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Adhesives — Test methods for isotropic electrically conductive adhesives —

Part 9:
Determination of high-speed signal-transmission characteristics

Adhésifs — Méthodes d'essai pour adhésifs à conductivité électrique isotrope —

Partie 9: Détermination des propriétés de transmission de signal à haute vitesse

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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TThe committee responsible for this document is ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

ISO 16525 consists of the following parts, under the general title *Adhesives — Test methods for isotropic electrically conductive adhesives*:

— *Part 1: General test methods*

— *Part 2: Determination of electric characteristics for use in electronic assemblies*

— *Part 3: Determination of heat-transfer properties*

— *Part 4: Determination of shear strength and electrical resistance using rigid-to-rigid bonded assemblies*

— *Part 5: Determination of shear fatigue*

— *Part 6: Determination of pendulum-type shear impact*

— *Part 7: Environmental test methods*

— *Part 8: Electrochemical migration test methods*

— *Part 9: Determination of high-speed signal-transmission characteristics*

Adhesives — Test methods for isotropic electrically conductive adhesives —

Part 9: Determination of high-speed signal-transmission characteristics

SAFETY STATEMENT — Persons using this part of ISO 16525 should be familiar with normal laboratory practice. This part of ISO 16525 does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any regulatory conditions.

IMPORTANT — Certain procedures specified in this part of ISO 16525 might involve the use or generation of substances, or the generation of waste, that could constitute a local environmental hazard. Reference should be made to appropriate documentation on safe handling and disposal after use.

1 Scope

This part of ISO 16525 specifies test methods to investigate the high-speed signal-transmission characteristics in the bonded portions of an isotropic electrically conductive adhesive, which joins the terminals of a surface mounted device (SMD) and the land grid patterns of a printed circuit board. It also investigates the characteristics of wiring with an isotropic electrically conductive adhesive, which can be applied on the printed circuit board.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 472, *Plastics — Vocabulary*

IEC 60194, *Printed board design, manufacture and assembly — Terms and definitions*

IEC 61190-1-2, *Attachment materials for electronic assembly — Part 1-2: Requirements for solder pastes for high-quality interconnections in electronics assembly*

IEC 61192-1, *Workmanship requirements for soldered electronic assemblies — Part 1 General*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures — Part 2-7: Reinforced base materials clad and unclad — Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC 61249-2-8, *Materials for printed boards and other interconnecting structures — Part 2-8: Reinforced base materials clad and unclad — Modified brominated epoxide woven fibreglass reinforced laminated sheets of defined flammability (vertical burning test), copper-clad*

IEC 61760-1, *Surface mounting technology — Part 1: Standard method for the specification of surface mounting components (SMDs)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and IEC 60194 and the following apply.

3.1
characteristic of high-speed signal transmission
characteristic of the deflection of an output signal, which is measured according to eye pattern

3.2
eye pattern
eye of the trapezoidal clock wave pattern used to check the transmission characteristics of digital signals

3.3
characteristic impedance of transmission line
specific impedance of the transmission line with its cross-sectional profile, which meets the signal transmission direction

3.4
scattering parameter
transmission energy at output port (port 2) and reflection energy at input port (port 1) under the electromagnetic energy of the sine wave at a certain frequency input form port 1

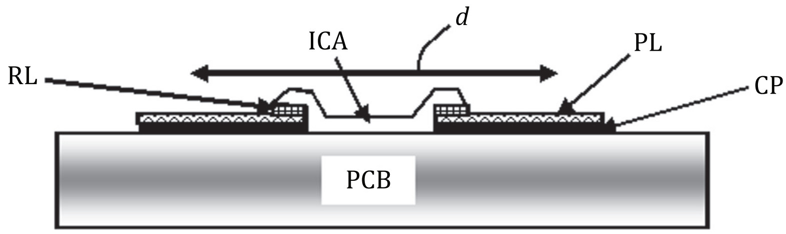
3.5
ball grid array package
BGA package
array of electrodes formed on the reverse side of, and connected to, the printed circuit using ball-like bumps of solder

4 Principle

There are two methods to investigate high-speed signal-transmission characteristics. In one method, a signal-transmission pattern is printed on a circuit board using an isotropic electrically conductive adhesive and then, the high-speed signal-transmission characteristics of the heat-hardened transmission pattern with an isotropic electrically conductive adhesive is measured. In the other method, the terminals and electrodes of SMDs are bonded to the land grid patterns of the printed circuit board using an isotropic electrically conductive adhesive. For reference, a lead-free solder is also used, and the high-speed signal transmission characteristics of the bonded portions is measured. The dimensions of the line and bonded portions with an isotropic electrically conductive adhesive are shorter than that of the copper line that is commonly used in circuit boards and SMDs. Therefore, the influence of the copper line on measurement is unavoidable, and it is difficult to extract the characteristics of the isotropic electrically conductive adhesive.

Therefore quantitative test methods need to be specified for showing the high-speed signal characteristics of wiring and bonded portions without the influence of copper lines.

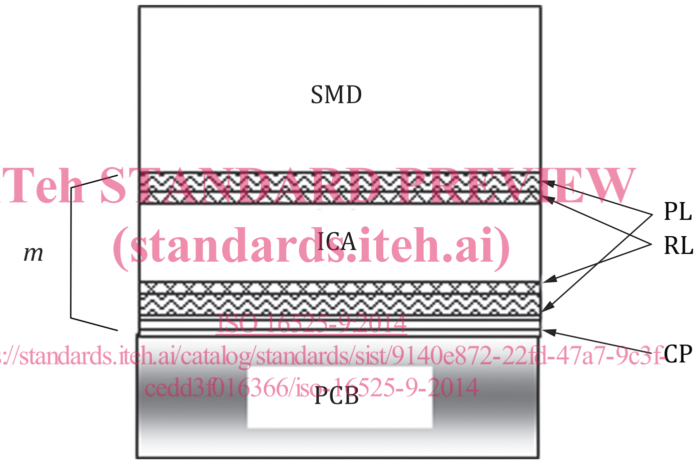
NOTE These test methods are not intended for the high-speed signal properties of SMDs or printed circuit boards. Printed and bonded portions to be investigated are illustrated in Figure 1 (the X-Y plane) and Figure 2 (the Z-direction). Conditions of the isotropic electrically conductive adhesive in Figures 1 and 2 are intended to be according to the procedures (surface treatments, printing and curing) recommended by adhesive manufacturers.



Key

ICA	isotropic electrically conductive adhesive	PL	plating layer
CP	copper pattern	RL	reactive layer
PCB	printed circuit boards		
d	direction of signals		

Figure 1 — Illustration of circuit to be investigated (X-Y plane)



Key

ICA	isotropic electrically conductive adhesive	PL	plating layer
CP	copper pattern	RL	reactive layer
PCB	printed circuit boards	SMD	surface mounted device
m	measurement area		

Figure 2 — Illustration of bonded portions under investigation (Z-direction)

5 Apparatus and test circuit board

5.1 Apparatus for measuring digital signals, capable of measuring signal integrity using the eye patterns of the output signal, which is generated when clock-synchronizing random digital signals. It consists of two devices described in 5.1.1 and 5.1.2. For measurement, a standard circuit board should be screwed directly to each device using a coaxial cable. A typical eye pattern of the output signal is shown in Figure 3.

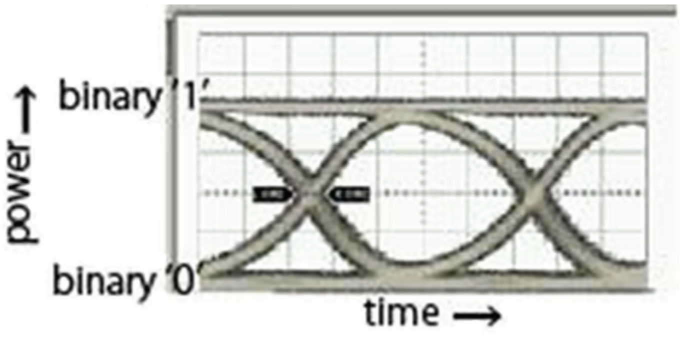


Figure 3 — A typical eye pattern

5.1.1 Random pulse generator, capable of generating digital random pulses, and which is connected to the input port of a standard circuit board. A random pulse generator with an output capacity from 0,05 Gbps to 12 Gbps is recommended.

5.1.2 Oscilloscope, used to measure the eye patterns of random waveforms generated through the output terminal of a test circuit board. It is connected to the output terminal of a test circuit board using a coaxial cable. An oscilloscope with a band up to 18 GHz is recommended.

5.1.2 Coaxial cable and a subminiature type A (SMA) connector, and an **SMA connector** with a band up to 20 GHz.

5.2 Apparatus for characteristic impedance measurement, consisting of a transmission line, used to measure the high-frequency characteristic. The transmission line shows characteristic impedance, and therefore the test circuit board is designed so that it can match the internal impedance of a measuring apparatus. A general value of the internal characteristic impedance of a test apparatus is 50 Ω. The apparatus is used to check whether or not the test standard circuit boar adapts to such internal impedance.

5.2.1 TDR-mode oscilloscopes, of high frequency, and equipped with the time domain reflection (TDR) mode for measurement. Firstly, match the y-axis with impedance and examine a reflection state of the step wave pattern. Then, examine the output value and profile to judge whether or not the characteristic impedance of the standard test circuit board has been matched with the designed one. Figure 4 shows an example of typical measurement. Apparatus with the rise time of step waveform 30 ps or shorter is recommended.

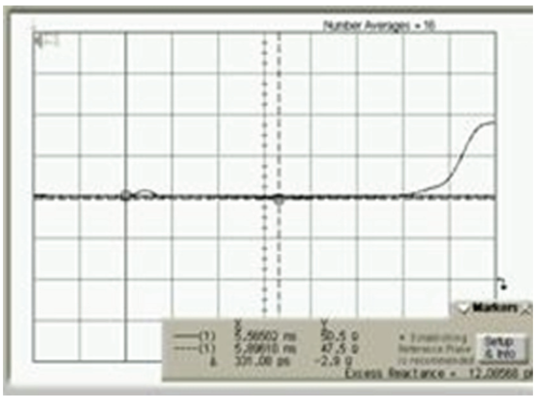
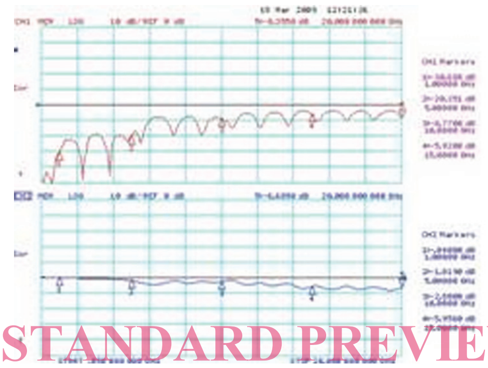


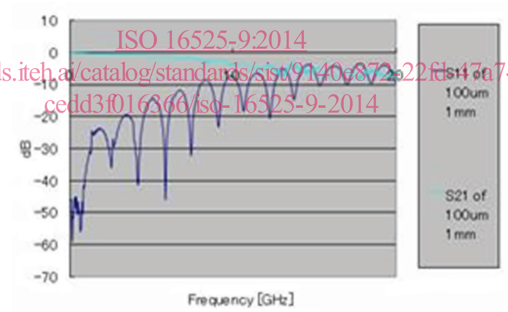
Figure 4 — Example of typical profile of the characteristic impedance measured in the TDR mode

5.3 Apparatus for measuring frequency characteristic. A digital signal is a composite wave that consists of sine waves, and in signal transmission it is essential not to change the ratio of such composite waves. Therefore after measuring the characteristic of wide-ranging frequencies of sine waves, the maximum level of the measured wave should be confirmed.

5.3.1 Network analyser, capable of measuring the scattering parameter, starting with calibration of the copper line pattern (on the test circuit board described in 5.4), whose line is identical in length to that of the standard test circuit board. By subtracting the measured value of the copper line pattern from that of the standard pattern, the characteristic of the line can be cancelled. This means that only the characteristic of the printed or bonded portion can be extracted. Connect the test circuit board to the network analyser using a coaxial cable. Figure 5 shows an example of typical measurement of S21 and S11. Apparatus with a measurement range from 50 MHz to 40 GHz is recommended. The range of measurement is usually from 100 MHz to 30 GHz (or 20 GHz depending on the relevant purpose).



a) Before subtraction



b) After subtraction

Key

X frequency (GHz)

Y signal (dB)

Figure 5 — Example of typical measurement of the scattering parameter

5.4 Test circuit boards, with the following specifications.

a) **Material of substrate**

Glass fabric-based epoxy resin copper-clad laminate with a double-sided (the X-Y plane), three-layer conductor (the Z-direction) substrate, as specified in IEC 61249-2-7.

b) **Thickness of substrate**

1,6 ± 0,2 mm (the X-Y plane) and 1,0 ± 0,15 mm (the Z-direction) as specified in IEC 61249-2-7.

c) **Dimensions of substrate**

As specified in 5.4 d). The substrate should be screwed to the test apparatus with its end-face soldered to an SMA connector (18 GHz).

Both ends of the board are connected to the SMA. Therefore, it is recommended that the dimensions of the ends of the substrate and the pattern comply with the drawing.

d) **Pattern and its dimensions**

Circuit pattern as outlined in Figure 6 (for a standard test circuit board for measurement of the X-Y plane) and Figure 7 (for a standard test circuit board for measurement of the Z-direction). Details are specified in Figure A.3. These dimensions are designed to minimize the influence of wiring and are therefore recommended.

e) **Plating**

Various substrates, according to the applications and specifications (recommended by the manufacturer) of isotropic electrically conductive adhesives, if their specifications conform to those in 5.4 d). Variation will be reflected in the high-speed signal transmission characteristic of printed and bonded portions. In other words, measured values will contain the characteristics of the interface of the bonded portions.

Dimensions in millimetres

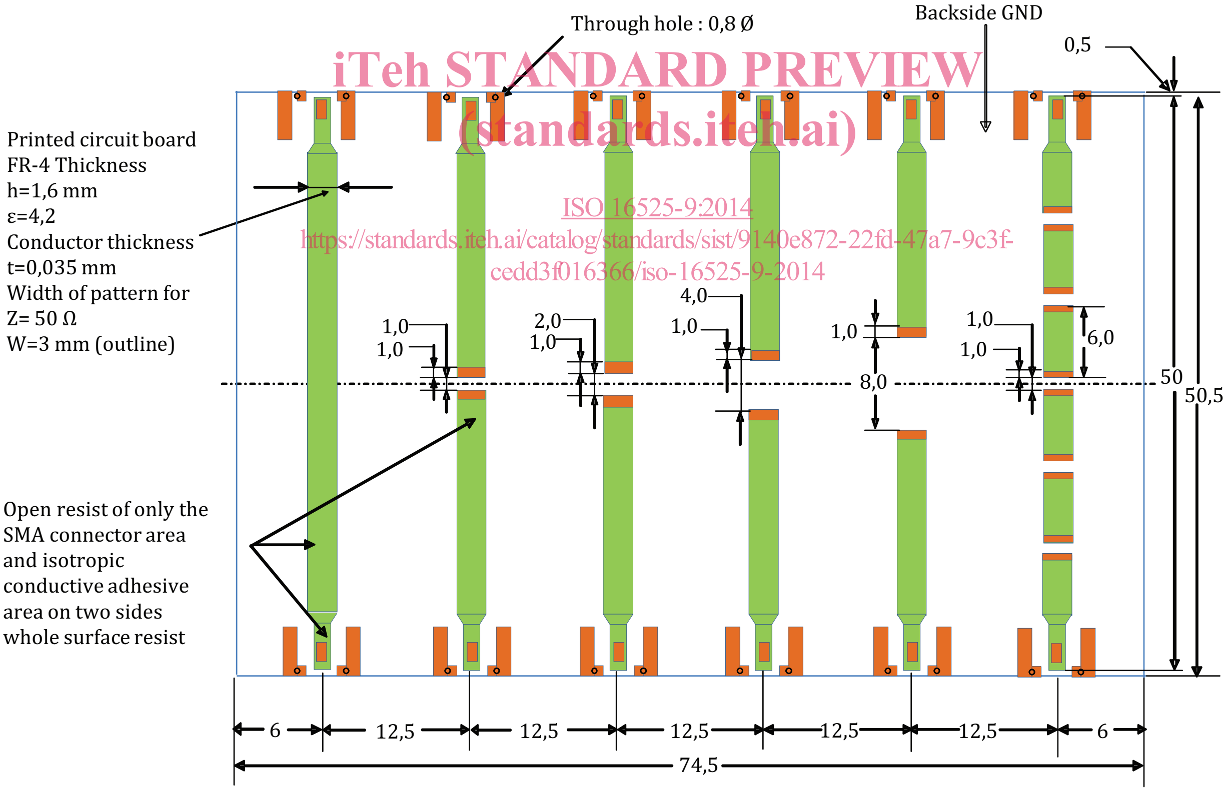
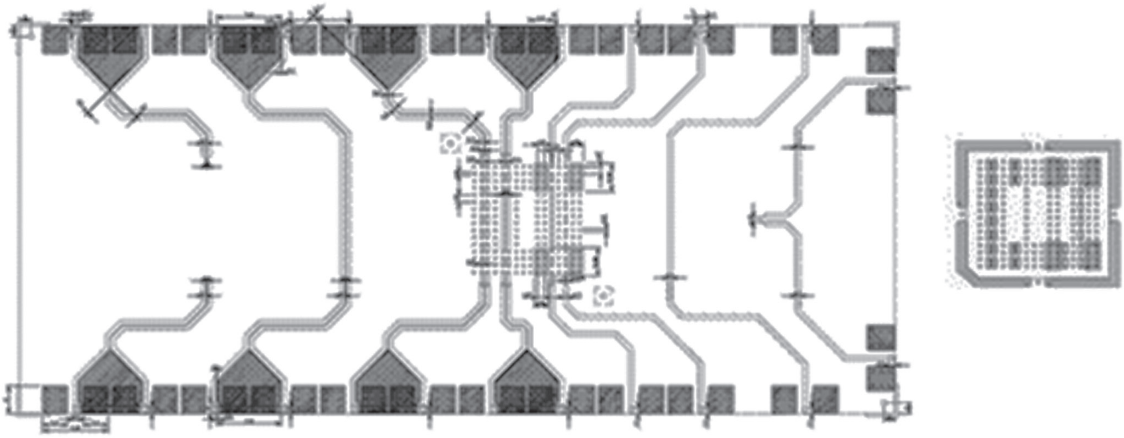


Figure 6 — Surface pattern of a test circuit board (in the X-Y plane)



The corresponding pattern of BGA package is shown on the right-hand side.

Figure 7 — Surface pattern of a test circuit board (in the Z-direction) and its corresponding pattern of BGA package

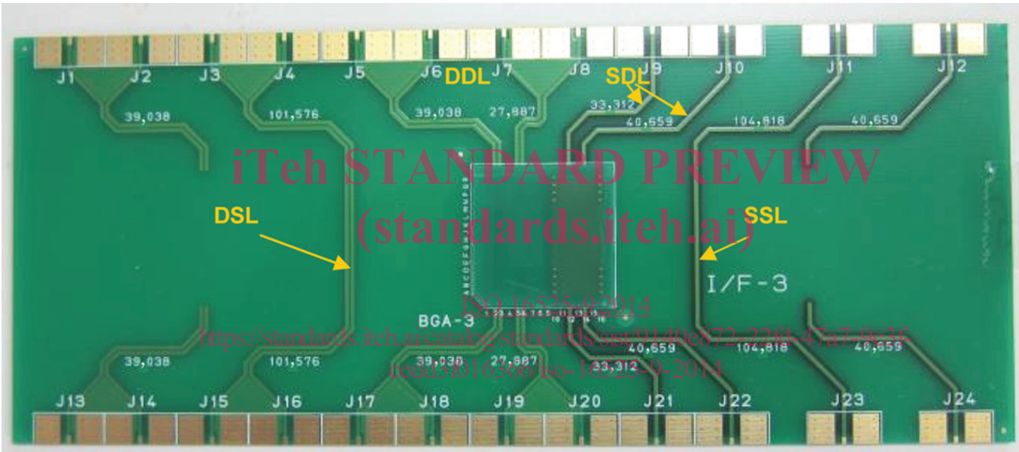
5.5 Isotropic electrically conductive adhesive, consisting of a paste material, containing an organic binder, generally a heat-curing resin, in which metal particles or flakes are dispersed. The isotropic electrically conductive adhesive is applied to the circuit board or package electrode by screen printing, potting by a dispenser, or inkjet spraying as wiring material, connection terminal, or bonding agent for LSI chips.

If necessary, heat is applied it after the secondary processing (assembly) to harden for the final procedure to create a test circuit board (see Annex B). The test circuit board is classified in two types: one for investigating the characteristics of the X-Y plane (i.e. wiring) and the other for investigating the characteristic of the Z-direction (i.e. connecting terminals or adhesive). This part of ISO 16525 uses the isotropic electrically conductive adhesive for the two types of standard test circuit board (see Figures 6 and 7).

6 Preparation of test circuit board

Assemble a standard test circuit board (see Figures 6 and 7) as follows: apply an isotropic electrically conductive adhesive to the test circuit board in accordance with the procedure described in 5.5, then solder an SMA connector (18 GHz) to the standard test circuit board (see Annex B). Figure 8 (the X-Y plane) and Figure 9 (the Z-direction) show the appearance of an assembly.

Figure 8 — Assembly of standard test circuit board for measurement in the X-Y plane



Key

BGA ball grid array

DDL differential daisy lines

DSL differential standard line

SDL single end daisy lines

SSL single end standard line

Figure 9 — Assembly of standard test circuit board for measurement in the Z-direction

7 Set-up

Set up the measuring apparatus by connecting one end of a coaxial cable with an SMA connector (attenuation 1,5 dB/m, 18 GHz) to the SMA connector (18 GHz) of the test circuit board, and the other end to the test apparatus using a 0,9 N·m torque wrench. Figures 10 and 11 show examples of set-up.

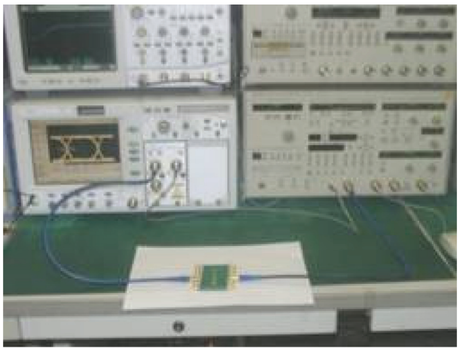


Figure 10 — Example of set-up for measurement of eye patterns

Figure 11 — Example of set-up for measurement of the scattering parameter

8 Tests

8.1 Test procedure

8.1.1 Measurement of the characteristic impedance on the TDR mode

Details of TDR measurement are specified in Annex C. An outline of TDR measurement is as follows: connect one end of the transmission line to be measured to the oscilloscope, leaving the other end unconnected; choose the TDR mode of the oscilloscope; with impedance indicated on the y-axis, and record the result. Since an isotropic electrically conductive adhesive will be applied to the centre of each standard test circuit board, set the marker at the midpoint between the input port of profile SMA and the output port of SMA. Get the value of the characteristic impedance at the marker position indicated. An example of typical measurement is shown in Figure 4 (as described in Clause 5).

8.1.2 Measurement of the digital signal characteristic

Details of measurement are specified in Annex C. An outline of the measurement procedure is as follows: connect one end of the transmission line to be measured to the pulse generator, and the other to the oscilloscope (see Figure 10); to match triggers, connect the output terminals of the pulse generator to the input terminal of the oscilloscope using a coaxial cable (see Figure 10).

a) As the first step of measurement, choose the 1 GHz clock-generating mode with the rise and fall time of the pulse generator, for example, at 35 ps (time between 10 % and 90 % of the voltage level) or shorter, the output waveform shall be recorded on the oscilloscope it. Set the measurement system so that values of the rise and fall time and Vamp (or VAMP, the voltage at the end of rise) can be recorded.

b) The random–pulse generating mode of the pulse generator shall be used to output pulses by clock frequency. Measure output waveforms using a satisfactory oscilloscope, and record the results. Set the measurement system so that values of eye height, eye width, intensity ratio of signal to noise (S/N) of the eye-pattern, and jitter root-mean-square (RMS) amplitude can be recorded.

8.1.3 Measurement of the scattering parameter

a) Details of measurement are specified in Annex C. Preparation for measurement starts with calibration of the network analyser. A coaxial cable with an 18-GHz SMA connector with attenuation 1,5 dB/m or lower is recommended. Connect one end of the coaxial cable to port 1 of the network analyser, and carry out SOLT calibrations (see Annex D). Connect the transmission line to be measured to the input and output ports (see Figure 11). Set the sweep frequency range of the network analyser to 50 MHz to 20 GHz, for example, measure the characteristics of S11 (reflection) and S21 (transmission), and record the results. Record the results at 1 GHz, 3 GHz and 20 GHz in order to check the differences in phases. Calculate the characteristics of the bonded vector portions (see Annex D).

b) For the standard circuit board for measurement of the X-Y plane, calibrate the network analyser using SOLT (see Annex D) (the copper line in the test circuit board for measurement in the X-Y plane) standards adjusted in accordance with Annex B. As in 8.1.3 a), connect the transmission line to be measured to the input and output ports (see Figure 11). Set the sweep frequency range of the network analyser to 50 MHz to 20 GHz, for example, measure the characteristics of S11 (reflection) and S21 (transmission), and record the results. Record the results at 1 GHz, 3 GHz, 10 GHz and 20 GHz in order to check the differences in phases. Caluculate the characteristics of the bonded vector portions (see Annex D).

8.2 Judgement

8.2.1 General

Criteria for judgement vary, according to the intended purposes; therefore, they cannot be expressed as values. An example is described as guidelines in Annex D. General criteria for judgement include the following.

8.2.2 Measurement of the characteristic impedance in the TDR mode

Compare the value of the characteristic impedance at the marked position in the standard pattern with that in the test circuit board.

8.2.3 Measurement of the digital signal characteristics

a) Compare the rise and fall times and VAMP (voltage after a rise is finished: called voltage amplitude) of the standard pattern with those of the test circuit board. The smaller the difference, the higher the high-speed performance.

b) Compare the eye pattern data, such as eye height, eye width and jitter RMS of the standard pattern with those of the test circuit board. Regarding S/N of the standard eye pattern, the smaller the difference, the higher the high-speed performance.

8.2.4 Measurement of the scattering parameter

The S parameter obtained as a result of vector operation is the extracted datum of the connection port. The high-speed performance is higher, as S11 is minimized and S12 is maximized against the sweep frequency.

9 Test report

The test report shall contain the following items. Some items may be selected from items b) to f) upon agreement between the delivering and receiving parties:

a) a reference to this part of ISO 16525, i.e. ISO 16525-9;

b) the name of the isotropic electrically conductive adhesive and its data, including the kinds of resin, filler material, manufacturer's code and lot number;

c) the method of preparation of the test circuit board, including the method of application, curing temperature, setting time, temperature, applied pressure and the procedures of adhesion;

d) the dimensions of the test circuit board, including the material and dimensions of the substrate, the pattern and dimensions of the circuit, and the number of substrates or samples;

e) the type of surface treatment for the electrode of the test circuit board;

f) the date, institution and atmospheric conditions (temperature and humidity) of the measurement;

g) the calculation conditions, such as voltage and current, of electrically volume resistivity and interfacial contact resistivity.