

JIS

JAPANESE INDUSTRIAL STANDARD

Measuring methods for transistors

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Measuring methods for transistorsC 7030-1993

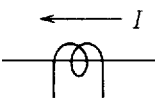
1. Scope This Japanese Industrial Standard specifies the measuring methods for electrical performances of bipolar transistors and field-effect transistors (hereafter referred to only "transistors" when they are not classified) mainly used in electronic equipment.

- 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 standards corresponding to this Standard are given below:
IEC 747-7 (1988) Semiconductor discrete devices and integrated circuits
Part 7: Bipolar transistors
IEC 747-8 (1984) Semiconductor devices, Discrete devices
Part 8: Field-effect transistors

2. Graphical symbols used For the purpose of this Standard, in addition to the symbols specified in JIS C 0301, the symbols in Table 1 are used in the measuring circuit diagram.

Table 1

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

3. Measuring power supply and instrument

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

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

3.2 Instruments Unless otherwise specified, d.c. and a.c. voltmeters, ammeters and the like shall be the ones of accuracy index 0.5 specified in JIS C 1102. In the case of uniform scale instruments, ones with a maximum scale within 10 times the measured value; in the case of instrument in which the scale is shortened in the vicinity of zero, ones with a maximum scale within 4 times the measured value shall be used. Provided that, the measured value means the maximum value, if the maximum value is specified in the Standard, and the minimum value if only the minimum value is specified.

In the following cases, instruments are not necessarily be accuracy index 0.5.

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

An instrument which can sufficiently follow the specified pulse conditions shall be used as the instrument which detects pulses. The internal impedance and noise of instruments shall be such that their effect on the measuring system is sufficiently ignored.

4. Reference measuring conditions

4.1 Temperature and humidity The temperature and humidity shall be as follows:

- (1) Reference temperature The reference temperature shall be 25°C.
- (2) Reference humidity The reference humidity shall be a relative humidity 45 %.
- (3) Measuring temperature The measuring temperature means the ambient temperature under such condition that the transistor to be tested (hereafter called "specimen") is not directly ventilated, and shall be $25 \pm 3^\circ\text{C}$.
- (4) Measuring humidity The measuring humidity shall be a relative humidity not exceeding 75 %.

4.2 Measuring frequency The measuring frequency of low frequency parameters shall be 270 ± 30 Hz or 1000 ± 50 Hz. If the correlation with frequency is obvious, other frequencies may be used.

4.3 Signal amplitude In the measurements of a.c. parameters, small (amplitude) signal shall be used unless otherwise specified.

Remarks: The small (amplitude) signal means such a signal that no change equal to or more than the tolerance on instruments is produced on the measured value even if the amplitude of the signal is reduced by $\frac{1}{2}$.

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

- (1) Ideal voltage supply The ideal voltage supply used here means such one that no change equal to or more than the tolerance on instrument is produced on the measured value even if the load impedance is reduced to $\frac{1}{2}$ thereof. If breakdown of specimen might occur in actual measurements, a voltage supply with current limiting function shall be used or a protective resistor shall be introduced in series to the voltage supply.
- (2) Ideal current supply The ideal current supply used here means such one that no change equal to or more than the tolerance on instrument is expected on the measured value, even if the load impedance is increased to two times thereof. If breakdown of specimen might occur in actual measurements, a current supply with voltage limiting function shall be used.

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

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

- (1) Open circuit Open circuit means such one that no change equal to or more than the tolerance on instrument is produced on the measured value even if the termination impedance is reduced to $\frac{1}{2}$.
- (2) Closed circuit Closed circuit means such one that no change equal to or more than the tolerance on instrument is produced on the measured value even if the termination impedance is doubled.

5. Precaution for measurements

5.1 Keeping of maximum rating The maximum rating of the specimen shall not be exceeded in any case including the transient state. The measurements on the extent exceeding the maximum rating shall be as specified in Annex.

5.2 Precaution at attaching and detaching The specimen shall not be attached or detached while the supply voltage is being applied.

5.3 Treatment of insulated-gate field-effect transistors The precaution given below shall be kept to protect insulated-gate field-effect transistors from the damage due to static electricity.

- (1) The charging by static electricity shall be avoided by using static electricity conductive materials, static charging preventive materials, or the like, when the transistors are transported, stored, or allowed to stand.
- (2) The measurements shall be carried out in a place where no static electricity is generated. About 50 % relative humidity is desirable.

It is also recommended to make the potential of the measuring person, tool and measuring equipment equal to the potential of the place where the specimen is handled.

5.4 Condition of temperature stabilization (thermal equilibrium) When the measured value changes with lapse of time due to heat generation of the specimen, the measurement shall be made after temperature stabilization is accomplished or the measuring time point shall be previously determined.

Informative reference: If the measured value does not change exceeding the anticipated error when the measurement time point is doubled, it is considered that the temperature stabilization is achieved.

5.5 Measurement of pulse It is recommended to carry out the measurement by means of pulses to avoid the errors in the measurements due to heat generation of the specimen.

5.6 Measuring circuit The measuring circuit illustrated in this Standard shows an example of the circuit used for the measurement. Therefore, alternative circuit may be used so far as the same results are obtained.

The measuring circuit of bipolar transistors shows the case of npn type transistors, but the same circuit can be used for pnp type transistors by changing the polarities of power supply, instruments, etc.

The measuring circuit of field-effect transistors shows the case of n-channel, insulated-gate depletion type or junction-gate field-effect transistors, but the same circuit can be used for p-channel devices by changing the polarities of instrument and power supply. The symbols used as title of each measuring method are given in Table 2.

Table 2. Symbols denoting kinds

Symbol	Kind
A	Junction-gate type or Schottky barrier gate type
B	Insulated-gate depletion type
C	Insulated-gate enhancement type

The equations shown in the measuring circuit means the requirements for the measuring circuit.

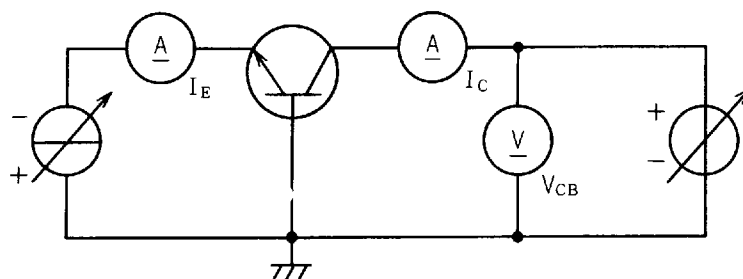
6. Measuring methods

6.1 Measuring methods for bipolar transistors

6.1.1 Measurement of collector current (d.c. method) The measurement of collector current (d.c. method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the collector current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 1.

Fig. 1. Measuring circuit of collector current (d.c. method)

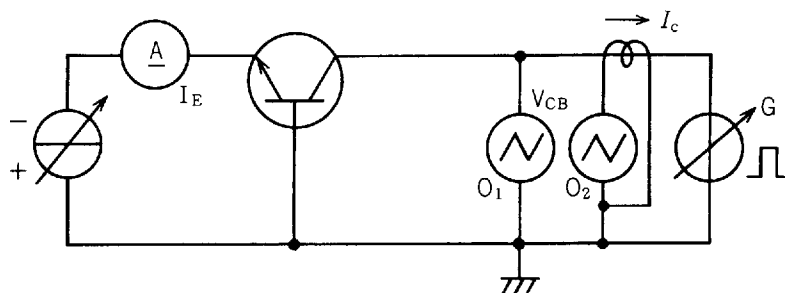


- (3) **Procedures** Pass the specified emitter current (I_E), apply the specified voltage (V_{CB}) across the collector and the base, and measure the collector current (I_C).
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- Emitter current
 - Collector-base voltage
 - Ambient temperature or reference point temperature

6.1.2 **Measurement of collector current (pulse method)** The measurement of collector current (pulse method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the collector current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 2.

Fig. 2. Measuring circuit of collector current (pulse method)



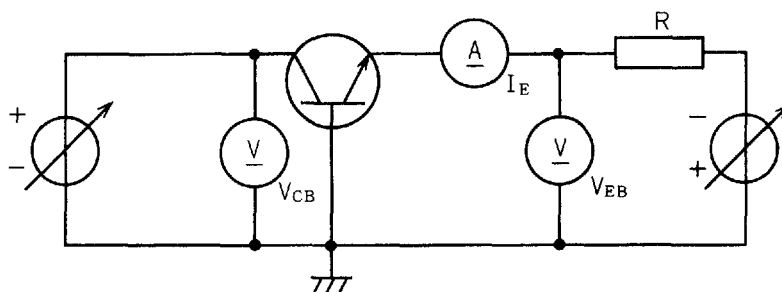
- (3) **Procedures** Pass the specified emitter current (I_E), apply a constant voltage of the specified pulse width and duty cycle (V_{CB}) across the collector and the base while observing with oscilloscope O_1 and measure the collector current (I_C) with the oscilloscope O_2 .
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- Emitter current
 - Collector-base voltage

- (c) Pulse width and duty cycle of collector-base voltage
- (d) Ambient temperature or reference point temperature

6.1.3 Measurement of emitter current (d.c. method) The measurement of emitter current (d.c. method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the emitter current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 3.

Fig. 3. Measuring circuit of emitter current (d.c. method)



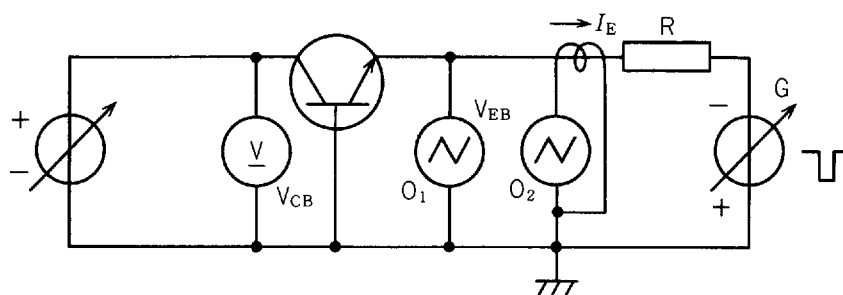
R: protective resistor, $RI_E \gg V_{EB}$

- (3) **Procedures** Apply the specified voltages (V_{CB} and V_{EB}) across the collector and the base, and across the emitter and the base, respectively, and measure the emitter current (I_E).
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
 - (a) Collector-base voltage
 - (b) Emitter-base voltage
 - (c) Ambient temperature or reference point temperature

6.1.4 Measurement of emitter current (pulse method) The measurement of emitter current (pulse method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the emitter current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 4.

Fig. 4. Measuring circuit of emitter current (pulse method)



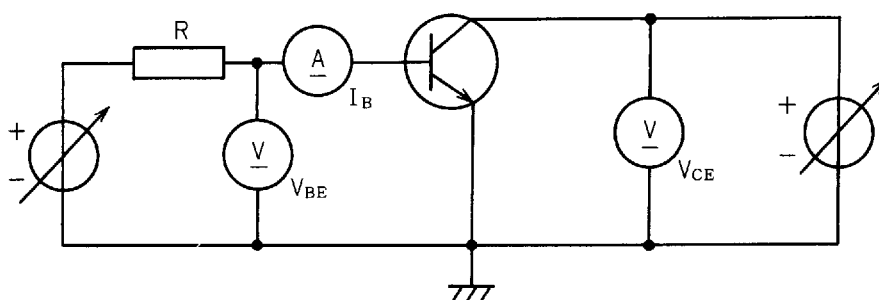
R: protective resistor, $RI_E \gg V_{EB}$

- (3) **Procedures** Apply the specified voltage (V_{CB}) across the collector and the base, apply a constant voltage of the specified pulse width and the duty cycle (V_{EB}) across the emitter and the base while observing with the oscilloscope O_1 , and measure the emitter current (I_E) with the oscilloscope O_2 .
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- Collector-base voltage
 - Emitter-base voltage
 - Pulse width and duty cycle of emitter-base voltage
 - Ambient temperature or reference point temperature

6.1.5 **Measurement of base current (d.c. method)** The measurement of base current (d.c. method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the base current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 5.

Fig. 5. Measuring circuit of base current (d.c. method)



R: protective resistor, $RI_B \gg V_{BE}$

- (3) **Procedures** Apply the specified voltages (V_{CE} and V_{BE}) across the collector and the emitter and across the base and the emitter, respectively, and measure the base current (I_B).

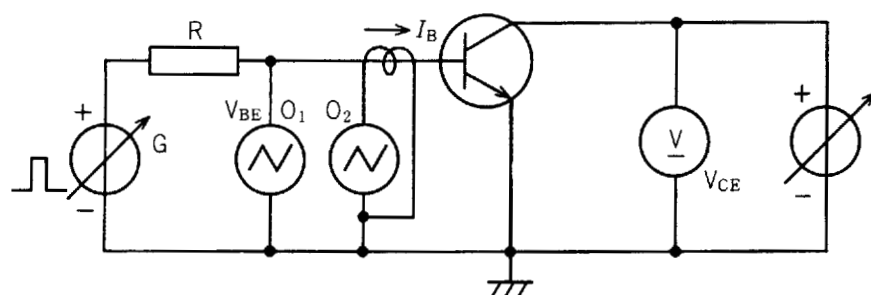
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Collector-emitter voltage
- (b) Base-emitter voltage
- (c) Ambient temperature or reference point temperature

- 6.1.6 Measurement of base current (pulse method) The measurement of base current (pulse method) shall be as stated below:

- (1) Purpose This measuring method intends to measure the base current of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 6.

Fig. 6. Measuring circuit of base current (pulse method)



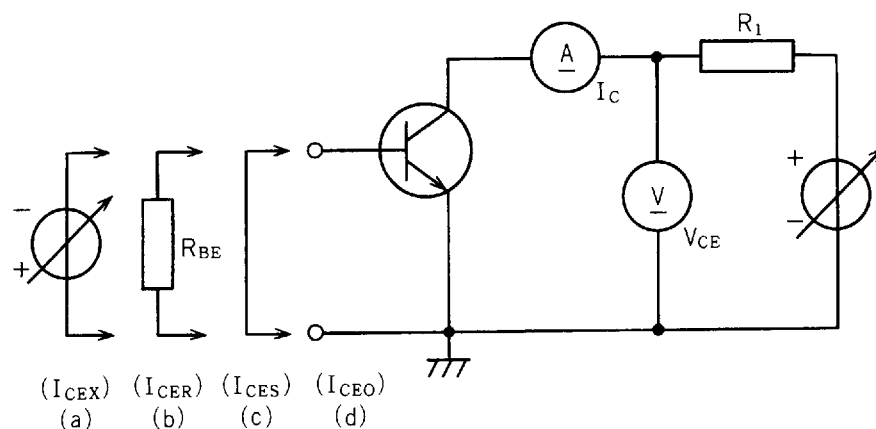
R: protective resistor, $RI_B \gg V_{BE}$

- (3) Procedures Apply the specified voltage (V_{CE}) across the collector and the emitter, apply a constant voltage of the specified pulse width and duty cycle (V_{BE}) across the base and the emitter while observing with oscilloscope O_1 , and measure the base current (I_B) with oscilloscope O_2 .
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:
 - (a) Collector-emitter voltage
 - (b) Base-emitter voltage
 - (c) Pulse width and duty cycle of base-emitter voltage
 - (d) Ambient temperature or reference point temperature

- 6.1.7 Measurement of collector-emitter cut-off current The measurement of collector-emitter cut-off current shall be as stated below:

- (1) Purpose This measuring method intends to measure the collector-emitter cut-off current of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 7.

Fig. 7. Measuring circuit of collector-emitter cut-off current



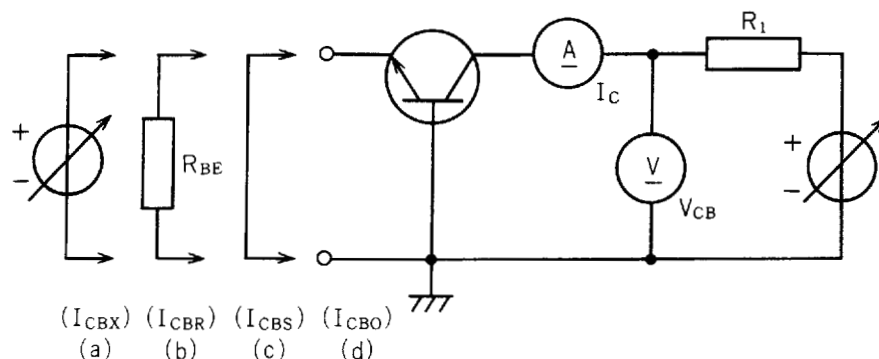
R_1 : protective resistor

- (3) **Procedures** Keep the conditions between the base and the emitter as specified, apply the specified voltage (V_{CE}) across the collector and the emitter, and measure the collector current (I_C) [collector-emitter cut-off current (I_{CE-})].
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- (4.1) **Biasing conditions between base and emitter**
- (a) Base-emitter voltage for the case of I_{CEX}
 - (b) Resistance value of R_{BE} to be connected between base and emitter for the case of I_{CER}
 - (c) Short circuit of base and emitter for the case of I_{CES}
 - (d) Open circuit of base and emitter for the case of I_{CEO}
- (4.2) **Collector-emitter voltage**
- (4.3) **Ambient temperature or reference point temperature**

6.1.8 Measurement of collector-base cut-off current The measurement of collector-base cut-off current shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the collector-base cut-off current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 8.

Fig. 8. Measuring circuit of collector-base cut-off current



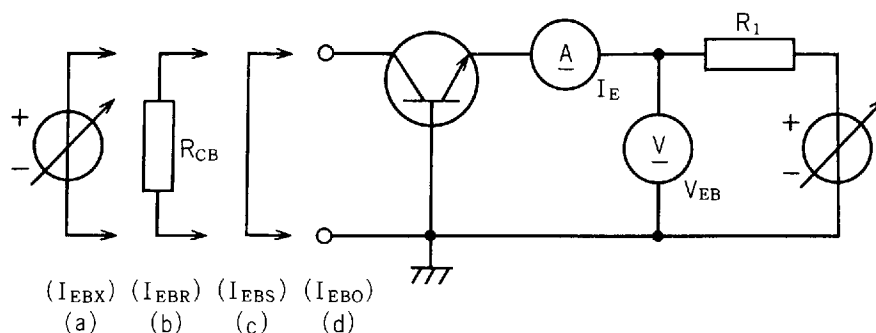
R_1 : protective resistor

- (3) **Procedures** Keep the conditions between the emitter and the base as specified, apply the specified voltage (V_{CB}) across the collector and the base, and measure the collector current (I_C) [collector-base cut-off current (I_{CB})].
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- (4.1) **Bias conditions between emitter and base**
- (a) Emitter-base voltage for the case of I_{CBX}
 - (b) Resistance value of R_{BE} to be connected between emitter and base for the case of I_{CBR}
 - (c) Short circuit of emitter and base for the case of I_{CBS}
 - (d) Open circuit of emitter and base for the case of I_{CBO}
- (4.2) **Collector-base voltage**
- (4.3) **Ambient temperature or reference point temperature**

6.1.9 Measurement of emitter-base cut-off current The measurement of emitter-base cut-off current shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the emitter-base cut-off current of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 9.

Fig. 9. Measuring circuit of emitter-base cut-off current



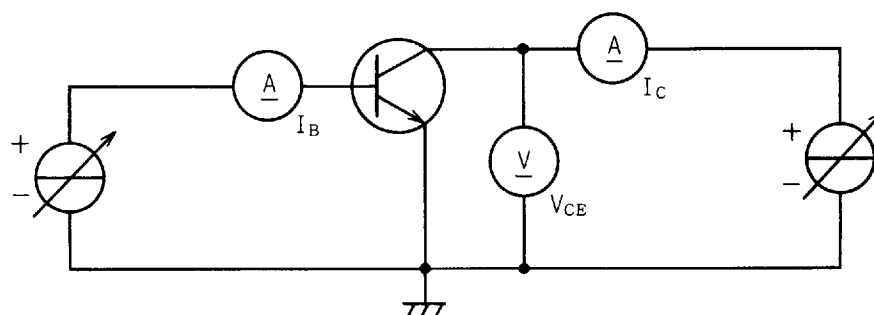
R_1 : protective resistor

- (3) **Procedures** Keep the conditions between the collector and the base as specified, apply the specified voltage (V_{EB}) across the emitter and the base, and measure the emitter current (I_E) [emitter-base cut-off current (I_{EB})].
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- (4.1) **Bias conditions between collector and base**
- (a) Collector-base voltage for the case of I_{EBX}
 - (b) Resistance value of R_{CB} to be connected between collector and base for the case of I_{EBR}
 - (c) Short circuit of collector and base for the case of I_{EBS}
 - (d) Open circuit of collector and base for the case of I_{EBO}
- (4.2) **Emitter-base voltage**
- (4.3) **Ambient temperature or reference point temperature**

6.1.10 **Measurement of collector-emitter saturation voltage (d.c. method)** The measurement of collector-emitter saturation voltage (d.c. method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the collector-emitter saturation voltage of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 10.

Fig. 10. Measuring circuit of collector-emitter saturation voltage (d.c. method)



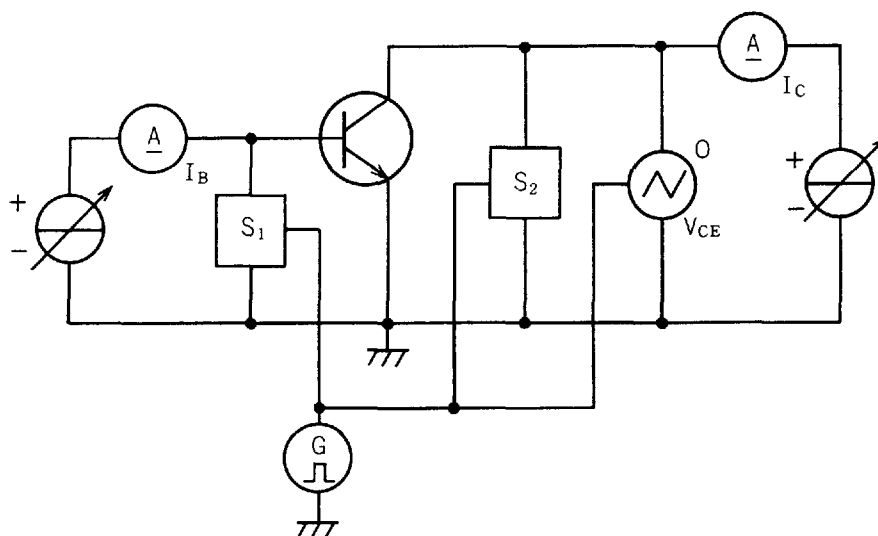
- (3) **Procedures** Pass the specified base current (I_B), gradually increase the collector current (I_C), and measure the collector-emitter voltage (V_{CE}) [collector-emitter saturation voltage [$V_{CE(sat)}$]] at the instant when the collector current (I_C) reaches the specified value. The current supply for collector current shall have voltage limiting function, and the limiting voltage shall be set to a voltage not exceeding the collector-emitter withstand voltage of the specimen.
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- (a) Collector current
 - (b) Base current
 - (c) Ambient temperature or reference point temperature

6.1.11 Measurement of collector-emitter saturation voltage (pulse method)

The measurement of collector-emitter saturation voltage (pulse method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the collector-emitter saturation voltage of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 11.

Fig. 11. Measuring circuit of collector-emitter saturation voltage (pulse method)



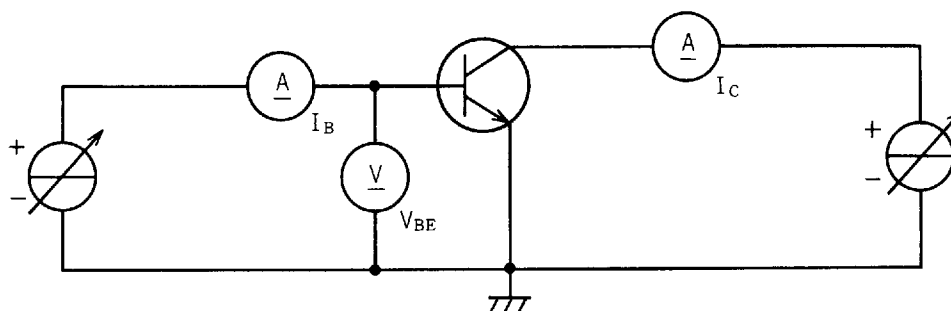
- (3) **Procedures** Set the pulse generator G to the specified pulse conditions, adjust switches S_1 and S_2 so that they open and close simultaneously, then set base current (I_B) and collector current (I_C) to the specified values. Measure the collector-emitter voltage (V_{CE}) [collector-emitter saturation voltage [$V_{CE(sat)}$]] with an oscilloscope O triggered by the pulse generator while the base current and the collector current are fed to the specimen. The current supply which feeds the collector current shall have voltage limiting function, and the limiting voltage shall be set to a voltage not exceeding the collector-emitter withstand voltage of the specimen.

- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:
- (a) Collector current
 - (b) Base current
 - (c) Pulse width and duty cycle
 - (d) Ambient temperature or reference point temperature

6.1.12 Measurement of base-emitter saturation voltage (d.c. method) The measurement of base-emitter saturation voltage (d.c. method) shall be as stated below:

- (1) Purpose This measuring method intends to measure the base-emitter saturation voltage of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 12.

Fig. 12. Measuring circuit of base-emitter saturation voltage (d.c. method)



- (3) Procedures Pass the specified base current (I_B), gradually increase the collector current (I_C), and measure the base-emitter voltage (V_{BE}) [base-emitter saturation voltage [$V_{BE(sat)}$]] at the instant when the collector current (I_C) reaches the specified value. The current supply for collector current shall have voltage limiting function, and the limiting voltage shall be set to a voltage not exceeding the collector-emitter withstand voltage of the specimen.
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:
 - (a) Collector current
 - (b) Base current
 - (c) Ambient temperature or reference point temperature

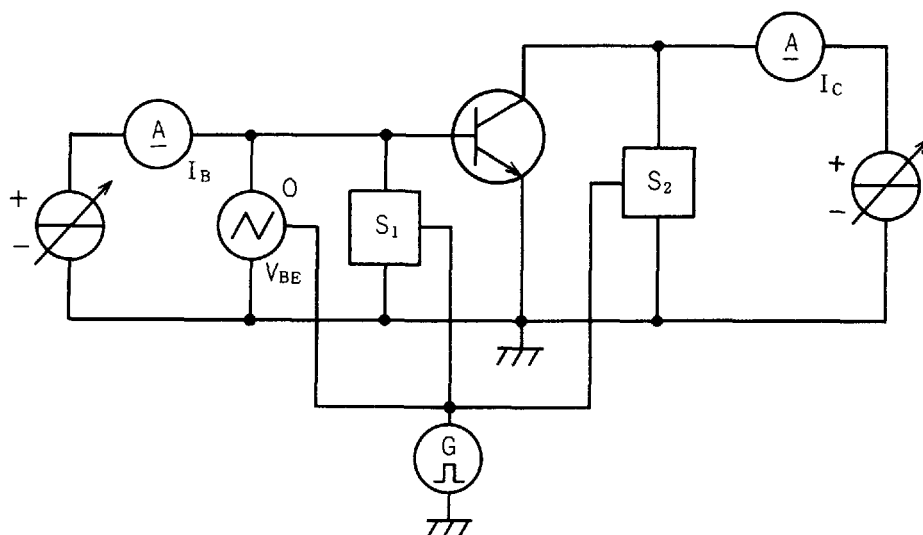
6.1.13 Measurement of base-emitter saturation voltage (pulse method) The measurement of base-emitter saturation voltage (pulse method) shall be as stated below:

- (1) Purpose This measuring method intends to measure the base-emitter saturation voltage of specimen under specified conditions.

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- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 13.

Fig. 13. Measuring circuit of base-emitter saturation voltage (pulse method)

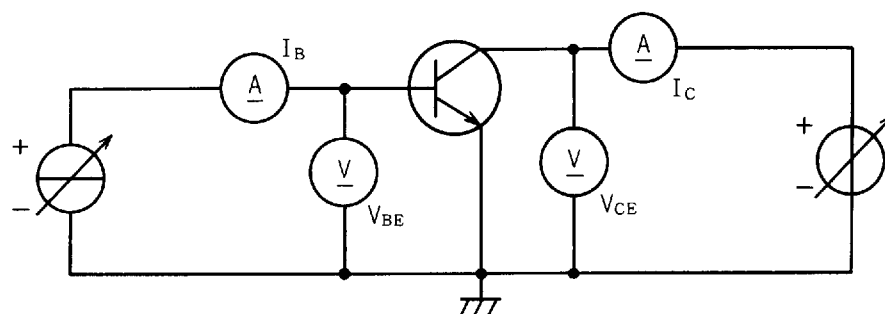


- (3) Procedures Set the pulse generator G to the specified pulse conditions, adjust switches S_1 and S_2 so that they open and close simultaneously, then set base current (I_B) and collector current (I_C) to the specified values. Measure the base-emitter voltage (V_{BE}) {base-emitter saturation voltage [$V_{BE(sat)}$]} with an oscilloscope O triggered by the pulse generator while the base current and the collector current are fed to the specimen. The current supply which feeds the collector current shall have voltage limiting function, and the limiting voltage shall be set to a voltage not exceeding the collector-emitter withstand voltage of the specimen.
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:
- Collector current
 - Base current
 - Pulse width and duty cycle
 - Ambient temperature or reference point temperature

6.1.14 Measurement of base-emitter voltage The measurement of base-emitter voltage shall be as stated below:

- (1) Purpose This measuring method intends to measure the base-emitter voltage of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 14.

Fig. 14. Measuring circuit of base-emitter voltage

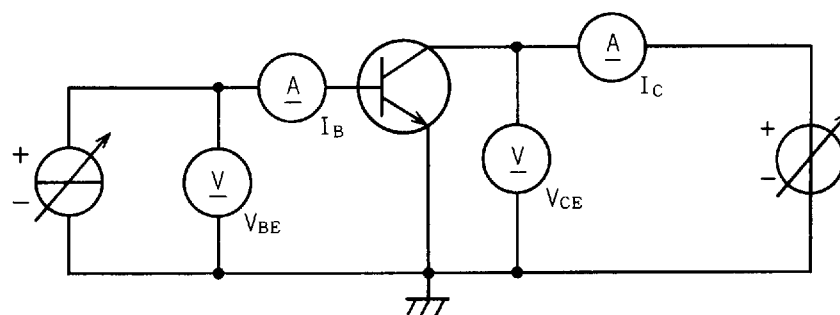


- (3) **Procedures** Set the collector-emitter voltage (V_{CE}) to the specified value, and measure the base-emitter voltage (V_{BE}) when the collector current (I_C) becomes the specified value.
- (4) **Items to be specified in detail specifications** The following items shall be specified in detail specifications:
- Collector-emitter voltage
 - Collector current
 - Ambient temperature or reference point temperature

6.1.15 **Measurement of d.c. current amplification (d.c. method)** The measurement of d.c. current amplification (d.c. method) shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the forward current transfer ratio of specimen under specified conditions.
- (2) **Measuring circuit** An example of the measuring circuit is shown in Fig. 15.

Fig. 15. Measuring circuit of d.c. current amplification (d.c. method)



- (3) **Procedures** Set the collector-emitter voltage (V_{CE}) to the specified value, and adjust the base current (I_B) so as to obtain the specified collector current (I_C). Calculate the forward current transfer ratio (h_{FE}) from the following formula:

$$h_{FE} = \frac{I_C}{I_B}$$

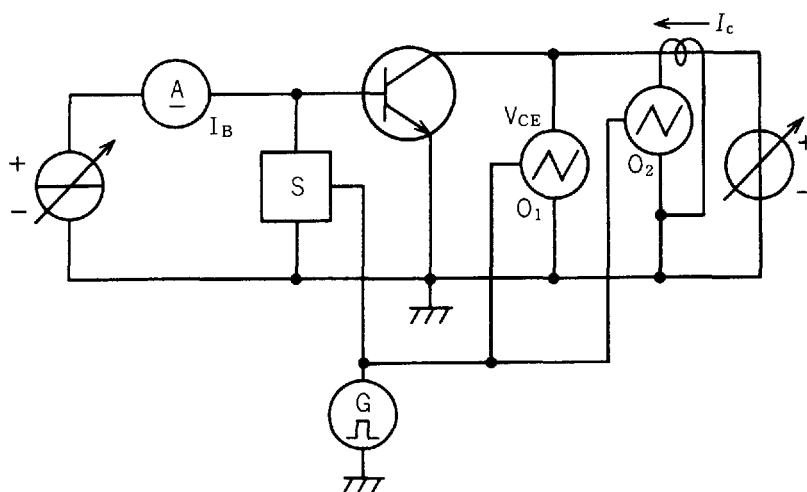
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Collector-emitter voltage
- (b) Collector current
- (c) Ambient temperature or reference point temperature

6.1.16 Measurement of d.c. current amplification (pulse method) The measurement of d.c. current amplification (pulse method) shall be as stated below:

- (1) Purpose This measuring method intends to measure the forward current transfer ratio of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit is shown in Fig. 16.

Fig. 16. Measuring circuit of d.c. current amplification (pulse method)



- (3) Procedures Supply the pulse of specified conditions from pulse generator G to the input terminals of triggers for switch S, and oscilloscopes of O₁ and O₂.

Set the collector-emitter voltage (V_{CE}) to the specified value by means of the constant voltage supply, while observing oscilloscope O₁. Then adjust the base current (I_B) so that the collector current (I_C) becomes the specified value by means of the constant current supply while observing oscilloscope O₂. Calculate the forward current transfer ratio (h_{FE}) from the following formula:

$$h_{FE} = \frac{I_C}{I_B}$$

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

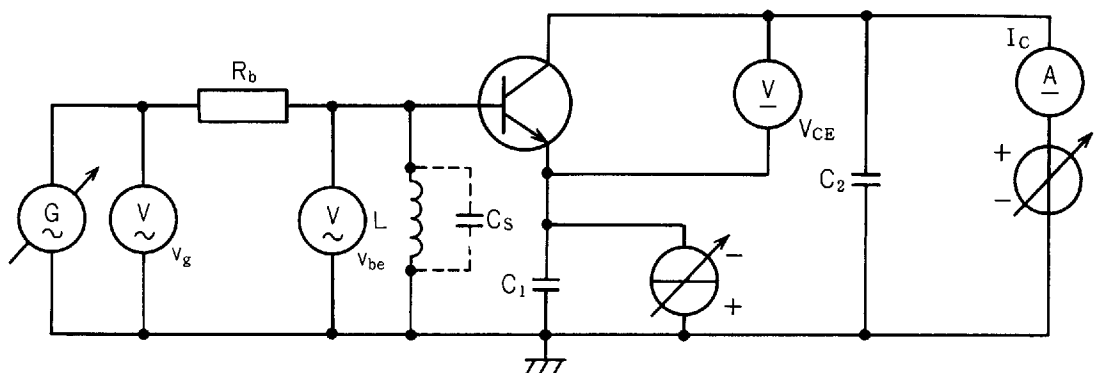
- (a) Collector-emitter voltage
- (b) Collector current

- (c) Pulse width and duty cycle
- (d) Ambient temperature or reference point temperature

6.1.17 Measurement of small-signal short-circuit input impedance The measurement of small signal short-circuit input impedance shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the small-signal short-circuit input impedance of specimen under specified conditions.
- (2) **Measuring circuit** Examples of the measuring circuits with the emitter grounded and that with the base grounded are shown in Fig. 17 and Fig. 18 respectively.

Fig. 17. Measuring circuit of small-signal short-circuit input impedance (emitter grounded)

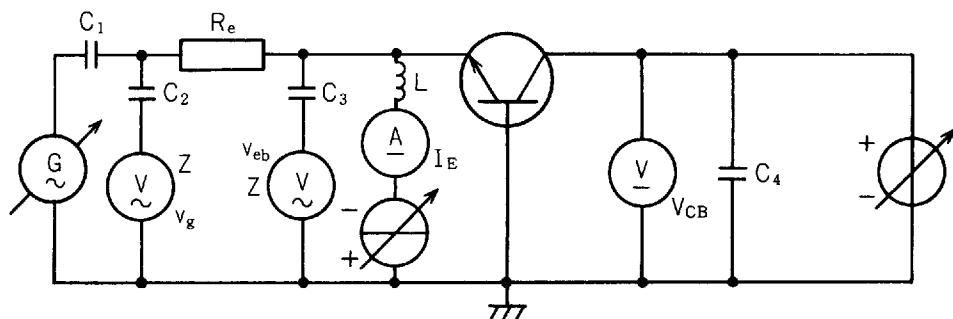


$$\frac{1}{\omega C_1} \ll \frac{|h_{ie}|}{|h_{fe}| + 1}, \quad \omega L \gg |h_{ie}|$$

$$R_b \gg |h_{ie}|, \quad \omega C_2 \gg |h_{oe}|$$

Remarks: If $\omega L \gg |h_{ie}|$ is not satisfied, L and stray capacitance C_s shall be resonanced.

Fig. 18. Measuring circuit of small-signal short-circuit input impedance (base grounded)



$$\frac{1}{\omega C_1} \ll R_e, \quad \frac{1}{\omega C_2} \ll Z, \quad \frac{1}{\omega C_3} \ll Z, \quad \omega C_4 \gg |h_{oe}|$$

$$R_e \gg |h_{ib}|, \quad \omega L \gg |h_{ib}|$$

Z : impedance of a.c. voltmeter

(3) Procedures The procedures shall be as follows:

- (a) When emitter is grounded Adjust the voltage and current of specimen to the specified values by repeating the adjustments of voltage and current, apply a signal of the specified frequency to the input side and measure v_g and v_{be} with a high impedance a.c. voltmeter. Calculate the small-signal short-circuit input impedance (h_{ie}) from the following formula:

$$h_{ie} = \frac{v_{be}}{i_b}$$

$$\text{where, } i_b = \frac{v_g - v_{be}}{R_b}$$

- (b) When base is grounded Adjust the voltage and current of specimen to the specified values, apply a signal of the specified frequency to the input side, and measure v_g and v_{eb} with a high-impedance a.c. voltmeter. Calculate the small signal short-circuit input impedance (h_{ib}) from the following formula:

$$h_{ib} = \frac{v_{eb}}{i_e}$$

$$\text{where, } i_e = \frac{v_g - v_{eb}}{R_e}$$

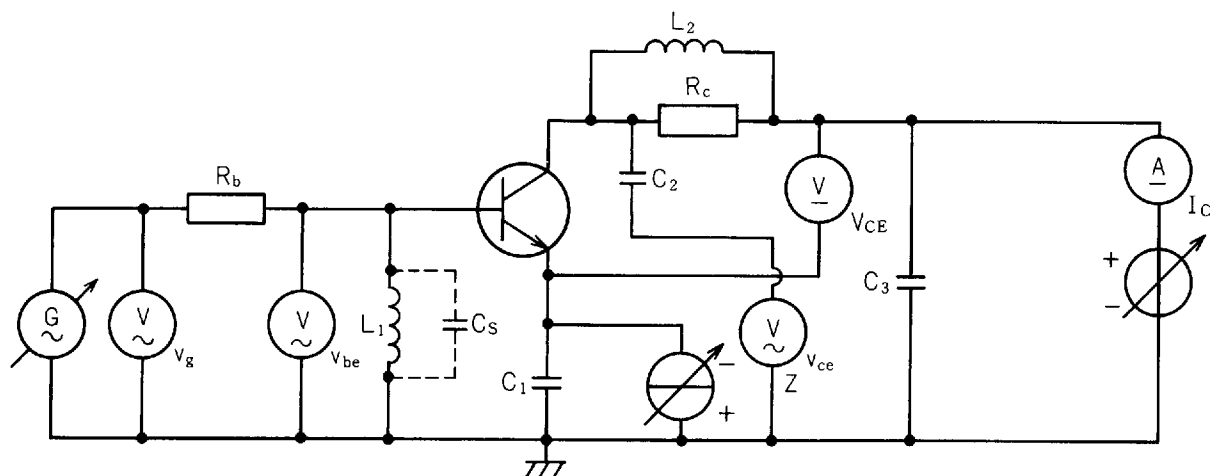
(4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Measuring voltage and current
- (b) Measuring frequency
- (c) Grounding system
- (d) Ambient temperature or reference point temperature

6.1.18 Measurement of small-signal short-circuit forward current transfer ratio
The measurement of small-signal short-circuit forward current transfer ratio shall be as stated below:

- (1) Purpose This measuring method intends to measure the small-signal short-circuit forward current transfer ratio of specimen under specified conditions.
- (2) Measuring circuit An example of the measuring circuit when the emitter is grounded is shown in Fig. 19.

Fig. 19. Measuring circuit of small-signal short-circuit forward current transfer ratio



$$\frac{1}{\omega C_1} \ll \frac{|h_{ie}|}{|h_{fe}| + 1}, \quad \frac{1}{\omega C_2} \ll Z, \quad \frac{1}{\omega C_3} \ll \frac{1}{|h_{oe}|} \quad Z: \text{impedance of a.c. voltmeter}$$

$$\omega L_1 \gg |h_{ie}|$$

$$R_b \gg |h_{ie}|, \quad R_c \ll 1/|h_{oe}|, \quad \omega L_2 \gg R_c$$

Remarks: If $\omega L_1 \gg |h_{ie}|$ is not satisfied, L_1 and stray capacitance C_s shall be resonanced.

(3) Procedures The procedures shall be as follows:

- (a) When emitter is grounded Adjust the voltage and current of specimen to the specified values by repeating the adjustment of voltage and current, apply a signal of the specified frequency to the input side and measure v_g , v_{be} and v_{ce} with a high-impedance a.c. voltmeter. Calculate the small-signal short-circuit forward current transfer ratio (h_{fe}) from the following formula:

$$h_{fe} = \frac{i_c}{i_b}$$

$$\text{where,} \quad i_c = \frac{v_{ce}}{R_c}, \quad i_b = \frac{v_g - v_{be}}{R_b}$$

- (b) When base is grounded Obtain the ratio from h_{fe} by means of the following formula:

$$h_{fb} \doteq \frac{-h_{fe}}{1 + h_{fe}}$$

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

- (a) Measuring voltage and current
(b) Measuring frequency

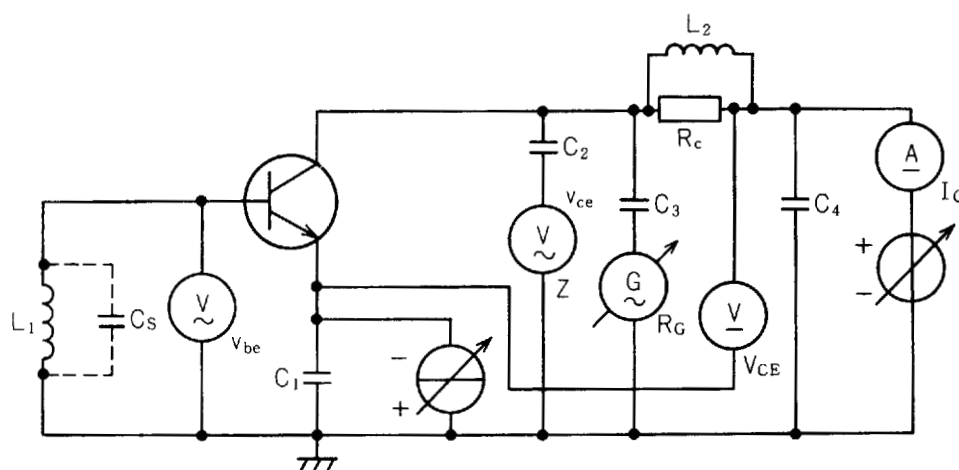
- (c) Grounding system
- (d) Ambient temperature or reference point temperature

6.1.19 Measurement of small-signal open-circuit reverse voltage transfer ratio

The measurement of small-signal open-circuit reverse voltage transfer ratio shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the small-signal open-circuit reverse voltage transfer ratio of specimen under specified conditions.
- (2) **Measuring circuit** Examples of the measuring circuits when emitter is grounded and that when base is grounded are shown in Fig. 20 and Fig. 21 respectively.

Fig. 20. Measuring circuit of small-signal open-circuit reverse voltage transfer ratio (emitter grounded)



$$\frac{1}{\omega C_1} \ll \frac{|h_{ie}|}{|h_{fe}| + 1}, \quad \frac{1}{\omega C_2} \ll Z, \quad \frac{1}{\omega C_3} \ll R_c$$

$$\omega L_1 \gg |h_{ie}|$$

$$\omega L_2 \gg R_c$$

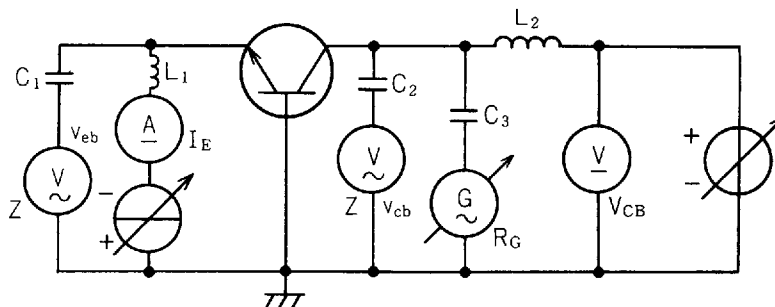
$$\frac{1}{\omega C_4} \ll R_c$$

R_c : impedance of signal generator

Z : impedance of a.c. voltmeter

Remarks: If $\omega L_1 \gg |h_{ie}|$ is not satisfied, L_1 and stray capacitance C_s shall be resonanced.

Fig. 21. Measuring circuit of small-signal open-circuit reverse voltage transfer ratio (base grounded)



$$\frac{1}{\omega C_1} \ll Z, \quad \frac{1}{\omega C_2} \ll Z, \quad \frac{1}{\omega C_3} \ll R_G$$

$$\omega L_1 \gg |h_{ie}|, \quad \omega L_2 \gg R_G$$

R_G : impedance of signal generator

Z : impedance of a.c. voltmeter

- (3) **Procedures** The procedures shall be as follows:

- (a) When emitter is grounded Adjust the voltage and current of specimen to the specified values by repeating the adjustment of voltage and current, apply a signal of the specified frequency to the output side, and measure v_{be} and v_{ce} with a high-impedance a.c. voltmeter. Calculate the small-signal open-circuit reverse voltage transfer ratio (h_{re}) from the following formula:

$$h_{re} = \frac{V_{be}}{V_{ce}}$$

- (b) When base is grounded Adjust the voltage and current of specimen to the specified values, apply a signal of the specified frequency to the output side, and measure v_{eb} and v_{cb} with a high-impedance a.c. voltmeter. Calculate the small-signal open-circuit reverse voltage transfer ratio (h_{rb}) from the following formula:

$$h_{rb} = \frac{V_{eb}}{V_{cb}}$$

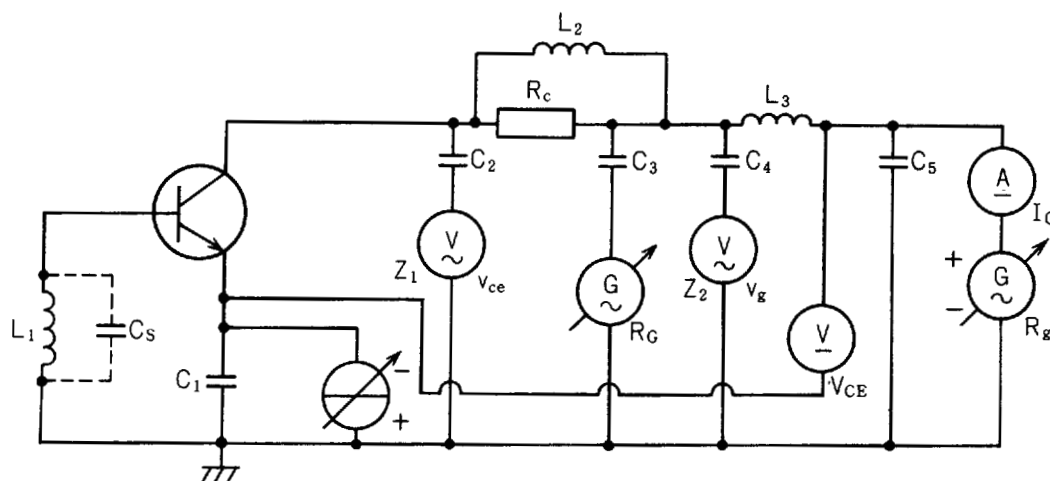
- (4) Items to be specified in detail specifications The following items shall be specified in detail specifications:

- (a) Measuring voltage and current
- (b) Measuring frequency
- (c) Grounding system
- (d) Ambient temperature or reference point temperature

6.1.20 Measurement of small-signal open-circuit output admittance The measurement of small-signal open-circuit output admittance shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the small-signal open-circuit output admittance of specimen under specified conditions.
- (2) **Measuring circuit** Examples of the measuring circuits when emitter is grounded and that when base is grounded are shown in Fig. 22 and Fig. 23 respectively.

Fig. 22. Measuring circuit of small-signal open-circuit output admittance (emitter grounded)



$$\frac{1}{\omega C_1} \ll \frac{1}{|h_{oe}|}, \quad \frac{1}{\omega C_2} \ll Z_1, \quad \frac{1}{\omega C_3} \ll R_G, \quad \frac{1}{\omega C_4} \ll Z_2, \quad \frac{1}{\omega C_5} \ll \omega L_3, \quad \omega L_2 \gg R_C, \quad \omega L_3 \gg R_G$$

$$\omega L_1 \gg |h_{ie}|$$

$$R_C \ll \frac{1}{|h_{oe}|}$$

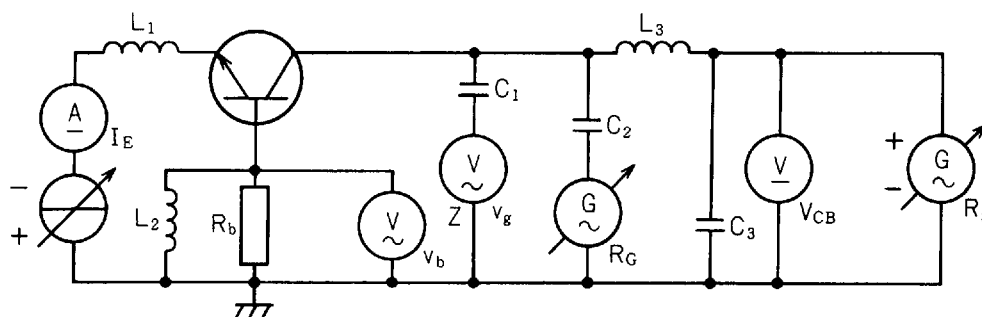
$$R_G \ll \frac{1}{|h_{oe}|}$$

R_C : impedance of signal generator

Z_1, Z_2 : impedance of a.c. voltmeter

Remarks: If $\omega L_1 \gg |h_{ie}|$ is not satisfied, L_1 and stray capacitance C_s shall be resonanced.

Fig. 23. Measuring circuit of small-signal open-circuit output admittance (base grounded)



$$\frac{1}{\omega C_1} \ll Z, \quad \frac{1}{\omega C_2} \ll R_G, \quad \frac{1}{\omega C_3} \ll \omega L_3,$$

$$R_b \ll \frac{1}{|h_{ob}|}, \quad \omega L_1 \gg |h_{ib}|, \quad \omega L_2 \gg R_b, \quad \omega L_3 \gg R_G, \quad R_G \ll \frac{1}{|h_{ob}|}$$

R_G : impedance of signal generator

Z : impedance of a.c. voltmeter

(3) **Procedures** The procedures shall be as follows:

- (a) When emitter is grounded Adjust the voltage and current of specimen to the specified values by repeating the adjustment of voltage and current, apply a signal of the specified frequency to the output side and measure v_g and v_{ce} with a high-impedance a.c. voltmeter. Calculate the small-signal open-circuit output admittance (h_{oe}) from the following formula:

$$h_{oe} = \frac{i_c}{v_{ce}}$$

where,
$$i_c = \frac{v_g - v_{ce}}{R_c}$$

- (b) When base is grounded Adjust the voltage and current of specimen to the specified values, apply a signal of the specified frequency to the output side, and measure v_g and v_b with a high-impedance a.c. voltmeter. Calculate the small-signal open-circuit output admittance (h_{ob}) from the following formula:

$$h_{ob} = \frac{i_c}{v_{cb}} \div \frac{i_b}{v_{cb}}$$

where,
$$i_b = \frac{v_b}{R_b}, \quad v_{cb} = v_g - v_b$$

(4) Items to be specified in detail specifications

The following items shall be specified in detail specifications:

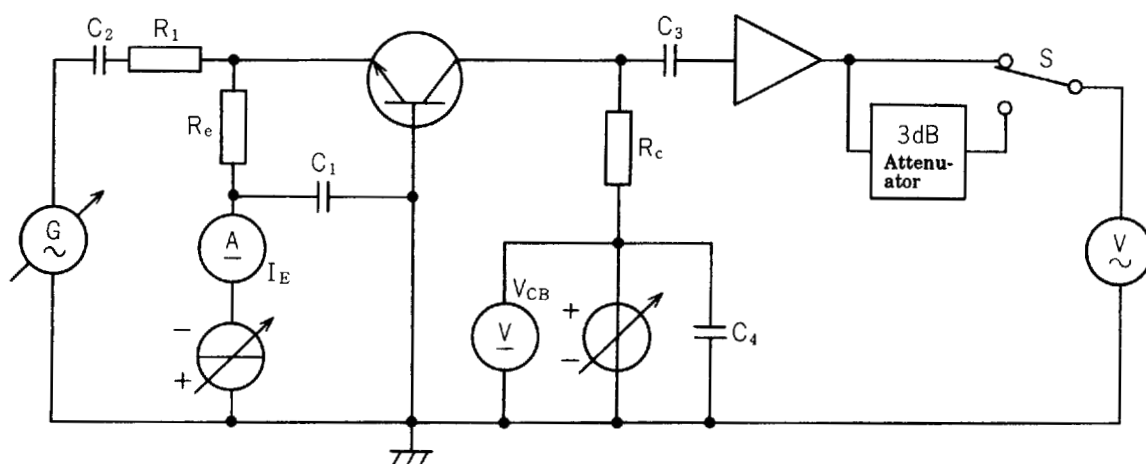
- (a) Measuring voltage and current

- (b) Measuring frequency
- (c) Grounding system
- (d) Ambient temperature or reference point temperature

6.1.21 Measurement of small-signal short-circuit forward current transfer ratio cut-off frequency The measurement of small-signal short-circuit forward current transfer ratio cut-off frequency shall be as stated below:

- (1) **Purpose** This measuring method intends to measure the small-signal short-circuit forward current transfer ratio cut-off frequency of specimen under specified conditions.
- (2) **Measuring circuit** Examples of the measuring circuits with the base grounded for one line system and that for two line system are show in Fig. 24 and Fig. 25.

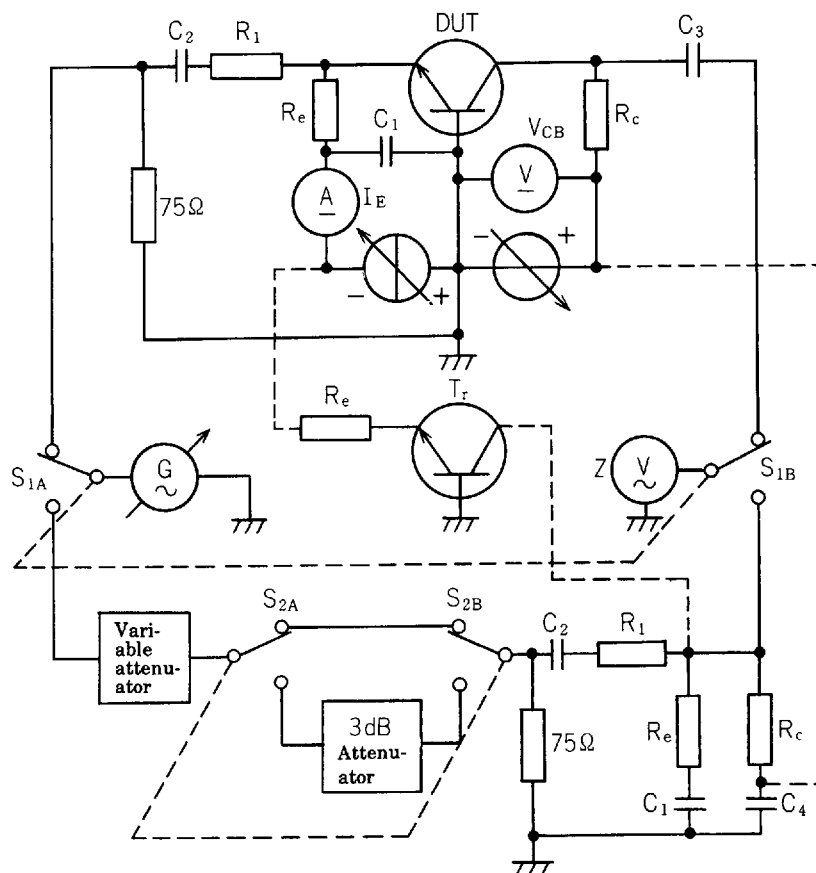
Fig. 24. Measuring circuit of small-signal short-circuit forward current transfer ratio cut-off frequency (one-line system)



$$R_1, R_e \gg |h_{ib}|, R_c \ll \frac{1}{|h_{ob}|}, \frac{1}{\omega C_1} \ll |h_{ib}|, \frac{1}{\omega C_1} \ll R_e, \frac{1}{\omega C_2} \ll R_1, \frac{1}{\omega C_3} \ll Z, \frac{1}{\omega C_4} \ll R_c$$

Z : input impedance of amplifier

Fig. 25. Measuring circuit of small-signal short-circuit forward current transfer ratio cut-off frequency (two-line system)



$$R_1, R_e \gg |h_{ib}|, R_c \ll \frac{1}{|h_{ob}|}, \frac{1}{\omega C_1} \ll R_e, \frac{1}{\omega C_2} \ll R_1, \frac{1}{\omega C_3} \ll Z, \frac{1}{\omega C_4} \ll R_c$$

Z : impedance of voltmeter

(3) Procedures The procedures shall be as follows:

- (a) For measuring circuit of one-line system Adjust the voltage and current of specimen to the specified values, throw switch S on the attenuator side, and read the output at low frequency with a high-impedance a.c. voltmeter. Then, throw switch S on the short-circuit side, increase the signal frequency and obtain the frequency at which the reading of the high-impedance a.c. voltmeter becomes the above-mentioned value. This frequency is the forward current transfer ratio cut-off frequency.

Remarks 1. The measuring circuit shall have no frequency dependency at least within the measuring range. That is, to verify that the reading of the high-impedance a.c. voltmeter does not change with the change of signal frequency under such conditions that the specimen is removed from the circuit and the emitter and the collector are short-circuited without biased, on both positions of switch S.