Design of the Multifunction IC-EMC Test Board with Off-Board Probes for Evaluating a Microcontroller

Yin-Cheng Chang[1,2], Ping-Yi Wang[1], Shawn S. H. Hsu[1], *Member*, *IEEE*, Mao-Hsu Yen[3],
Yen-Tang Chang[4], Chiu-Kuo Chen[4], and Da-Chiang Chang[2]
[1]Institute of Electronics Engineering, National Tsing Hua University, Hsinchu, Taiwan
[2]National Chip Implementation Center, National Applied Research Laboratories, Hsinchu, Taiwan
[3]Department of Computer Science and Engineering, National Taiwan Ocean University, Keelung, Taiwan
[4]Bureau of Standards, Metrology and Inspection, M.O.E.A, Taipei, Taiwan

***Abstract*—A multifunction test board is designed for a microcontroller (MCU) testing. This board can be used to verify the function of the MCU by running several basic instructions. Furthermore, six different IC-EMC measurements complied with IEC standards can be performed on the same board by careful design and the preservation of test points with certified off-board probes. The experimental results show the capability of providing the confident measurements up to 1 GHz. Meanwhile, the cost of performing a bunch of different testing methods on implementing various test boards is reduced.**

Keywords—emission; immunity; integrated circuit (IC); electromagnetic compatibility (EMC); microcontroller (MCU)

I. Introduction

The continuous miniature of the feature size in IC technology increases the significance of EMC 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. Regarding the growing applications of MCUs, both high density design and higher operating clock rate lead to the importance on characterizing MCUs' emission and immunity. To investigate these problems, several measurement methods have been developed as the standards.

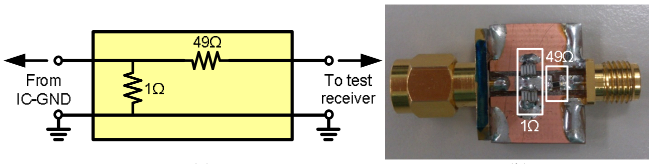
The technology subcommittee 47A of International Electrotechnical Commission (IEC) published a series of IC level test methods on electromagnetic interference (61967 series) [1] and electromagnetic susceptibility (62132 series) [2]. In order to investigate the EMC characteristics of an IC by applying these IEC standards, sometimes more than two versions of PCBs are needed to perform these measurements. In general, one version of PCB design corresponding to one specific test method. For example, the IEC 62132-3 test board with a large central hole for inserting the probe can only be used in the BCI method. The dedicated test boards can be costly and wasteful while performing the necessary EMC design evaluations. Fortunately, IEC standard has a flexible principle that allows the test board to be designed in accordance with general specifications and in accordance with the additional specifications as required for the individual measurement methods. Therefore, different methods with similar technique or using the same facilities are desired to be merged together on the same test board. For instance, the radiation tests, like IEC 61967-2 and IEC 62132-2 TEM cell methods use identical test board and are possible to perform the conducted test like IEC 62132-4 by building the injection network on the test pin. This work aggressively attempts to combine more methods on a same test board. The approach is to build the probes and networks needed in these standards to be off-board type. These off-board probes can be used repeatedly with certified characteristics. This solution not only saves the cost without building these probes on the various one-time-use test boards, but also keeps the measured results highly repeatable and reproducible because each of them can be verified carefully before experiment. As a result, the proposed test board could cover six IC-EMC measurements in IEC standards for IC-EMC which is helpful to designer for evaluating the EMC performance of the MCU.

This paper proposes a multifunction PCB design with the capability of verifying the basic functions of a MCU and investigating the EMC characteristics with several methods. The probes and the designed network comply with specifications in the standards are reviewed in section II. The extra consideration of the test board design principle is highlighted in section III. with test setups and measured results for demonstration of the practical experiments.

II. Off-Board EMI/EMS Probes

In order to fulfill the flexibility of multifunction test board, the probes and networks are designed as off-board type. All the adaptors of the probes and the test points of the test board in this work use SMA adaptor because of its small size feature and stability. The connector type of the probes which will be connected to test board are all designated as the male type SMA, so the test points on test board should adopt female type SMA for fool-proofing. The coplanar-waveguide (CPW) transmission line is utilized for the traces on probes. The CPW structure with grounds plane located at two sides of signal path make it easy for shunt connection. In this work, the vector network analyzer used to characterize these probes is Agilent PNA N5230A with the measurement capability of 300 KHz to 20 GHz.

978-1-4799-6670-7/15/$31.00



(a) (b)

Fig. 1. The 1Ω current probe: (a) schematic, (b) photograph.

TABLE I. SPECIFICATION OF THE 1Ω CURRENT PROBE

Frequency range	DC-1GHz
Measurement resistor	1Ω (1%)
Matching resistor	49Ω (1%)
Maximum current	<0.5A
Output impedance Zo	40 Ω -60 Ω
Insertion loss in calibration circuit	-34dB±2dB
Decoupling	Larger than the limit line as shown in standard.

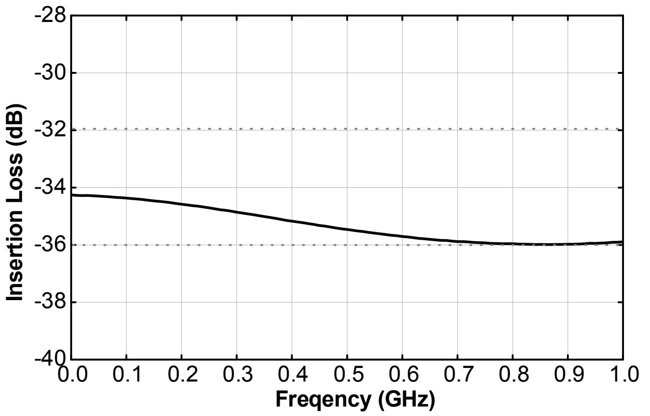
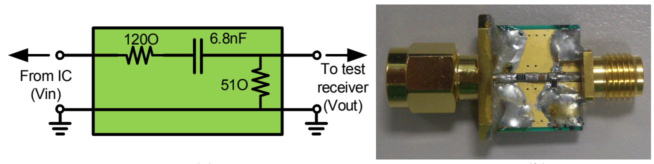


Fig. 2. The insertion loss of the 1Ω probe connected to the calibration board.

A. 1Ω Current Probe for Emission Test

The return path of an IC is mostly via the ground plane. Therefore, the ground pin of IC is a great position for measuring the RF return current. An 1Ω probe is inserted between the ground pin of the IC and the global ground. The 1Ω probe as shown in Fig. 1 is composed of a 1Ω resistor and a 49Ω resistor. The 1Ω resistor is connected to the ground pin of IC. The 49Ω resistor is placed between the ground pin of IC and the test receiver with 50Ω input impedance. As a result, this configuration achieves the 50Ω (49Ω plus about 1Ω) impedance matching which satisfies maximum power transmission by looking from test receiver side. From the ground pin side, the 1Ω provides a low impedance current path for IC operation. The specification of current probe is listed in table I. The most critical item is the insertion loss with a calibration circuit board. The sensitivity is desired to exhibit a flat frequency response over the test bandwidth of 1GHz. The realization of the current probe proposed in the previous work [3] was adopted. Fig. 2 shows the measured sensitivity which meets the specification in the standard. All other items in the speciation table are reviewed and verified to make the probe



(a) (b)

Fig. 3. The 150Ω voltage probe: (a) schematic, (b) photograph.

TABLE II. SPECIFICATION OF THE 150Ω VOLTAGE PROBE

Frequency range	150k - 1GHz
Input impedance with 50Ω termination Z_i	145Ω ± 20Ω
Insertion loss within a 50Ω system	0.2586 (-11.75dB±2dB)
Voltage ratio Vout/Vin	0.1738(-15.2dB±2dB)

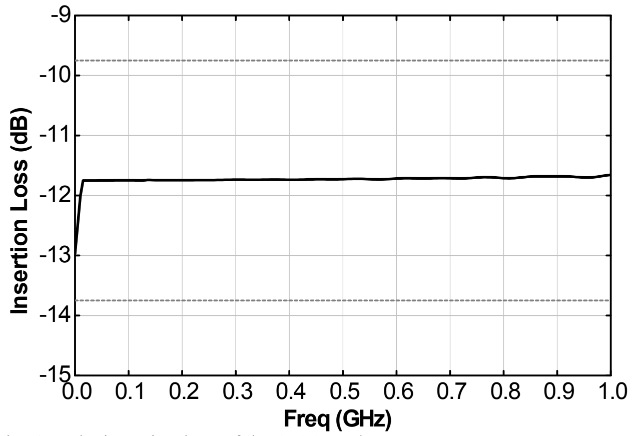


Fig. 4. The insertion loss of the 150Ω probe.

become certified in the IEC 61967-4 direct coupling method.

B. 150Ω Voltage Probe for Emission Test

The pin of an IC would be linked to a quite long path through PCB trace, interconnects, cable harness, and the receiver. According to IEC 61000-4-6, these networks show the impedance of 150Ω in general. In order to obtain the conducted emission level by using a test receiver with 50Ω input impedance, a matching network as shown in Fig. 3 is needed for impedance transfer.

The specification of voltage probe in direct coupling method is listed in table II. Unlike the difficulty of realizing the current probe with low impedance resistor which shows poor characteristic at high frequency band, the voltage probe is easier to be implanted. The capacitor of 6.8nF dominates the lower 3dB bandwidth of the insertion loss and shows a flat response without resonance over the frequency range of 1GHz as shown in Fig. 4. And the measured voltage ratio also meets the specification of -15.2±2dB as shown in Fig. 5. Therefore, it is verified to be able to serve as a voltage probe used in the IEC 61967-4 direct coupling method.

C. Direct Power Injection (DPI) Probe for Immunity Test

The DPI method is defined to characterize the immunity of IC in the presence of conducted RF disturbances. The disturbance injects into an IC through the cable harness or

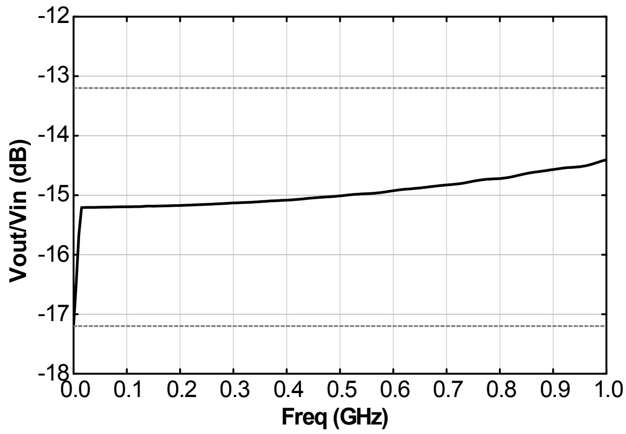
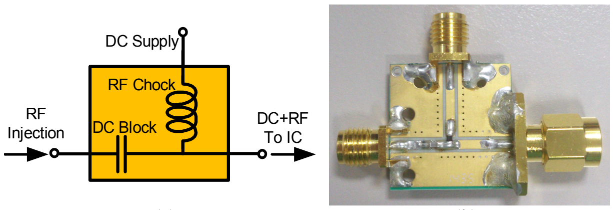


Fig. 5. The voltage ration of the 150Ω probe.



(a) (b)

Fig. 6. The DPI probe: (a) schematic, (b) photograph.

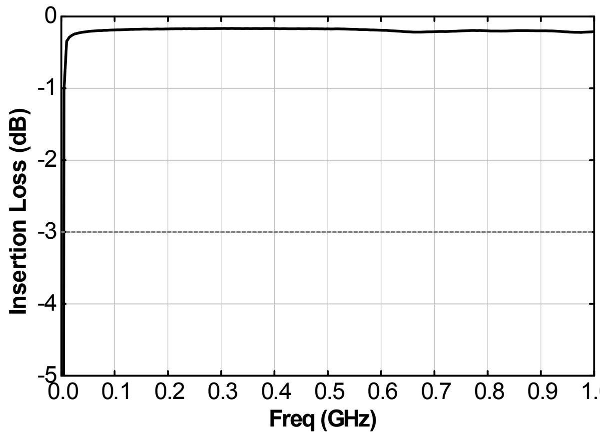
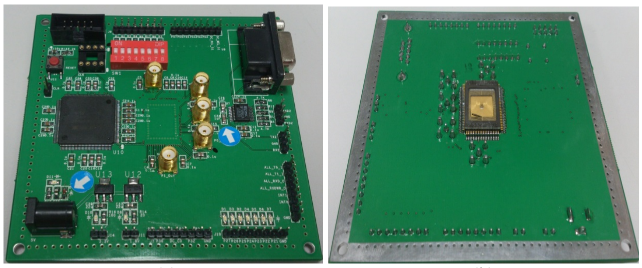


Fig. 7. The insertion loss of the DPI probe.



(a) (b)

Fig. 8. The photographs of multifunction EMC test board: (a) top side with all needed componets with test point adapters, (b) bottom side with MCU chip for TEM/GTEM cell measurement.

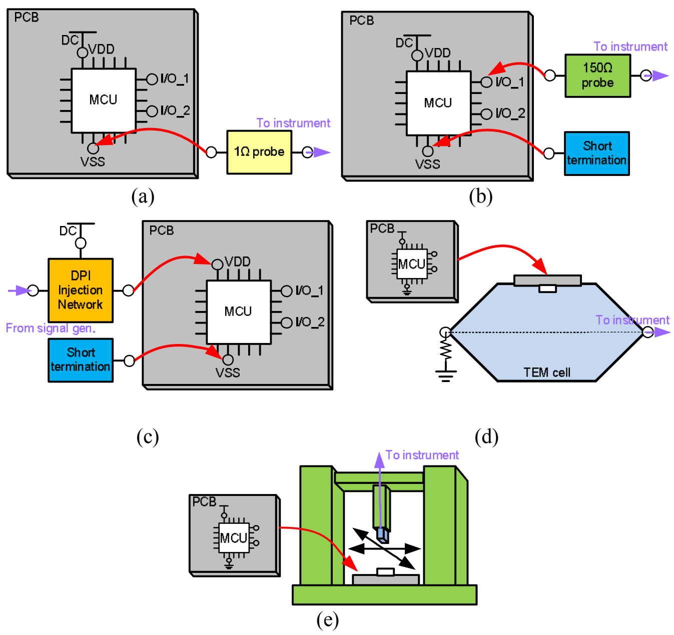


Fig. 9. The test setups for IC-EMC evaluation based on the mutifunction test board: (a) 1Ω method for conducted emission, (b) 150Ω method for conducted emission, (c) DPI method for conducted immunity, (d) TEM cell method for both radiated emission and immunity, and (e) near field scan method for radiated emission.

the traces on a PCB. The general test setup contains the DC power supply, directional coupler, test board with injection network and DUT, monitoring device, and a control unit. In order to fulfill the multifunction test on the same board, the in-situ injection network is realized as an off-board probe as shown in Fig. 6. Two important components are needed to build the probing structure for practical use. The RF power from amplifier is expected to transmit onto the pin of DUT. If the pin under test is supplied by a DC source, a decoupling component is necessary to avoid the injected RF power heading to the DC source where presents a low AC impedance path. Generally, a RF choke like the inductor is a good candidate to have the AC impedance over 400Ω in the test frequency range without causing too much DC voltage drop on the path. Besides, a DC block capacitor is inserted in the injection path to prevent DC current destroying the amplifier. The larger capacitance can achieve lower 3dB bandwidth and present a high pass response. In the standard, a 3dB insertion loss of the injection network is permitted to perform the DPI test. The measured 3dB bandwidth reveals the DPI measurement frequency range of 1 GHz as defined in standard can be covered as shown in Fig. 7.

III. Multifunction EMC Test Board for MCU

The test board is designed originally to demonstrate the MCU function by running arithmetic, logic, data transfer, jump, and I/O instructions with various sockets, components, and I/O interfaces. Fig. 8 shows the fabricated mutifunction test board, and the MCU is solely mounted on the other side for TEM/GTEM cell measurement. To garantee the meaningful EMC results measured from the proposed test board, basic design recommendation described in the standard should be followed. For this multifunction test board, extra critical principles should be noted. The location of these EMC test points hould be reserved preferentially and is desired to be put as close as possible to the pin under test to ruduce parcitics. The most important part in this board design is the partition between local ground under IC and the global ground which is especially designed for 1Ω direct coupling method. When other test method is proceeded, a short termination is used to connect the local ground and global ground together. Fig. 9 shows possible cases of the test setup to demonstrate the practical experiments with different methods. Fig. 10 shows the measured emission by using the 150Ω while the designated I/O port output a signal of 6kHz clock rate. The result can be used to estimate the conducted emission level form the MCU. For immunity evaluation, Fig. 11 shows the measured waveform at an I/O port to monitor the noise variation while the RF interference is injected through the DPI probe. With measured data from various methods could help to analyze and model the MCU. The investigation of the correlation among these data is in progress.

IV. Conclusion

The consideration on implementing the multifunction test board for EMC characterization of the MCU is proposed. The detailed design principles of the conducted emission and immunity measurements including IEC 61967-4 and IEC 62132-4 with certified probes are depicted. In addition, the radiated emission and immunity measurement including IEC 61967-2, IEC 61967-3, IEC 61967-6 and IEC 62132-2 could also be performed with commercial facilities, such as TEM/GTEM cell and near field scanner. In summary, six different IC-EMC measurements complied with IEC standards can be performed on the same board which significantly saves the expense during the phase of evaluating the EMC performance of an IC. Furthermore, the measured results give an opportunity to investigate the correlation among different characterization methods.

Acknowledgment

The authors would like to thank research group of BSMI (Bureau of Standards, Metrology and Inspection) for their technical support. The original research work presented in this paper was made possible in part by the BSMI under Contract No. 1D101021217-181, grant from BSMI, Taiwan.

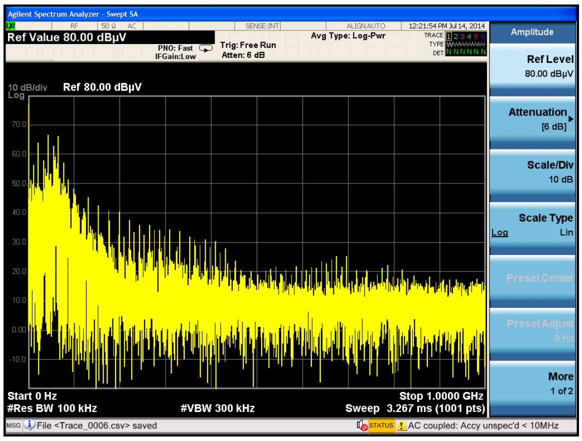


Fig. 10. The measured emission spectrum by using the 150Ω probe.

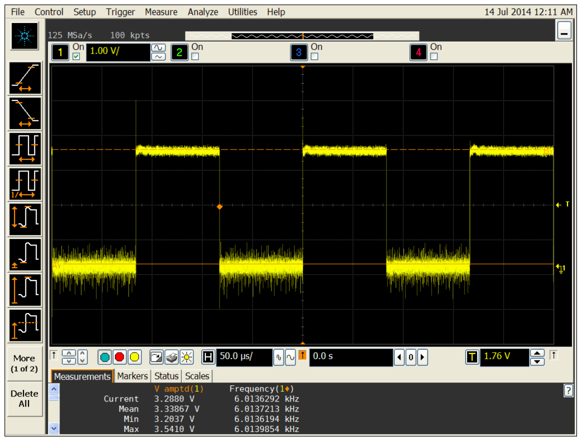


Fig. 11. The measured waveform while applying DPI method.

References

[1] *Integrated Circuits, Measurement of Electromagnetic Emission, 150 KHz to 1 GHz*, International Electrotechnical Commission Standard IEC61967, 2002.

[2] *Integrated Circuits, Measurement of Electromagnetic Immunity, 150 KHz to 1 GHz*, International Electrotechnical Commission Standard IEC62132, 2006.

[3] Yin-Cheng Chang, Ping-Yi Wang, Shawn S. H. Hsu, Yen-Tang Chang, Chiu-Kuo Chen, Hsu-Chen Cheng, and Da-Chiang Chang, "Investigation on Realizing 1Ω Current Probe Complied with IEC 61967-4 Direct Coupling Method," in *Proc. International Symposium on Electromagnetic Compatibility (EMC'14)*, May, 2014, pp. 573-576.