. Therefore, this topology is adopted to realize the 1Ω probe for EMI measurement.

III. IMPLEMENTATION AND MEASURMENT

A commercial amplifier (Mini-Circuits MAR-6+) with the nominal gain of 21 dB and *NF* of 2.3 dB is chosen to realize the proposed topology. The critical 1-Ω resistor which dominates the bandwidth is fabricated by using IPD technology. To minimize the parasitic, the IPD 1-Ω resistor is flipped and soldered onto the PCB via the solder bumps as shown in Fig. 2. Therefore, the accuracy of 1-Ω resistance can be maintained and the interconnect between 1-Ω resistor and amplifier can be optimized to guarantee the performance.

The measured S_{21} of different topologies of 1Ω probes are compared in Fig. 3. The passive 1Ω probe with the amplifier connected directly shows an insertion loss of 12 dB. On the other hand, the proposed topology shows the best insertion loss of 6 dB, which is a 28 dB improvement than the conventional passive probe. And the operating bandwidth of 1GHz is complied with the IEC standard.

IV. CONCLUSIONS

A discrete 1Ω active probe for conducted EMI inspection is proposed. With the proposed topology, a high precision 1-Ω resistance was achieved by using the flip-chip IPD resistor. And a high gain amplifier is added to provide the needed gain. The insertion loss was significantly improved from 34 dB (conventional passive probe) to 6 dB. As the result, the proposed 1Ω probe can be used to inspect the EMI for a packaged IC with the improved sensitivity.

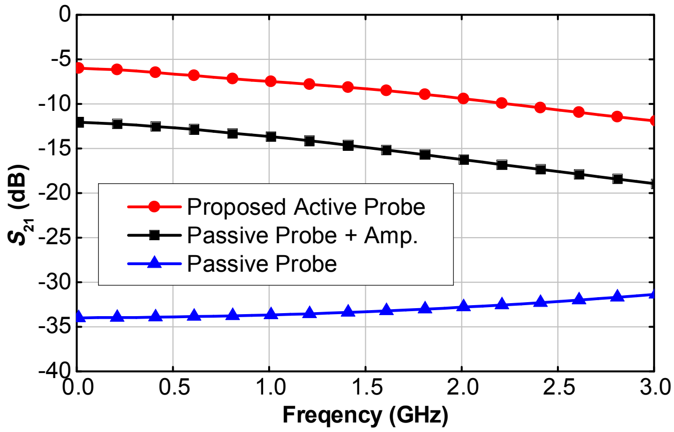

Fig. 3. Measured insertion loss of different 1Ω probe topolgies.

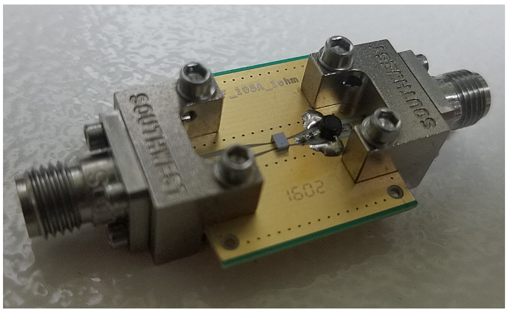

Fig. 4. Photograph of the proposed discrete 1Ω probe.

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