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JAPANESE INDUSTRIAL STANDARD

Measuring methods for small signal diodes

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Measuring methods
for small signal diodes

C 7031-1993

1. Scope This Japanese Industrial Standard specifies electrical measuring methods for small signal semiconductor diodes to be used for detection, switching, mixing, etc. in electronic equipment (hereafter referred to as "diodes").

Remarks 1. The following standards are cited in this Standard:

JIS C 0301 Graphical symbols for electrical apparatus

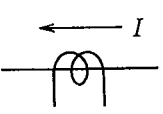
JIS C 1102 Electrical indicating instruments

2. The International Standard corresponding to this Standard is given below.

IEC 747-3 (1985) Semiconductor devices, Discrete devices
Part 3: Signal (including switching) and
regulator diodes

2. Graphical symbols to be used The graphical symbols to be used in the measuring circuit diagram of this Standard shall, in addition to those specified in JIS C 0301, be as given in Table 1.

Table 1

Graphical symbol	Name	Graphical symbol	Name
	Two-phenomenon oscilloscope		Current probe

3. Measurement power supply and instruments

3.1 Measurement power supply A d.c. power supply with a ripple content not exceeding 3 % or an a.c. power supply with a higher harmonic content not exceeding 5 % shall be used. However, in the case of power frequency, a supply with a content not exceeding 10 % shall be used. In the measurements of a.c. characteristics, the percent ripple content of d.c. power supply, the percent higher harmonic content of a.c. power supply, and the a.c. impedance of d.c. power supply circuit through which a.c. current flows shall be sufficiently small so that they will not affect the measurements.

Unless otherwise specified, the a.c. voltage and a.c. current shall be expressed in the r.m.s. values.

3.2 Instruments Unless otherwise specified, the d.c. and a.c. voltmeters, ammeters, etc. shall be of class index 0.5 specified in JIS C 1102. The maximum scale of an instrument with uniform scale shall be within ten times the measuring value and that of an instrument with shortened scale interval in the vicinity of zero shall be within four times the measuring value. The measuring value means the maximum value if stated in the Standard or it means the minimum value if only the minimum value is specified in the Standard.

In the following cases, instruments of class index 0.5 are not necessarily used:

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- (1) When the instrument has a tolerance equivalent to class index 0.5 or better.
- (2) When the instrument does not significantly affect the measurement results.

The instrument which detects pulses shall be sufficiently capable of responding to the specified pulse conditions. The internal impedance and noise shall be such that the influences on the measuring system are sufficiently ignored.

4. Reference measurement conditions

4.1 Temperature and humidity The temperature and humidity shall be as stated below:

- (1) Reference temperature The reference temperature shall be 25°C.
- (2) Reference humidity The reference humidity shall be 45 % in relative humidity.
- (3) Measurement temperature The measurement temperature means the ambient temperature where the diode under test is not directly ventilated, and it shall be $25 \pm 3^\circ\text{C}$.
- (4) Measurement humidity The measurement humidity shall be 75 % or less in relative humidity.

4.2 Measurement frequency The measurement frequency for low frequency parameters shall be 270 ± 30 Hz or 1000 ± 50 Hz. If it is possible to show the correlativity, other frequencies may be used.

4.3 Signal amplitude Unless otherwise specified, small (amplitude) signals shall be used in the measurements of a.c. parameters.

Remarks: The small (amplitude) signal means such a signal that the signal does not cause variation equal to or more than the tolerance of the instrument on the measured value when the amplitude of the signal is reduced to 1/2.

4.4 Ideal voltage supply and ideal current supply The ideal voltage supply and ideal current supply shall be as stated below:

- (1) Ideal voltage supply The ideal voltage supply to be used here shall not cause variation equal to or more than the tolerance of the instrument on the measured value when the load impedance is reduced to 1/2 of the original. However, in the actual measurement, a voltage supply with current limiting function is used or a protective resistor is connected in series to the voltage supply, if there is a possibility of breaking the diode under test (specimen).
- (2) Ideal current supply The ideal current supply to be used here shall not cause variation equal to or more than the tolerance of the instrument on the measured value when the load impedance is increased to twice the original. However, in the actual measurement a current supply with voltage limiting function is used if there is a possibility of breaking the specimen.

4.5 Pulse conditions Unless otherwise specified, the pulse width and the duty factor shall be so selected that no variation equal to or more than the tolerance of the instrument shall appear on the measured value if each of them is doubled.

4.6 Open circuit and closed circuit The open circuit and closed circuit shall be as follows:

- (1) Open circuit The open circuit shall be such a circuit that it does not cause variation equal to or more than the tolerance of the instrument on the measured value if the terminal impedance is reduced to 1/2 of the original.
- (2) Closed circuit The closed circuit shall be such a circuit that it does not cause variation equal to or more than the tolerance of the instrument on the measured value if the terminal impedance is increased to twice the original.

5. Precautions for measurements

5.1 To observe maximum ratings Unless otherwise specified, the maximum ratings of the specimen shall not be exceeded in any case including the transient state. As for the measurements in the area where the maximum ratings are exceeded, the method is shown in Annex.

5.2 Precaution for attaching and detaching specimen The specimen shall not be attached or detached while the circuit is in operation.

5.3 Precaution for electrostatic breakdown For diodes having risk of breakdown due to static electricity, the following precautions shall be observed:

- (1) At transportation, storage and standing alone, charging of static electricity shall be prevented by using static electricity conductive materials, charge preventive treated materials and so on.
- (2) The measurements shall be carried out in a place where static electricity does not generate. The relative humidity is desired to be about 50 %.

To prevent generation of static electricity, it is desired to make the potential of the measurer, tool and measuring equipment equal to that of the place where the specimen is handled.

5.4 Temperature stabilization (thermal equilibrium) condition When the measured value changes with elapse of time due to heat generation of the specimen, the measurement shall be carried out after the temperature has been stabilized or the time of measurement shall be previously determined.

Informative reference: If the measured value does not change over the predetermined error when the duration of measurement is doubled, it is considered that the temperature stabilization is achieved.

5.5 Pulse measurement To avoid the measurement error due to heat generation of the specimen, it is desirable to carry out the measurement by means of pulses.

5.6 Measuring circuit The measuring circuit illustrated in this Standard shows an example of the circuit to be used for the measurement. Therefore, alternative circuit may be used if the same results are obtainable.

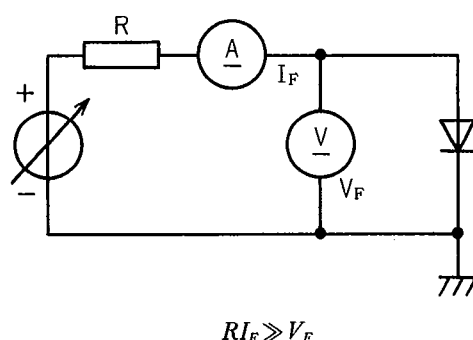
The equation shown in the measuring circuit diagram means the necessary conditions for the measuring circuit.

6. Measuring methods

6.1 Forward current measurement The forward current measurement shall be as follows:

- (1) Purpose The purpose of this method is to measure the forward current of the specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 1.

Fig. 1. Forward current measuring circuit



- (3) Procedure Apply the specified forward voltage (V_F) across the electrode terminals of the specimen and measure the forward current (I_F) at that time.

A method in which a voltmeter and an ammeter are used or a method in which the current waveform and voltage waveform are drawn on an oscilloscope by using an a.c. power supply at 1 kHz or below may be used for this measurement.

When considerable power is consumed in the specimen, the temperature rise of junction due to the consumption largely affects the measured value. In such a case, employ either of the methods given below.

- (a) Use d.c. power, and carry out the measurement after thermal equilibrium i.e. temperature stabilization is achieved. Otherwise carry out the measurement after the specified time from application of the specified voltage.
- (b) Carry out the measurement by using pulses or within such a short time that the temperature rise of junction is negligible.

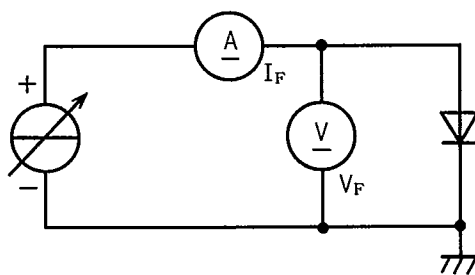
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Forward voltage
- (b) Time to measurement from voltage application (if necessary)
- (c) Pulse width and duty cycle (if pulse is used)
- (d) Ambient temperature or reference point temperature

- 6.2 Forward voltage measurement The forward voltage measurement shall be as follows:

- (1) Purpose The purpose of this method is to measure the forward voltage of specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 2.

Fig. 2. Forward voltage measuring circuit



- (3) Procedure Pass the specified forward current (I_F) through the specimen, and measure the forward voltage (V_F) at that time.

A method in which a voltmeter and an ammeter are used or a method in which the current waveform and voltage waveform are drawn on an oscilloscope by using an a.c. power supply at 1 kHz or below may be used for this measurement.

When considerable power is consumed in the specimen, the temperature rise of junction due to the consumption largely affects the measured value. In such a case, employ either of the methods given below.

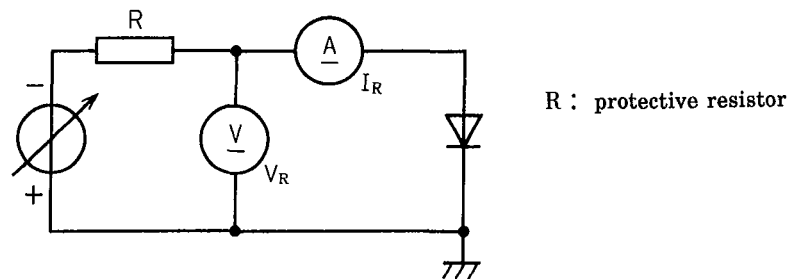
- (a) Use d.c. power and carry out the measurement after thermal equilibrium i.e. temperature stabilization is achieved. If temperature stabilization is not achieved, carry out the measurement after the specified time from application of the specified voltage or passing of the specified current.
 - (b) Carry out the measurement by using pulses or within such a short time that the temperature rise of junction can be neglected.
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:
- (a) Forward current
 - (b) Time to measurement from application of forward current (if necessary)

- (c) Pulse width and duty cycle (if pulse is used)
- (d) Ambient temperature or reference point temperature

6.3 Reverse current measurement The reverse current measurement shall be as follows:

- (1) Purpose The purpose of this method is to measure the reverse current of specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 3.

Fig. 3. Reverse current measuring circuit



- (3) Procedure Gradually increase the reverse voltage applied across the electrode terminals of specimen to the specified value, and measure the reverse current (I_R) at that time. Provided that the reverse voltage to be applied does not exceed the maximum value of breakdown voltage given in relevant Standard.

A method in which a voltmeter and an ammeter are used or a method in which the current waveform and voltage waveform are drawn on an oscilloscope by using an a.c. power supply at 1 kHz or below may be used for this measurement.

When considerable power is consumed in the specimen, the temperature rise of junction due to the consumption largely affects the measured value. In such a case, employ either of the methods given below.

- (a) Use d.c. power, and carry out the measurement after thermal equilibrium i.e. temperature stabilization is achieved. Otherwise carry out the measurement after the specified time from application of the specified voltage.
- (b) Carry out the measurement by using pulses or within such a short time that the temperature rise of junction is negligible.

- Remarks
- 1. If the voltage drop due to the ammeter is not negligible as compared with the voltage condition at measurement, the reading of the voltmeter shall be corrected by the said voltage drop.
 - 2. If the specified reverse voltage is higher than the maximum d.c. reverse voltage and lower than the maximum peak reverse voltage, use the method of above (b) only.

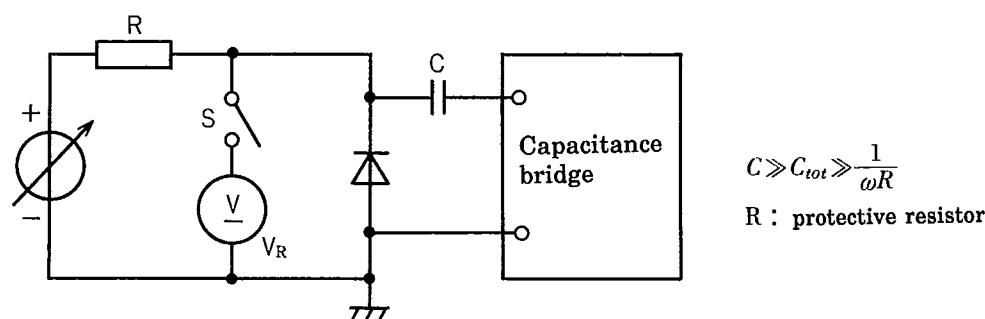
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Reverse voltage (provided, it does not exceed the maximum rating)
- (b) Time to measurement from voltage application (if necessary)
- (c) Pulse width and duty cycle (if pulse is used)
- (d) Ambient temperature or reference point temperature

- 6.4 Measurement of capacitance between terminals The measurement of capacitance between terminals shall be as follows:

- (1) Purpose The purpose of this method is to measure the capacitance between terminals of specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 4.

Fig. 4. Measuring circuit for capacitance between terminals



- (3) Procedure Apply the specified voltage to the specimen, take out the voltmeter from the circuit, and measure the capacitance between both terminals of specimen by the capacitance bridge. Subtract the capacitance when the specimen is removed from the capacitance measured in the above procedure and take the remainder as the capacitance between terminals (C_{tot}).

- Remarks
- 1. A circuit which biases the diode without decreasing the measurement accuracy shall be attached to the capacitance bridge. The measuring signal voltage shall be sufficiently small as compared with the bias voltage.
 - 2. If the measured capacitance is very small and the mounting conditions will affect the accuracy of the results, the conditions shall be specified.
 - 3. If the capacitance between terminal and case (C_c) has been obtained separately, junction capacitance (C_j) can be obtained as $C_j = C_{tot} - C_c$.

- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

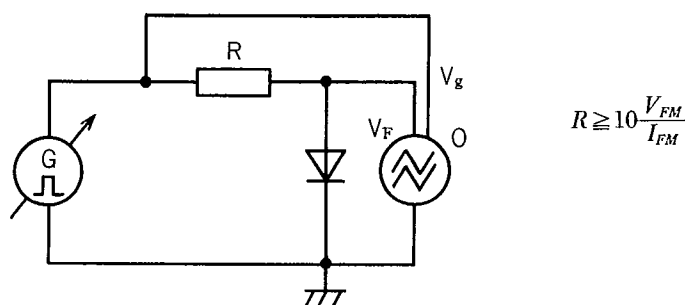
- (a) Measuring voltage
- (b) Measuring frequency (normally 1 MHz)

- (c) Mounting conditions (if necessary)
- (d) Ambient temperature or reference point temperature

6.5 Forward recovery time measurement The forward recovery time measurement shall be as follows:

- (1) Purpose The purpose of this method is to measure the forward recovery time of specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 5.

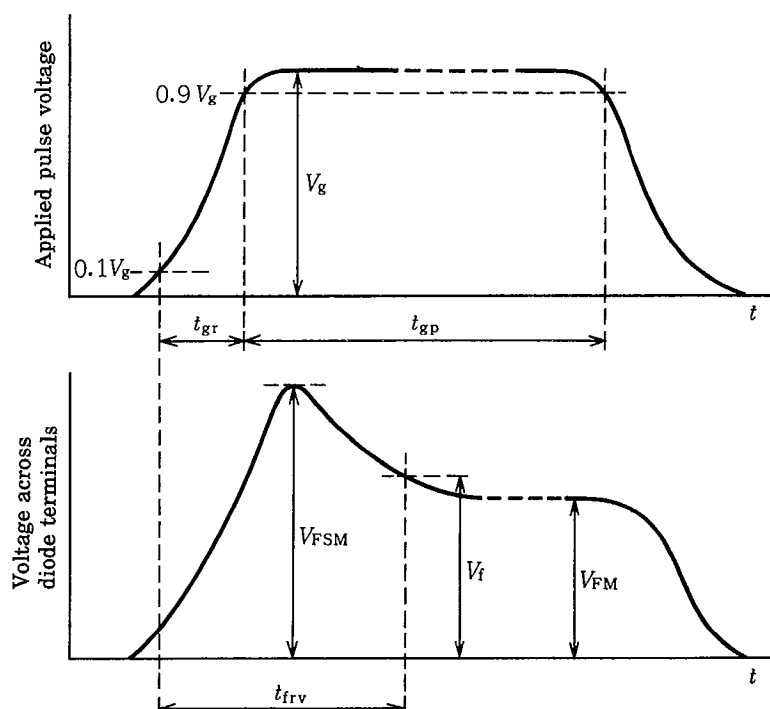
Fig. 5. Forward recovery time measuring circuit



- (3) Procedure Set the pulse voltage (V_g) so that the forward current of the specimen shows the specified value (I_{FM}). Observe the applied pulse voltage and the voltage across the terminals of the specimen by means of an oscilloscope O. (Fig. 6).

The forward recovery time (t_{frv}) is the time from the instant when the applied voltage becomes 10 % of the steady state value (V_g) to the instant when the voltage across terminals of the diode becomes the specified value (V_F) via decrease from the peak value (V_{FSM}).

Fig. 6. Pulse waveforms



Remarks 1. Applied pulse conditions:

$$\begin{aligned} \text{Rise time} & t_{gr} \leq \frac{t_{frv}}{10} \\ \text{Pulse width} & t_{gp} \geq 10 t_{frv} \\ \text{Repetition frequency} & f_p \leq \frac{1}{10 t_{gp}} \end{aligned}$$

2. Oscilloscope conditions:

$$\begin{aligned} \text{Rise time} & t_{dr} \leq \frac{t_{frv}}{4} \\ \text{Input resistance} & R \geq 100 \cdot \frac{V_{FM}}{I_{FM}} \end{aligned}$$

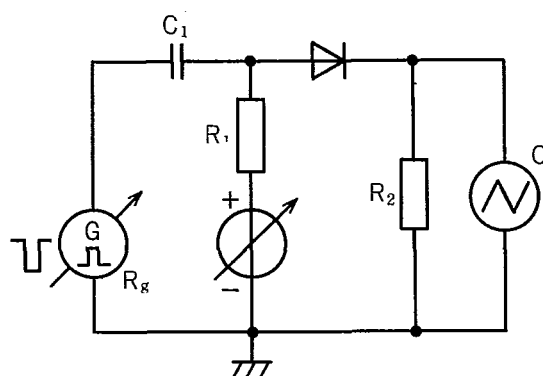
(4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Forward current
- (b) Forward voltage (normally $1.1 V_{FM}$)
- (c) Width and repetition frequency of pulse
- (d) Ambient temperature or reference point temperature

6.6 Reverse recovery time measurement The reverse recovery time measurement shall be as follows:

- (1) Purpose The purpose of this method is to measure the reverse recovery time of specimen under specified conditions.
- (2) Measuring circuit An example of measuring circuit is shown in Fig. 7.

Fig. 7. Reverse recovery time measuring circuit



$$R_g \leq R_1$$

R_2 : it shall be small enough not to affect the measurement

$$C_1 \gg \frac{t_{rr \text{ MAX}}}{R_g + R_2}$$

- (3) Procedure Pass the specified forward current (I_F) through the diode while observing it with oscilloscope O and then adjust pulse generator G so that peak reverse current (I_{RM}) shows the specified value.

The reverse recovery time (t_{rr}) is the time from the instant when the diode current becomes zero to the instant when the current becomes the specified value [reverse recovery current (i_{rr})] via decrease from the peak value (I_{RM}) (Fig. 8).