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SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1752-1

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ELECTROMAGNETIC COMPATIBILITY MEASUREMENT PROCEDURES FOR INTEGRATED CIRCUITS—INTEGRATED CIRCUIT EMC MEASUREMENT PROCEDURES—GENERAL AND DEFINITIONS

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1. Scope—This SAE Recommended Practice provides supporting information for the emission and immunity measurement procedures defined in SAE J1752.

1.1 Measurement Philosophy—The near field magnetic or electromagnetic radiation from an integrated circuit can be measured in a controlled manner that yields repeatable results. These emissions are related to the far field electromagnetic radiation potential of the IC and of the electronic module of which it is a part. The intent is to provide a quantitative measure of the RF emissions from ICs for comparison or other purposes. Similar quantitative measures of the immunity of an IC to RF fields and transients are being investigated.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113-1—Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components
SAE J1752-2—Integrated Circuit Radiated Emissions Diagnostic Procedure, 1 MHz to 1000 MHz, Magnetic Field—Loop Probe
SAE J1752-3—Integrated Circuit Radiated Emissions Measurement Procedure, 150 kHz to 1000 MHz, TEM Cell

2.1.2 IEEE STANDARD—Available from IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331.

IEEE Standard Dictionary, STD100

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

ANSI EMC Definitions
Goulette, R. R., Crawhall, R. J., and Xavier, S. K., of Bell Northern Research, Ottawa, Ontario, Canada, “The Determination of Radiated Emissions Limits for Integrated Circuits within Telecommunications Equipment,” IEICE Transactions on Communications, Vol. E75-B, No. 3, March 1992
Goulette, R. R. of Bell Northern Research, Ottawa, Ontario, Canada, “The Measurement of Radiated Emissions from Integrated Circuits,” 1992 IEEE International EMC Symposium Record, August 1992
Koepke, G. H. and Ma, M. T., “A New Method for Determining the Emission Characteristics of an Unknown Interference Source,” Proc. 5th Intl. Zurich Symposium and Technical Exhibition on EMC, (Zurich, Switzerland), March 1983, pp. 35-40

3. Definitions—Refer to the IEEE Standard Dictionary of Electrical and Electronic Terms (IEEE Std 100-1992) for additional definitions.

3.1 Auto Sweep—The fastest calibrated sweep which a spectrum analyzer will automatically select based on start frequency, stop frequency, resolution bandwidth, and video bandwidth.

3.2 Die Shrink—The amount of shrink of the mask used to produce the IC expressed as a percentage of the original artwork layout (drawn size).

3.3 Lead Frame—The supporting structure for the silicon die that interfaces the external pins to the die.

3.4 Loop Probe—A single turn (E-field shielded) magnetic field probe as described in SAE J1752-2.

3.5 MCM—Multichip module, an integrated circuit whose elements are formed on or within two or more semiconductor chips that are mounted in a single package.

3.6 MCU—Microcontroller unit.

3.7 Multi IC Sets—A set of ICs that function as a unit, in a higher level of integration the set could be a single IC.

3.8 1 GHz TEM Cell—A transverse electromagnetic mode (TEM) cell with a VSWR of 1.5:1 or less and an absence of multi-moding up to an operating frequency of 1 GHz, see Appendix A.

3.9 Preamp Noise Floor—The inherent thermal noise generated by the first stage amplifier that limits the signal resolution of the measurement system.

3.10 Significant IC Changes—New product, new source, die shrink, new package type, significant process change, int/ext clock changes, I/O drive capability changes, etc.

3.11 Standardized IC Test Board—See 6.2 and Figure 1.

3.12 System Gain—The gain (or attenuation) of the measuring equipment, exclusive of the TEM cell (or wideband TEM cell), if used.

3.13 Wideband TEM Cell (Sometimes referred to as a GTEM Cell)—A cell developed as a continuously expanding section of 50 Ω transmission line where the center conductor is transformed into an off center septum. Because of its construction, the wideband TEM cell does not suffer from the size versus frequency constraints of a conventional TEM cell and provides more test volume at high frequencies. Refer to SAE J1113-24 for additional information.

4. Test Conditions

4.1 Test Temperature and Supply Voltage—The ambient temperature during the test shall be 23 °C ± 5 °C for repeatability. IC emissions may vary with temperature. The supply voltage for modules shall be 13.5 V dc ± 0.5 V dc for 12-V electrical systems and 27 V dc ± 1 V dc for 24-V electrical systems. For an IC being tested on the standardized test board, the supply voltage shall be as specified by the IC manufacturer. If other values are agreed to by the users of this procedure, they shall be documented in the test report.

4.2 Frequency Bands—For emission testing, the frequency bands and spectrum analyzer RBW settings in Table 1 are recommended.

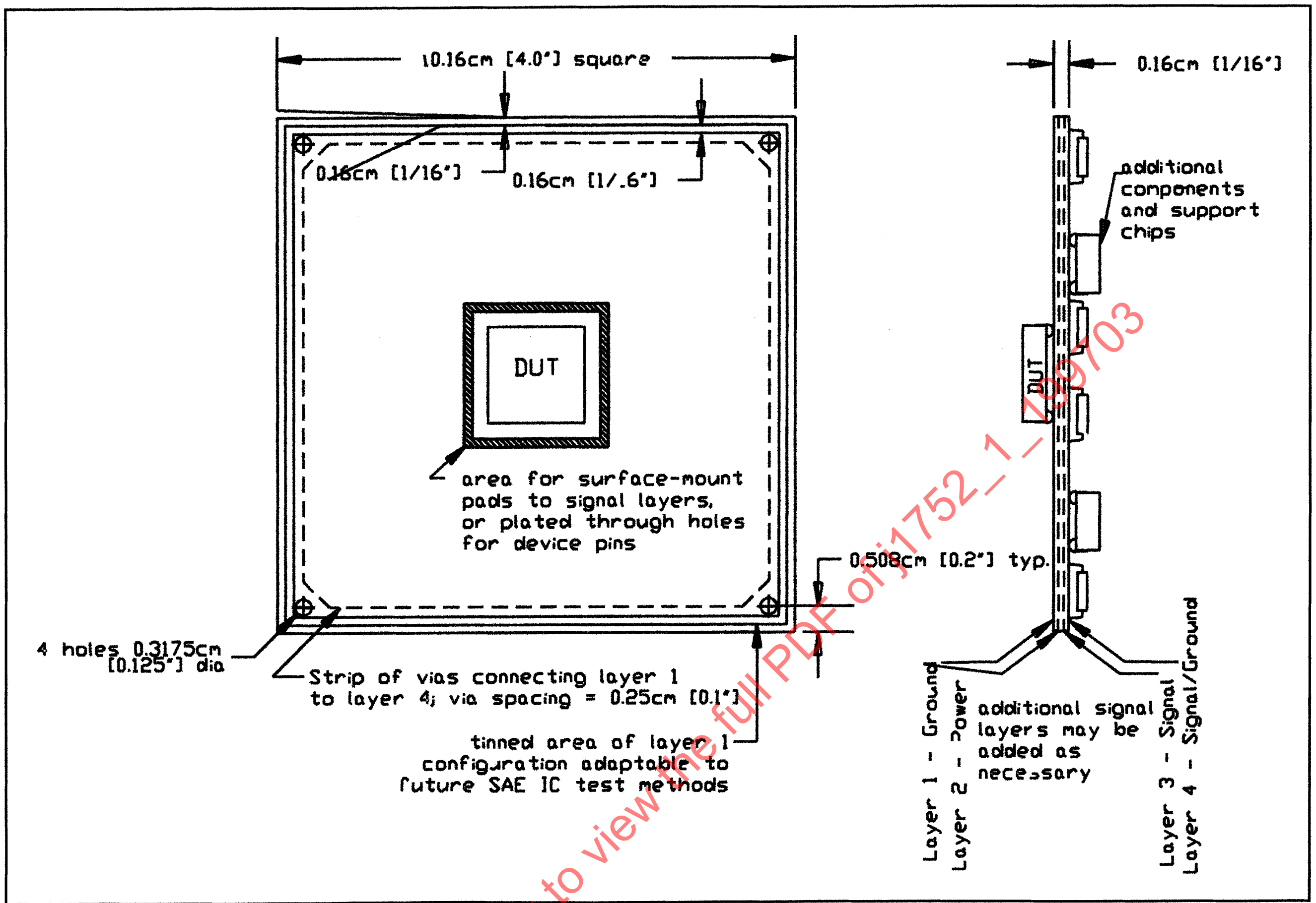

FIGURE 1—STANDARDIZED IC TEST BOARD

TABLE 1—SPECTRUM ANALYZER SETTINGS

Start Frequency (MHz)	Stop Frequency (MHz)	Applications	Res. Bandwidth (kHz)
0.15	2	AM Broadcast	1
2	30	AM & SW Broadcast	10
30	200	FM & Communication	10
200	400	UHF TV	10
400	600	UHF Communication	10
600	800	UHF TV	10
800	1000	Cellular Telephone	10

5. Test Equipment

5.1 Shielding—A shielded room may be required to provide a controlled ambient for emission or immunity measurements. Double shielded or semi-rigid coaxial cable is required.

5.2 Spectrum Analyzer or Receiver—The spectrum analyzer setup for emission measurements is given in Table 1 with video bandwidth at least three times the resolution bandwidth and sweep in calibrated (coupled) mode (auto sweep). The instrument is to be set up for peak reading and max hold with measurements in dBµV [for 50 Ω system: (measurement in dBm) + 107 = dBµV].

5.3 System Gain—The gain (or attenuation) of the measuring equipment, exclusive of the TEM cell (or wideband TEM cell), if used, shall be known with an accuracy of ±0.5 dB.

The gain of the equipment shall remain within a 6 dB envelope for each frequency band.

6. Test Setup

6.1 System Setup and Calibration—All test equipment shall be calibrated on a regular basis. The minimum resolution for calibration of the preamplifier is 10 points per decade.

6.2 Standardized IC Test Board—Refer to Figure 1. This special square printed circuit board includes a ground plane which serves as a shield; the periphery of this shield is tinned to facilitate contact to the edge of the mating hole cut in the top or bottom of a TEM cell (or wideband TEM cell), if used. The access wiring and other required components (such as crystals) shall be on the other side of this board (the side that would be outside the test cell, if used) or on a daughter board that is connected to the back side of the test board. Power bypass capacitors for the IC are to be chosen according to manufacturers recommendations and located to minimize lead length. All wiring should be minimized and controlled.

NOTE—These are recommended default values. If other values are more appropriate for a particular IC, they may be substituted for the values in Table 2 and shall be called out in the test report.

TABLE 2—IC PIN LOADING REQUIREMENTS

IC Pin Type	Pin Loading Requirements
Power - Digital	Per manufacturer's typ. load recommendations
Power - Analog	Per manufacturer's typ. load recommendations
Analog I/O	Same as digital I/O
Digital Input	GND or 10 K pullup to V_{cc} if cannot GND
Digital Output	50 pF to GND
Data/Address	Per manufacturer's typ. load recommendations
Control Input	GND or 10 K pullup to V_{cc} if cannot GND
Control Output	Per manufacturer's typ. load recommendations
Bidirectional	Configure as output - 50 pF to GND

6.3 Test Board Power Supply—The DUT shall be powered from a source with low conducted RF emissions that will not interfere with or confuse the test results. A low impedance battery (i.e., alkaline, nickel-cadmium or equivalent) is the preferred power source (carbon batteries are not acceptable). Check battery before and after test. An AC power supply may be used if it meets the low RF emissions requirement. All power supply lines to the DUT shall be adequately filtered per the IC manufacturer's recommendation.

6.4 IC Software—If a programmable integrated circuit is to be tested, software which flows in a continuous loop shall be written to assure that measurements are repeatable. The type of software used to exercise the IC (minimum, typical, or worst case) shall be documented with the test report.

6.4.1 MINIMUM—Implement counter function, see Appendix B: Test Code - Counter Circuit.

6.4.2 TYPICAL—Exercise microprocessor and I/O on a "normal" basis using production code.

6.4.3 WORST CASE—Exercise all I/O, see Appendix C: Worst Case Software Description.

6.5 Multi IC Sets—ICs that operate as part of a set shall be evaluated by one of the following methods:

6.5.1 INDIVIDUALLY WITH SIMULATED LOADS—Load I/O pins on the IC to simulate in-circuit values as given in Table 2.

6.5.2 INDIVIDUALLY WITH SUPPORTING ICS—The IC being evaluated shall be mounted on the top side of the standardized test board with the other supporting ICs located on the underside of the board with minimal connecting lead length.

6.5.3 AS AN IC CHIP SET—A set of ICs may be evaluated together in order to characterize the emissions from the system (i.e., operating a microprocessor in expanded mode). The set being evaluated shall be grouped together on the top side of the test board in a compact configuration.

7. Test Procedure

7.1 Ambient—For emissions testing, measure ambient levels to assure that any ambient signals present are at least 6 dB below the target reference level. The ambient data shall be a part of the test report. If the ambient is excessive, check the integrity of the overall system, especially the interconnecting cables and connectors. If necessary, use a shielded enclosure, a lower noise preamplifier or a narrower spectrum analyzer resolution bandwidth.

7.1.1 AMBIENT MEASUREMENT WITH TEM CELL—Ambient measurement with the 1 GHz TEM cell (or wideband TEM cell) requires the following verification procedure:

a. Check the ambient with a test board sized metal plate installed on the standardized IC test board TEM cell port (to evaluate the RF leakage through the TEM cell and cables).
b. Check the ambient with the unpowered test board in place and with the spectrum analyzer running on max hold for 1 h or as required to achieve confidence in the environment which may include sporadic local RF sources (to evaluate the RF leakage through the test board).

7.2 Operational Check—Energize the DUT and complete an operational check to assure proper function of the device (i.e., Run IC test code, see 6.4).

7.3 Specific Procedures—Follow the test technique described in the particular emission or immunity measurement procedure.

8. Data Presentation—In order to facilitate the use of the data for comparisons, the specification of critical parameters including the loading and decoupling capacitors used on the test board and the software used to exercise the IC under test is required.

PREPARED BY THE SAE IC-EMC TASK FORCE OF THE SAE EMR STANDARDS COMMITTEE

APPENDIX A

1 GHz TEM CELL

A.1 The TEM cell offers a broadband method of measuring either immunity of a DUT to fields generated within the cell or radiated emissions from a DUT placed within the cell. It eliminates the use of conventional antennas with their inherent measurement limitations of bandwidth, nonlinear phase, directivity, and polarization. The TEM cell is an expanded transmission line that propagates a TEM wave from an external or internal source. This wave is characterized by orthogonal electric (E) and magnetic (H) fields which are perpendicular to the direction of propagation along the length of the cell or transmission line. This field simulates a planar field generated in free space with an impedance of 377 Ω. The TEM mode has no low frequency cutoff. This allows the cell be used at frequencies as low as desired. The TEM mode also has linear phase and constant amplitude response as a function of frequency. This makes it possible to use the cell to generate or detect a known field intensity. The upper useful frequency for a cell is limited by distortion of the test signal caused by resonances and multimoding that occur within the cell. These effects are a function of the physical size and shape of the cell.

The 1 GHz TEM cell is of a size and shape, with impedance matching at the input and output feed points of the cell, that limits the VSWR to less than 1.5:1 up to its rated frequency. It is tapered at each end to adapt to conventional 50 Ω coaxial connectors and is equipped with an access port to accommodate the standardized IC test board. The first resonance is demonstrated by a high VSWR over a narrow frequency range. The high Q of the cell is responsible for this high VSWR. A cell verified for field generation to a maximum frequency will also be suitable for emission measurements to this frequency.

NOTE—The Crawford TEM Cell was originally developed at the National Bureau of Standards (now NIST) and one of its principal investigators was Myron Crawford.

APPENDIX B

TEST CODE—COUNTER CIRCUIT

B.1 This simple routine implements a counter function using a single 8-bit port. Every 100 ms, the port output is incremented or decremented. After 10 count cycles (256 ms) an LED output is complemented. This will provide a blinking light indication with a frequency of about 2 Hz. For consistency, equivalent loop times should be maintained. (Used in European IC emissions testing.) See Figure B1.

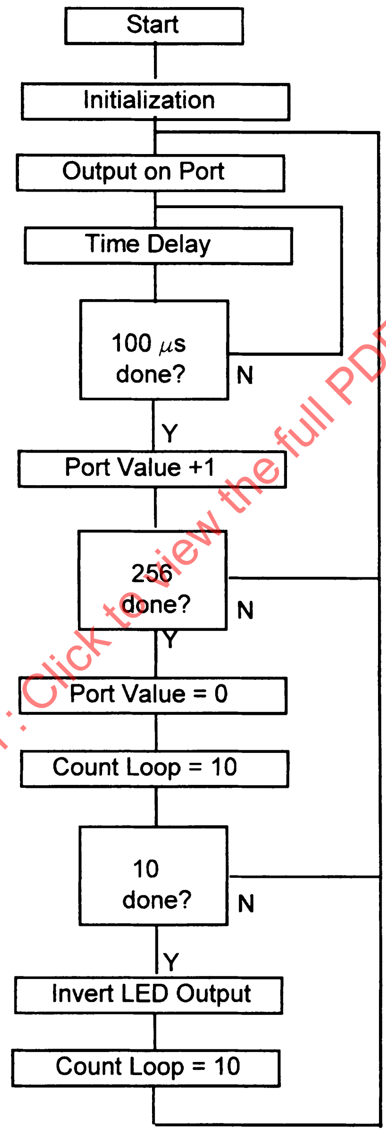

FIGURE B1—TEST CODE