

JIS

JAPANESE INDUSTRIAL STANDARD

Measuring Methods for Operational Amplifiers

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JAPANESE INDUSTRIAL STANDARD

J I S

Measuring Methods
for
General Use Operational Amplifiers

C 7061-1981

1. Scope

This Japanese Industrial Standards specifies the measuring methods for differential input type and single ended output type operational amplifiers used for electronic apparatus.

2. Definitions and Symbols

For the purposes of this standard, the main definitions and symbols given in Appendix 1, JIS C 5610 and JIS C 5620 apply.

3. Condition of Measurements

3.1 Temperature Unless otherwise specified the ambient or the reference point temperature during measurements shall be $25 \pm 2^\circ\text{C}$ under such condition that the operational amplifiers under measurement (specimen) is thermally in equilibrium with only natural convection and without direct blast.

3.2 Humidity Unless otherwise specified it shall be 45 to 85% in relative humidity and 65% in reference conditions.

3.3 Referee Conditions It shall be $25 \pm 1^\circ\text{C}$ in temperature, $50 \pm 5\%$ in relative humidity, 860 to 1060 mbar in atmospheric pressure⁽¹⁾.

Note (1) 1 mbar = 100 Pa

3.4 Equilibrium States The measured values on the specimen shall be the values obtained in non-variable and equilibrium state after lapse of a definite time from the beginning of measurements. However this definitions may not be conformed with if clearly specified as "Pulse measurement" or "IC tester measurement".

4. Electrical Characteristics4.1 Measuring Apparatuses and Equipments

4.1.1 Power Supply for Measurement Voltage fluctuation of the d.c. power supply shall be within $\pm 1\%$, and the ripple voltage shall be ± 10 mV or less. Impedance of the power supply shall be within the limit not to affect the measurements.

4.1.2 Measuring Apparatus or Instruments They shall be of the 0.5 class or better, unless otherwise specified. The influence of their impedances on the measuring systems shall be negligible. However the following cases are excepted.

- (1) In the case of having no serious influence on the measuring results.

Applicable Standard: See page 53.

- (2) In the case of having no serious influence on the judgement of acceptance criteria.

- (3) IC tester, CRT, display or others

4.1.3 Signal Generator for Measurements The frequency and output shall be stable and precise. The accuracy of frequency shall be under 10%. The contents of spurious wave shall be as little as possible.

4.2 Circuit Components The components used in measuring circuits shall be stable and reproducible in their characteristic values.

4.2.1 Resistors Allowable error of the resistance value for resistors used in measuring circuits shall be $\pm 1\%$, unless otherwise specified.

4.2.2 Capacitors Allowable error of the capacitance value for capacitors used in measuring circuits shall be $\pm 10\%$ unless otherwise specified. However this specification may not be conformed if the error has no relation with measuring accuracy.

4.3 Polarity of Voltage and Current

4.3.1 Polarity of Voltage It shall be determined as the polarity to the potential of common terminals for the input and output circuits as the reference.

4.3.2 Polarity of Current It shall be determined as positive for the direction of flowing into the specimen.

4.4 General Precaution The following attention matters shall be conformed in the measurements.

- (1) Absolutely Maximum Rating The rating which shall not be exceeded even in an instant. If the rating depends on temperature in the category temperature range, the rating shall not exceed the value specified in the detail specification.
- (2) Transient Phenomena Voltage and current of the specimen shall not exceed the respective ratings even in transient phenomena.
- (3) Pulse Measurement If the measurement of the static or dynamic parameters of the specimen is carried out in pulse state to avoid the measuring error caused by the heat generated by the specimen in the measuring period, such measurement shall be designated as "Pulse measurement" and the pulse conditions shall be defined clearly.
- (4) Confirmation of No Oscillation and Induction Before measurements, the existence of abnormal parasitic oscillations and inductions from power supplies in the measuring systems including the specimen shall be confirmed.
- (5) Auxiliary Amplifier It shall be an amplifier with the open loop gain of 60 dB min., the sufficient output amplitude, and the common mode input voltage range over the output voltage range from the specimen.
The measuring circuits shown in this text are the fundamental figures, therefore the detail precaution when auxiliary amplifiers are employed and the structure of measuring circuits employing

auxiliary amplifiers shall be as described in Appendix 2.

- (6) Auxiliary Circuit and Compensation Circuit The measurements shall be carried out by using auxiliary circuits and compensation circuit necessary for the measurements such as offset regulation circuits, oscillation blocking circuits and shields.
- (7) Small Signal Operation It means that the specimen is operated under small signal conditions where the specimen operates linearly and the measurements are carried out.
- (8) Confirmation of Temperature The temperature during a measurement shall be confirmed to check whether it is kept within specified value.
- (9) Soldering If soldering is necessary for measurements, adequate attention shall be paid so that the specimen is not damaged by heat or the induction of power sources.
- (10) Composite Type Operational Amplifiers to be Measured In the case of composite type specimen, it shall be confirmed that connection state of terminals except for measuring circuits is complying with the measuring conditions and the specimen is not affected by other circuits.
- (11) Connecting Order of Terminals The connection of the specimen to the power sources shall be made carefully by confirming existence of protection circuits and use of protection resistors. The common terminals shall be connected first.
- (12) Handling of MOS Integrated Circuit The following precaution shall be obeyed to protect MOS integrated circuits from the damage due to static electricity.
 - (a) In the case of storage or standing, electrification due to static electricity shall be avoided by using metal cases or plates.
 - (b) During application of bias voltages, the specimen shall not be plugged into or drawn out from the sockets.
 - (c) The signal shall be applied after the supply of power, and the power source shall be shut down after the suspension of signal.
 - (d) Measurements shall be performed in a place where no static electricity is caused. The relative humidity is desired to be about 50%. There is such a way to prevent generation of static electricity, that the electric potentials of operators, tools and measuring equipments are made equal to the potential of place where the specimen is handled.

4.5 D.C. Characteristics

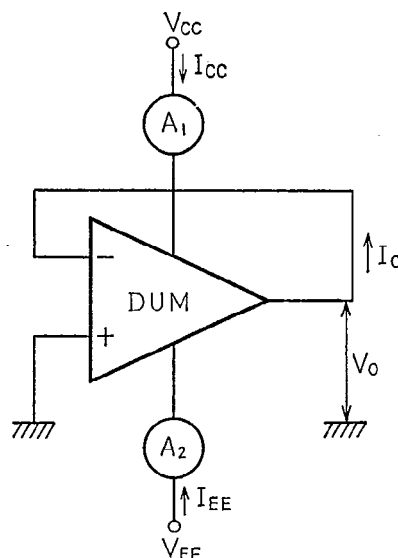
4.5.1 Power Consumption P_D The measurement of power consumption shall be as follows:

- (1) Purpose The purpose of this measurement is to measure the electric power consumed in the specimen (hereinafter denoted DUM) under the specified circuit condition.

Normally, the output current (I_o) and output voltage (V_o) shall be measured at $I_o = 0\text{A}$, $V_o = 0\text{V}$.

- (2) Measuring Circuit It shall conform to Fig. 1 as a rule.

Fig. 1. Measuring Circuit for Consumption Power



- (3) Principle of Measurements In the measuring circuit of Fig. 1, DUM satisfies the conditions $I_o = 0\text{A}$, $V_o = 0\text{V}$. From applied source voltage and source terminal current under such state, P_D is obtained from the equation (1.1).

$$P_D = V_{CC} \cdot I_{CC} + V_{EE} \cdot I_{EE} \quad \dots\dots\dots(1.1)$$

- (4) Explanation and Condition of the Circuit Internal impedances of the d.c. ammeter A_1 , and A_2 used for measuring the source terminal currents I_{CC} and I_{EE} shall be sufficiently small compared with the source terminal impedance of the DUM.

- (5) Attention For the DUM with one source terminal, the applied voltage and current shall be measured for the one terminal. An auxiliary amplifier (hereinafter denoted Null) may be used for the above measurement if the data for other d.c. characteristics are measured in the same circuit in common.

- (6) Measuring Procedures It shall be as follows:

- (a) V_{CC} and V_{EE} shall be set to specified values.
- (b) I_{CC} and I_{EE} shall be measured.
- (c) P_D shall be obtained from the following equation:

$$P_D = V_{CC} \cdot I_{CC} + V_{EE} \cdot I_{EE}$$

- (7) Measuring Conditions to be Specified The conditions are as follows:

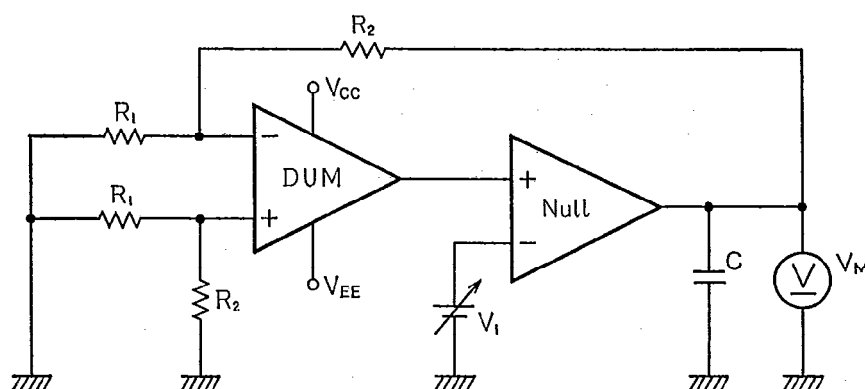
- (a) V_{CC} and V_{EE}
- (b) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (normally T_a , T_c or $T_{ref} = 25^\circ\text{C}$)

4.5.2 Input Characteristics

4.5.2.1 Input Offset Voltage V_{IO} It shall be measured conforming to the following:

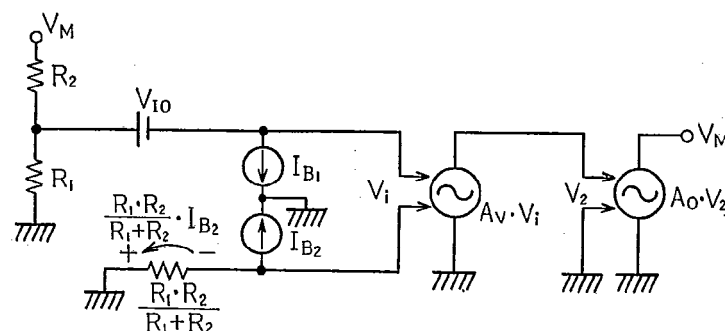
- (1) Purpose The purpose of this measurement is to measure the d.c. voltage across the input terminals of a DUM, when the output voltage of the DUM becomes 0V (or designated voltage) under the specified circuit conditions i.e. input offset voltage.
- (2) Measuring Circuit It shall conform to Fig. 2 as a rule.

Fig. 2. Measuring Circuit of Input Offset Voltage



- (3) Principle of Measurements At the measurement where the output voltage of DUM is 0V, adjustment is made to hold $V_1 = 0\text{V}$. When the output voltage of DUM is set at the specified value except 0V, and also V_1 is set at the same value, the input offset voltage is amplified by Null, and can be measured. The equivalent circuit at such state is shown in Fig. 2a.

Fig. 2a



As the voltage gain of Null A_0 is over 60 dB, $V_2 \approx 0$ in the normal operating range, therefore $V_1 = 0$. The equilibrium condition for this case is expressed in equation (2.1).

$$\frac{R_1}{R_1+R_2} \cdot V_M - \frac{R_1 \cdot R_2}{R_1+R_2} \cdot I_{B1} - V_{I0} = -\frac{R_1 \cdot R_2}{R_1+R_2} \cdot I_{B2} \quad (2.1)$$

then

$$V_{I0} = \frac{R_1}{R_1+R_2} \cdot V_M - \frac{R_1 \cdot R_2}{R_1+R_2} \cdot I_{I0} \quad (2.2)$$

Here, I_{I0} is the input offset current of DUM, and

$$I_{I0} = |I_{B1} - I_{B2}|$$

When the value of R_1 is so selected that the voltage drop in R_1 due to the input offset current is negligible compared with V_{I0} , V_{I0} can be approximated as follows:

$$V_{I0} = \frac{R_1}{R_1+R_2} \cdot V_M \quad (2.3)$$

V_{I0} shall be obtained by measuring V_M in the measuring circuit of Fig. 2.

The error caused by the approximate equation (2, 3) is, $(R_1 \cdot I_{I0} / V_{I0}) \times 100(\%)$. If $R_1 \cdot I_{I0}$ cannot be neglected, V_{I0} shall be calculated by means of equation (2.2) from the I_{I0} measured in the circuit of Fig. 4.

(4) Explanation and Condition of the Circuit

Normally, the value of R_1 shall be determined so small that the voltage drop due to the input offset current of DUM can be neglected compared with V_{I0} .

R_2 shall be determined smaller than the input impedance of DUM. The ratio of R_1 to R_2 shall be chosen so that the output voltage V_M does not exceed the linear operation range of Null, normally R_2/R_1 should be 100 to 1,000.

C is an oscillation preventive capacitor.

V_1 is a voltage source for the setting of voltage in such case that the output voltage of DUM is determined as a specified value except 0 V.

When the V_{I0} at which the output voltage becomes zero is measured, $V_1 = 0$ V shall hold.

V_M is a d.c. voltmeter with an internal impedance of 1 M Ω or more.

The standard measuring condition shall be as follows:

$R_1 = 50 \Omega$ Metal film resistor

$R_2 = 50 \text{ k}\Omega$ Metal film resistor

$C = 0.1 \mu\text{F}$ High frequency capacitor

$V_1 = 0 \text{ V}$

- (5) Attention For measuring an operational amplifier with V_{IO} of 10 mV or more, the ratio R_2/R_1 shall be made small, so that $|V_M|$ does not exceed 10V.
- (6) Measuring Procedure It shall be as follows:
- (a) V_{CC} , V_{EE} shall be set to the specified values.
 - (b) $V_I = 0$ V, however, when output voltage is not 0 V in the measurement of V_{IO} , V_I shall be set equal to the specified output voltage.
 - (c) R_1 , R_2 shall be set to the specified values.
 - (d) A compensating circuit, if necessary, shall be connected to satisfy the specified conditions.
 - (e) V_M shall be measured.
 - (f) V_{IO} shall be obtained from the following equation:

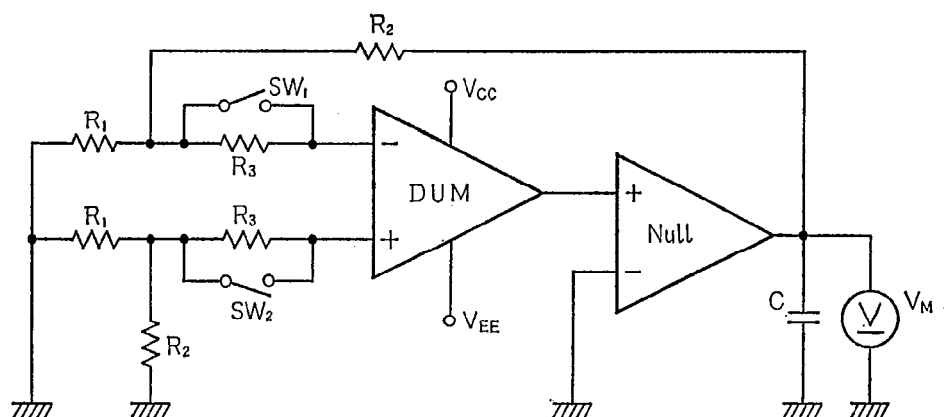
$$V_{IO} = \frac{R_1}{R_1 + R_2} \cdot V_M$$

- (7) Measuring Condition to be Specified It shall be as follows:
- (a) Power source V_{CC} and V_{EE}
 - (b) V_I (normally 0 V)
 - (c) R_1 and R_2
 - (d) Compensating circuit (if necessary)
 - (e) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (Normally, T_a , T_c or $T_{ref} = 25^\circ\text{C}$)

4.5.2.2 Input Bias Current I_B (or I_L) The measurement of input bias current shall be as follows:

- (1) Purpose The purpose of this measurement is to measure the mean value of the current flowing through two input terminals when the output voltage of DUM is 0 V, under the specified conditions (i.e. input bias current).
- (2) Measuring Circuit It shall conform to Fig. 3 as a rule.

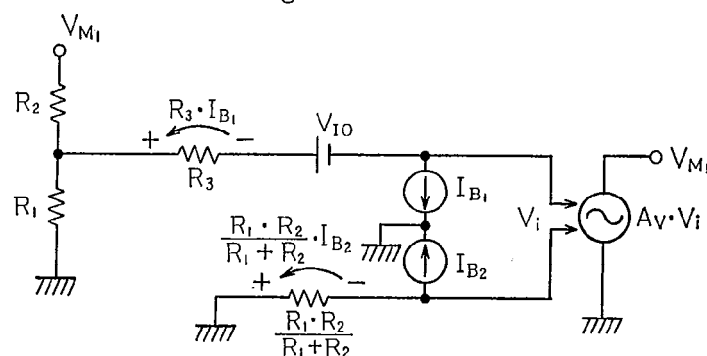
Fig. 3. Measuring Circuit of Input Bias Current

(3) Principle of Measurement

The measurement shall be made in the following two operations.

- (a) The V_M when SW_1 is opened and SW_2 is closed is read and called as V_{M1} .
- (b) The V_M when SW_1 is closed and SW_2 is opened is read and called as V_{M2} .
- (a) The equivalent circuit under the condition (a) is shown in Fig. 3a.

Fig. 3a

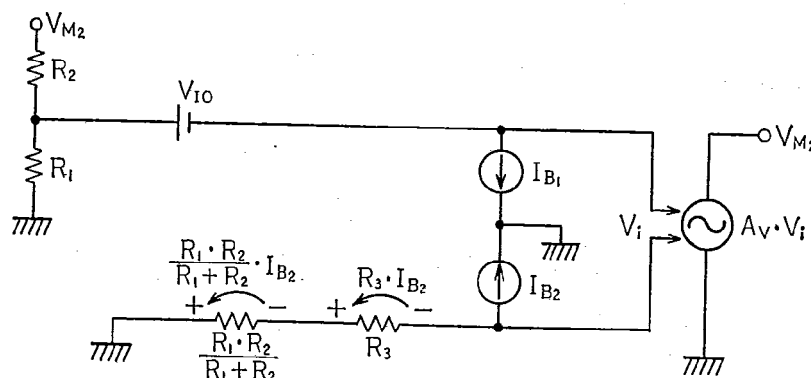


as $V_i = 0$

$$\frac{R_1}{R_1 + R_2} \cdot V_{M1} - \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot I_{B1} = R_3 \cdot I_{B1} + V_{I0} - \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot I_{B2} \dots (3.1)$$

- (b) The equivalent circuit under the condition (b) is shown in Fig. 3b.

Fig. 3b



Same as above $V_i = 0$

$$\frac{R_1}{R_1 + R_2} \cdot V_{M2} - \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot I_{B1} = V_{10} - R_3 \cdot I_{B2} - \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot I_{B2} \quad (3.2)$$

From (3.1) and (3.2)

$$\frac{R_1}{R_1 + R_2} (V_{M1} - V_{M2}) = R_3 (I_{B1} + I_{B2})$$

then

$$I_B = \frac{I_{B1} + I_{B2}}{2} = \frac{R_1}{2 \times R_3 (R_1 + R_2)} (V_{M1} - V_{M2}) \quad (3.3)$$

The input bias current I_B shall be obtained from equation (3.3) by measuring V_{M1} and V_{M2} with twice operation, i.e. under the condition of SW_1 , SW_2 defined in (a) and (b).

- (4) Explanation of Circuit and Condition The ratio of R_1 to R_2 shall be selected so that the output voltage V_M does not exceed the linear operation range of Null. Normally, R_2/R_1 should be 100 to 1,000. C is an oscillation preventive capacitor. Input impedance of a d.c. voltmeter to measure V_M shall be not less than $1M\Omega$. Each of leakage resistances of the switch SW_1 and SW_2 is in open state shall be not less than $100 \times R_3$. R_3 shall be chosen corresponding to the bias current range of DUM so that V_M can be read precisely. The standard measuring condition shall be as follows:

$R_1 = 50 \Omega$	Metal film resistor
$R_2 = 5 k\Omega$	Metal film resistor
$R_3 = 100 k\Omega$	Metal film resistor (at $I_B \div 0.1 \mu A$)
$C = 0.1 \mu F$	High frequency capacitor

- (5) Attention Value of R_3 shall be properly chosen using equation (3.3) after presuming the value of bias current so that V_M can be read precisely in normal operation range.
- (6) Measurement Procedure It shall be as follows:
- (a) R_1 and R_2 shall be set to the specified values.
 - (b) R_3 shall be chosen properly corresponding to the measurement range of I_B .
 - (c) Specified compensation circuit shall be attached if necessary.
 - (d) V_{CC} and V_{EE} shall be set to the specified values.
 - (e) The reading of V_M when SW_1 is in open state and SW_2 is in closed state is made as V_{M1} .
 - (f) The reading of V_M when SW_1 is in closed state and SW_2 is in open state is made as V_{M2} .
 - (g) I_B shall be obtained from the following equation.

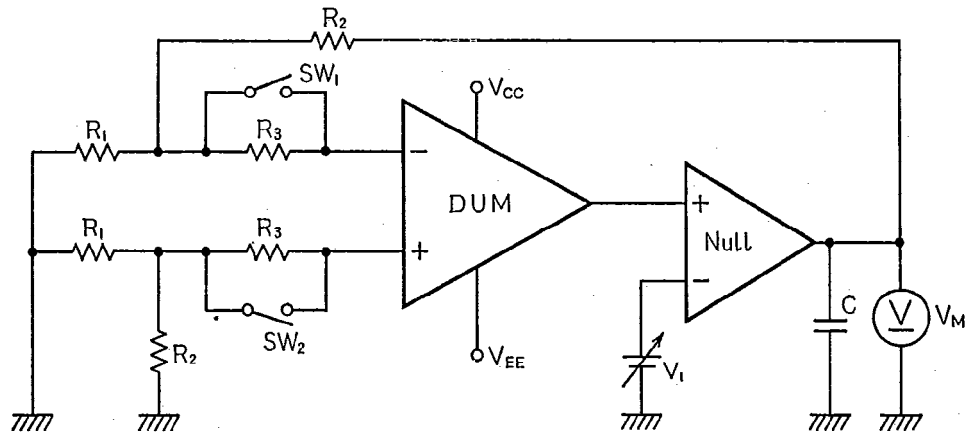
$$I_B = \frac{R_1}{2 \times R_3(R_1 + R_2)} (V_{M1} - V_{M2})$$

- (7) Measurement Conditions to be Specified It shall be as follows:
- (a) Power source voltage V_{CC} and V_{EE}
 - (b) R_1 and R_2
 - (c) Compensation circuit (if necessary)
 - (d) R_3
 - (e) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (Normally, T_a, T_c or $T_{ref} = 25^\circ\text{C}$).

4.5.2.3 Input Offset Current I_{io} Measurement of input offset current shall be as follows:

- (1) Purpose The purpose of this measurement is to measure the difference between two currents flowing to the two input terminals of DUM when the output voltage of DUM is 0 V (or specified value) under the specified conditions (i.e. input offset current).
- (2) Measuring Circuit It shall conform to Fig. 4 as a rule.

Fig. 4. Measuring Circuit of Input Offset Current



- (3) Principle of Measurement The measurement when the output voltage of DUM is 0 V, V shall be carried out under $V_1 = 0$ V. The measurement shall be made in the following two operations.

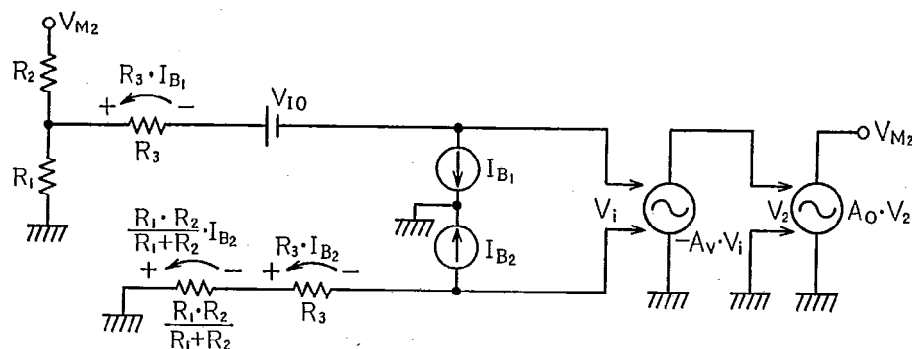
- (a) The V_M when SW_1 and SW_2 are closed is read and called as V_{M1} .
- (b) The V_M when SW_1 and SW_2 are opened is read and called as V_{M2} .

In the case (a), the circuit becomes same as Fig. 2 and the following equation holds same as equation (2.1):

$$\frac{R_1}{R_1 + R_2} \cdot V_{M1} = V_{IO} + \frac{R_1 \cdot R_2}{R_1 + R_2} (I_{B1} - I_{B2}) \quad \text{.....(4.1)}$$

In the case (b), an equivalent circuit is shown in Fig. 4a.

Fig. 4a



As $V_1 = 0$

$$\frac{R_1}{R_1+R_2} \cdot V_{M2} - \frac{R_1 \cdot R_2}{R_1+R_2} \cdot I_{B1} - R_3 \cdot I_{B1} - V_{I0} = -R_3 \cdot I_{B2} - \frac{R_1 \cdot R_2}{R_1+R_2} \cdot I_{B2}$$

then

$$\frac{R_1}{R_1+R_2} \cdot V_{M2} = V_{I0} + \frac{R_1 \cdot R_2}{R_1+R_2} (I_{B1} - I_{B2}) + R_3 (I_{B1} - I_{B2}) \dots\dots\dots (4.2)$$

From Eq. (4.1), (4.2)

$$\frac{R_1}{R_1+R_2} (V_{M2} - V_{M1}) = R_3 (I_{B1} - I_{B2})$$

As $I_{I0} = |I_{B1} - I_{B2}|$

$$I_{I0} = \frac{R_1}{R_3(R_1+R_2)} |V_{M2} - V_{M1}| \dots\dots\dots (4.3)$$

That is, I_{I0} can be obtained by measuring V_{M1} and V_{M2} by means of the operations in 2 circuits changed over by the switches. For the case that the output voltage of DUM is at the specified value except 0 V, the d.c. source voltage V_1 shall be set to the specified value and the measurement is made in the same way.

- (4) Explanation of Circuit and Condition The ratio of R_1 to R_2 shall be selected in accordance with equation (4.1) so that the output voltage V_M does not exceed the linear operating range of Null.

Normally, R_2/R_1 should be 100 to 1000.

C is an oscillation preventive capacitor.

Input impedance of d.c. voltmeter to measure V_M shall be not less than $1\text{M}\Omega$.

Leakage resistances of switches SW_1 and SW_2 at open state shall be not less than $10 \times R_3$.

D.C. source voltage V_1 is the one for setting the output voltage of DUM to the specified value.

The standard measuring condition shall be as follows:

$R_1 = 50\ \Omega$	Metal film resistor
$R_2 = 50\ \text{k}\Omega$	Metal film resistor
$R_3 = 100\ \text{k}\Omega$	Metal film resistor (at $I_{I0} \approx 50\text{nA}$)
$C = 0.1\ \mu\text{F}$	High frequency capacitor
$V_1 = 0\ \text{V}$	

- (5) Attention The value of R_3 shall be properly chosen in accordance with Eq. (4.3) presuming the value of input offset current to be measured, as larger than the value of $|V_{M2} - V_{M1}|$ as possible for reading out I_{I0} precisely. In this measuring circuit, relative error between two R_3 s affects the measuring accuracy. In general use operational amplifiers, the ratio of input offset current to input bias

current is 1/5 to 1/10, so that the measurement error is 5 to 10 times as large as the relative error of two R_3 s. For example, if the relative accuracy of two R_3 s is assumed as about 0.5%, the measurement error due to the resistance error becomes about 5%. Therefore, the relative error of two R_3 s must be adjusted corresponding to the expected measurement accuracy.

(6) Measurement Procedure It shall be as follows:

- (a) R_1 and R_2 shall be set to the specified values.
- (b) R_3 shall be determined properly corresponding to the measurement range of I_{IO} .
- (c) The condition that the relative accuracy of two R_3 s is smaller than 0.1 of expected measurement accuracy, shall be confirmed.
- (d) Set $V_1 = 0V$ (or specified value)
- (e) Set V_{CC} and V_{EE} to the specified values.
- (f) The read value of V_M when the SW_1 and SW_2 are in closed state shall be taken as V_{M1} .
- (g) The read value of V_M when the SW_1 and SW_2 are in open state shall be taken as V_{M2} .
- (h) I_{IO} shall be obtained from the following equation:

$$I_{IO} = \frac{R_1}{R_3(R_1 + R_2)} |V_{M2} - V_{M1}|$$

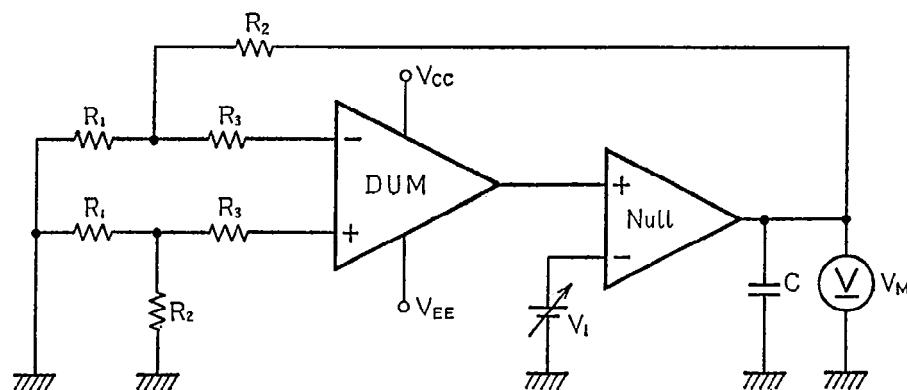
(7) Measuring Conditions to be Specified It shall be as follows:

- (a) Power source voltages V_{CC} and V_{EE}
- (b) R_1 and R_2
- (c) R_3
- (d) V_1 (normally 0 V)
- (e) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (Normally T_a , T_c or $T_{ref} = 25^\circ C$)

4.5.2.4 Input Resistance R_i Measurement of the input resistance by DC method, shall be as follows:

- (1) Purpose The purpose of this measurement is to measure the d.c. resistance between two input terminals of DUM.
- (2) Measuring Circuit It shall conform to Fig. 5 as a rule.

Fig. 5. Measuring Circuit of Input Resistance (DC method)

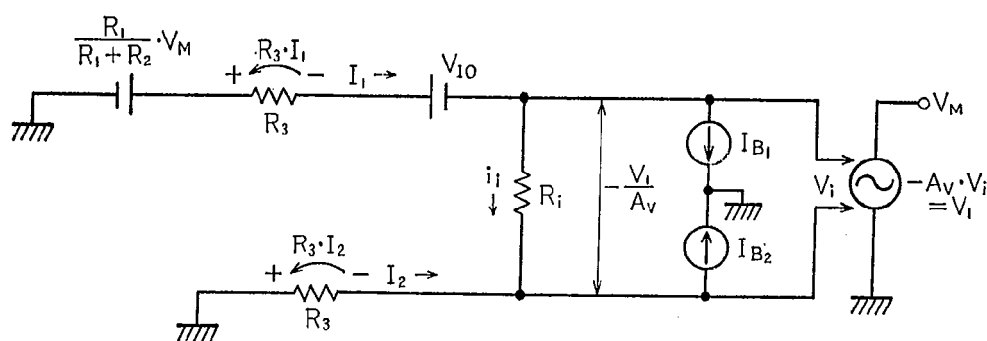


(3) Principle of Measurement The measurement shall be made in the following two operations while the d.c. voltage source V_1 in the measuring circuit of Fig. 5 being varied.

- (a) The V_M when $V_1 = V_{11}$ is read and called as V_{M1} .
- (b) The V_M when $V_1 = V_{12}$ is read and called as V_{M2} .

The output voltages of DUM in both cases are equal to V_1 , and if V_1 is the differential input voltage of DUM and A_v is the voltage gain, $-A_v V_1 = V_1$. On one hand $V_1 = R_i \cdot i_1$. The i_1 and bias current flow towards the input terminal. As generally R_3 is selected $\approx R_1$ in the measurement of R_i , R_1, R_2, R_3 are selected so that $R_1 \cdot R_2 / (R_1 + R_2)$ becomes much smaller than R_3 . In the above case, the equivalent circuit for the measuring circuit becomes as Fig. 5a.

Fig. 5a



$$V_1 = -\frac{V_1}{A_v}, \quad I_1 = I_{B1} - \frac{1}{R_1} \cdot \frac{V_1}{A_v}$$

$$I_2 = I_{B2} + \frac{1}{R_1} \cdot \frac{V_1}{A_v}$$

For $V_1 = V_{11}$

$$\begin{aligned} \frac{R_1}{R_1 + R_2} \cdot V_{M1} &= R_3 \cdot I_1 + V_{10} - \frac{V_{11}}{A_v} - R_3 \cdot I_2 \\ &= R_3(I_{B1} - I_{B2}) + V_{10} - \frac{V_{11}}{A_v} \left(1 + \frac{2 \times R_3}{R_1}\right) \quad \dots\dots\dots(5.1) \end{aligned}$$

For $V_1 = V_{12}$

$$\frac{R_1}{R_1 + R_2} \cdot V_{M2} = R_3(I_{B1} - I_{B2}) + V_{10} - \frac{V_{12}}{A_v} \left(1 + \frac{2 \times R_3}{R_1}\right) \quad \dots\dots\dots(5.2)$$

From Eq. (5.1). (5.2)

$$\frac{R_1}{R_1 + R_2} (V_{M2} - V_{M1}) = -\frac{1}{A_v} \left(1 + \frac{2 \times R_3}{R_1}\right) (V_{11} - V_{12}) \quad \dots\dots\dots(5.3)$$

Therefore

$$R_1 = \frac{\frac{2 \times R_3}{A_v} \cdot \frac{R_1}{R_1 + R_2} (V_{M2} - V_{M1}) - 1}{V_{11} - V_{12}} \quad \dots\dots\dots(5.4)$$

Then, R_1 is obtained from the measured value V_{M1} and V_{M2} i.e. the readings on the output voltage V_M when V_1 is V_{11} and V_{12} respectively, and from the measured value A_v in the circuit of Fig. 11 on other hand.

(4) Explanation and Condition of Circuit

Ratio of R_1 to R_2 shall be selected so that the output voltage V_M will not exceed the linear operation range of Null.

In the measurement of R_1 , R_2/R_1 should be about 1000. R_3 shall be nearly equal to the input resistance R_i of DUM.

$R_1 \cdot R_2 / (R_1 + R_2)$ shall be chosen as very small value compared with R_3 .

D.C. voltage source V_1 is an auxiliary power source to determine the output voltage of DUM. The sign of V_{11} and V_{12} in the said two operations are opposite each other, and the magnitude shall be enlarged to almost equal to the common mode input voltage width of Null.

C is an oscillation preventive capacitor.

Input impedance of the d.c. voltmeter for measuring V_M shall be not less than $1\text{M}\Omega$.

The standard measuring conditions shall be as follows:

$R_1 = 50 \Omega$	Metal film resistor
$R_2 = 50 \text{ k}\Omega$	Metal film resistor
$R_3 = 2 \text{ M}\Omega$	Metal film resistor
$C = 0.1 \mu\text{F}$	High frequency capacitor
$V_{11} = +10 \text{ V}$	
$V_{12} = -10 \text{ V}$	

- (5) Attention Measurement is difficult for DUM of large A_v . The value of R_s shall be $\approx R_i$ if possible, and a high accuracy voltmeter shall be used for measuring V_M .
If the measurement by means of the circuit shown in Fig. 5 is difficult due to too large A_v , the a.c. method (Appendix 3) shall be used.

- (6) Measurement Procedure It shall be as follows:

- (a) R_1 , R_2 and R_3 shall be set to the specified values.
- (b) Specified compensation circuit shall be attached if necessary.
- (c) V_{CC} and V_{EE} shall be set to specified values.
- (d) Read out value of V_M at $V_i = V_{i1}$ (normally +10V) shall be called as V_{M1} .
- (e) Read out value of V_M at $V_i = V_{i2}$ (normally -10V) shall be called as V_{M2} .
- (f) A_v shall be previously obtained from Eq.(10.5) in accordance with the measuring method of A_v .
- (g) R_i shall be obtained from the following equation:

$$R_i = \frac{2 \times R_3}{\frac{A_v}{V_{i1} - V_{i2}} \cdot \frac{R_1}{R_1 + R_2} (V_{M2} - V_{M1}) - 1}$$

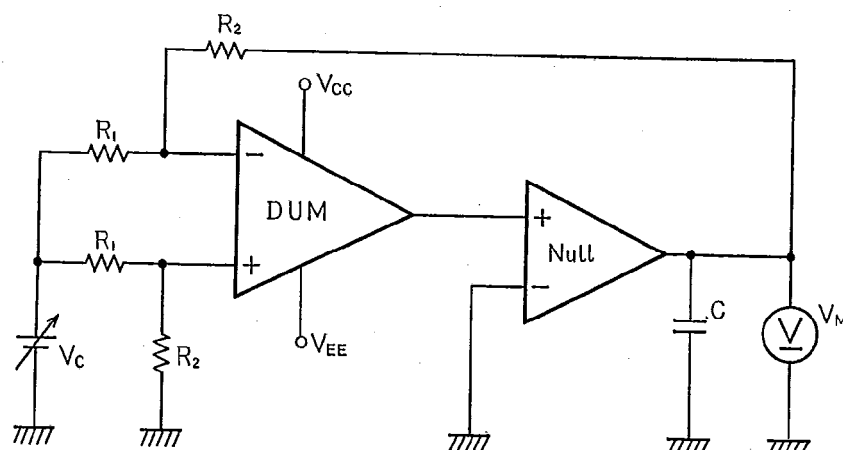
- (7) Measurement Condition to be Specified It shall be as follows:

- (a) Source voltage V_{CC} and V_{EE}
- (b) R_1 , R_2 and R_3
- (c) V_{i1} and V_{i2} (normally +10V and -10V)
- (d) Compensation circuits (if necessary)
- (e) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (normally, T_a , T_c or $T_{ref} = 25^\circ\text{C}$)

4.5.2.5 Common Mode Input Voltage Range V_{ICM} The measurement of common mode input voltage range shall be as follows:

- (1) Purpose The purpose of this measurement is to measure the common mode input voltage range which can apply to input terminals without lowering the common mode rejection ratio below the specified value.
 $V_{ICM}(+)$ in the case of applying the input voltage to positive direction, and $V_{ICM}(-)$ to negative direction shall both be measured.
- (2) Measuring Circuit It shall conform to Fig. 6 as a rule.

Fig. 6. Measuring Circuit of Common Mode Input Voltage Range

(3) Measurement Procedure It shall be as follows:

- (a) R_1 and R_2 shall be set to the specified values.
- (b) Compensation circuit shall be attached if necessary.
- (c) V_{CC} and V_{EE} shall be set to specified values.
The V_M at $V_C = 0$ V is read and called as V_{M0} .
- (d) Read value of V_M shall be V_{M0} at $V_C = 0$ V.
- (e) The V_M at $V_C = V_{C1}$ (Normally $= \frac{1}{2} \cdot V_{CC}$) is read and called as V_{M1} .
- (f) CMR_1 shall be calculated from the following equation:

$$CMR_1 = \left(1 + \frac{R_2}{R_1}\right) \frac{V_{C1}}{V_{M1} - V_{M0}} \quad \dots\dots\dots (6.1)$$

- (g) The V_M at $V_C = V_{C2}$ ($V_{C2} > V_{C1}$) is read and called as V_{M2} .
- (h) CMR_2 shall be calculated from the following equation:

$$CMR_2 = \left(1 + \frac{R_2}{R_1}\right) \frac{V_{C2}}{V_{M2} - V_{M0}} \quad \dots\dots\dots (6.2)$$

- (i) Until $\frac{CMR_1}{CMR_2} = \frac{V_{C1}}{V_{C2}} \cdot \frac{V_{M2} - V_{M0}}{V_{M1} - V_{M0}} \quad \dots\dots\dots (6.3)$

reaches the specified value, V_{C2} shall be increased.
Under the said condition,

$$V_{ICM}(+) = V_{C2} \text{ holds.}$$

- (j) The $V_{ICM}(-)$, is measured by increasing the V_C in (-) direction in accordance with the procedures of (e) to (i).

(4) Measuring Condition to be Specified It shall be as follows:

- (a) Source voltages V_{CC} and V_{EE}

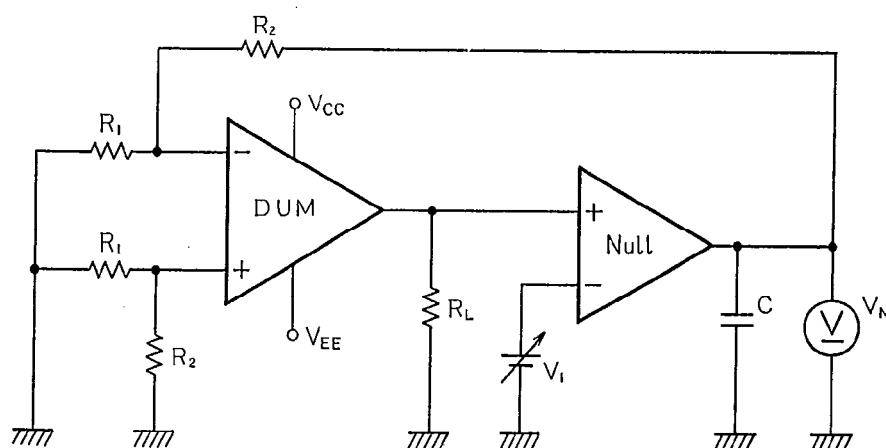
- (b) R_1 and R_2
- (c) Compensation circuit (if necessary)
- (d) V_{Ci} (normally $\frac{1}{2} \cdot V_{CC}$ or $\frac{1}{2} \cdot V_{EE}$.)
- (e) Lowering value of CMR (CMR_i/CMR_o)
- (f) Ambient temperature T_a , case temperature T_c or reference point temperature T_{ref} (normally T_a, T_c or $T_{ref} = 25^\circ\text{C}$.)

4.5.3 Output Characteristics

4.5.3.1 Output Resistance R_o It shall be measured as follows:

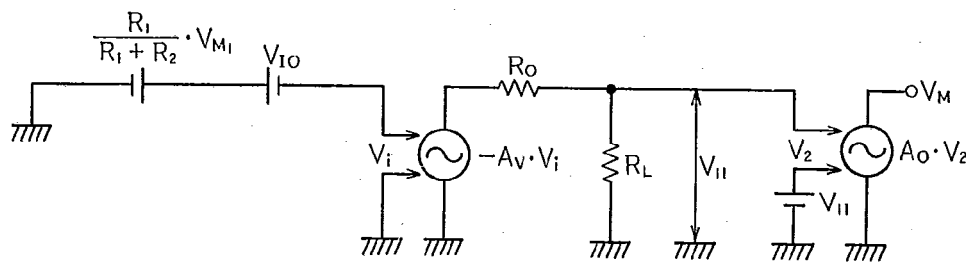
- (1) Purpose The purpose of this measurement is to measure the d.c. output resistance under the specified circuit conditions.
- (2) Measuring Circuit It shall conform to Fig. 7 as a rule.

Fig. 7. Measuring Circuit of Output Resistance



- (3) Principle of Measurement The measurement shall be made in the following two operations where the d.c. source voltage V_1 is set to V_{11} and V_{12} .
 - (a) The V_M at $V_1 = V_{11}$ is read and called as V_{M1} .
 - (b) The V_M at $V_1 = V_{12}$ is read and called as V_{M2} .
Equivalent circuit is shown in Fig. 7a at $V_1 = V_{11}$.
However, the bias current is omitted as it is not effective.

Fig. 7a



R_o : d.c. output resistance of DUM

As $V_2 = 0$

$$-A_v V_i \cdot \frac{R_L}{R_L + R_o} = V_{11} \quad (7.1)$$

Then the differential input voltage V_i of DUM will be

$$V_i = -\frac{V_{11}}{A_v} \cdot \frac{R_o + R_L}{R_L} \quad (7.2)$$

On one hand, as

$$\frac{R_1}{R_1 + R_2} \cdot V_{M1} - V_{10} - V_i = 0$$

Then

$$\frac{R_1}{R_1 + R_2} \cdot V_{M1} = V_{10} - \frac{V_{11}}{A_v} \cdot \frac{R_o + R_L}{R_L} \quad (7.3)$$

And same as above at $V_i = V_{12}$,

$$\frac{R_1}{R_1 + R_2} \cdot V_{M2} = V_{10} - \frac{V_{12}}{A_v} \cdot \frac{R_o + R_L}{R_L} \quad (7.4)$$

From Eqs. (7.3) and (7.4)

$$\frac{R_1}{R_1 + R_2} (V_{M2} - V_{M1}) = \frac{V_{11} - V_{12}}{A_v} \cdot \frac{R_o + R_L}{R_L}$$

Therefore

$$R_o = R_L \left[\frac{V_{M2} - V_{M1}}{V_{11} - V_{12}} \cdot \frac{R_1}{R_1 + R_2} \cdot A_v - 1 \right] \quad (7.5)$$

Here, A_v is the open loop voltage gain, and R_o can be measured using the value of A_v obtained from Eq (10.5) in the measuring method of 4.5.4.1.