
**User's
Manual**

**2752
Precision Double Bridge**

IM 2752-01E

Introduction

Thank you for purchasing our Precision double bridge.

This manual describes the specifications and handling precautions of the Precision double bridge.

Before using this product, thoroughly read this manual to understand how to use it properly.

Contact information of Yokogawa offices worldwide is provided on the following sheet.

PIM 113-01Z2: Inquiries List of worldwide contacts

Notice regarding This User's Manual

- The information covered in this User's manual is subject to change without prior notice.
- Every effort has been made to ensure accuracy in the preparation of this manual.
Should any errors or omissions come to your attention however, please inform YOKOGAWA accordingly.
- YOKOGAWA is by no means liable for any damage resulting from the user's mishandling of the product.
- This manual is intended to describe the functions of this product.
YOKOGAWA does not guarantee that these functions are suited to the particular purpose of the user.

Cautionary Notes for Safe Use of the Product

When operating the instrument, be sure to observe the cautionary notes given below to ensure correct and safe use of the instrument.

If you use the instrument in any way other than as instructed in this manual, the instrument's protective measures may be impaired.

This manual is an essential part of the product; keep it a safe place for future reference.

YOKOGAWA is by no means liable for any damage resulting from use of the instrument in contradiction to these cautionary notes.

■ The following safety symbols are used on the instrument and in the manual:



Danger! Handle with Care.

This mark indicates that operator must refer to an explanation in the instruction manual in order to avoid risk of injury or death of personnel or damage to the instrument.



This mark indicates earth (ground).

■ Since mishandling the instrument can result in an accident that may lead to injury or death of the operator, such as an electric shock, be sure to observe the following instructions.

WARNING

● Protective Measures

- If a crack appears in the instrument after it has been accidentally dropped or bumped, the safety-purpose insulation may be damaged.
By all means do not use the instrument, but ask the manufacture for repair.

● Connection

- To avoid electric shock, be sure to apply protective grounding to the grounding terminal.
- Install a protection fuse as shown in the example of measurement.

● Measurement

- Always maintain the instrument within the limits for allowable current, voltage and power, during operation.
If there is more than one limit for any of these parameters, the lowest limit takes precedence.

● External Power Supply

- Only operate the instrument on a supply voltage no greater than 60 VDC.

● Operating Environment

- Do not operate the instrument in a flammable or explosive gas atmosphere.
- Do not operate the instrument if there is any condensation on it.

● Do Not Remove the Case or Disassemble

- Do not open the case except when replacing batteries.
Only Yokogawa service personnel are authorized to remove the casing or disassemble or modify the instrument.
Do not attempt to repair the instrument yourself, as doing so is extremely dangerous.
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1. GENERAL

This equipment is a precision DC low resistance measuring instrument which is designed for precise measurement of values under 100 Ω .

This instrument uses resistance wire made of choice material aged for a long period of time. In addition, special consideration is taken in locating guards which are firmly enclosed in the metallic casing, so that they can be stably used for a long period of time. Detailed five-figure readings are available with six built-in standard resistors, three decade dials, and slide resistance. The in-line decade indication system is employed to express resistance values, insuring rapid reading.

This instrument can be used also for measurement of electric conductivity of a conductor and calibration of a resistance standard, as well as for precision measurement of general resistances.

In addition, is designed for use in combination with accessories for large-capacity shunt checks and measurement of bar conductor resistance.

2. SPECIFICATIONS

Measuring range: 0.10000 mΩ abs to 111.10 Ω abs
(Effective up to five digits)
(Ω abs: Absolute ohms)

Measuring Arm (at multiplier × 1):

| | |
|----------|------------------------------------------------------------------------------------|
| 1st dial | 100 mΩ × 10 |
| 2nd dial | 10 mΩ × 10 |
| 3rd dial | 1 mΩ × 10 |
| 4th dial | 0.05 mΩ to 1.05 mΩ (continuously variable) (Minimum scale division: 0.01 mΩ) |

Multiplier:

× 100, × 10, × 1, × 0.1, × 0.01, and × 0.001

Accuracy:

±(0.03% of reading + 1 μΩ)

with ambient temperature of 23 ± 2.5°C

±(0.05% of reading + 1 μΩ)

with ambient temperature of 10 to 40°C

The lead resistance between C₂ terminal and Rx is less than 10 mΩ.

Current Rating of standard resistance:

| | |
|---------------|---------------|
| × 100: 0.05 A | × 0.1: 3 A |
| × 10: 0.15 A | × 0.01: 10 A |
| × 1: 0.5 A | × 0.001: 30 A |

Dimensions:

Approx. 316 × 497 × 140 mm (not including rubber feet)

Note: Standard rack mounting is available.

Insulation resistance: 100 MΩ or more at 500 VDC
between the case and the circuit

Weight: Approximately 11.5 kg

Accessories: Two Plugs, User's manual

Accessories (Available upon request)

(1) Measuring cords (2753)

Current cord (two): 2 m long,
resistance value: approx. 3 m Ω

Voltage cord (two): 2 m long,
resistance value: approx. 8 m Ω

(A clamp fitting is attached to the end of each cord.)

(2) Clamp device (2754)

Effective measuring length of sample: 500 mm
(Distance between voltage terminals)

Maximum diameter of sample: 25 mm

Minimum length of sample: 650 mm

Current cord (two): 500 mm long,
resistance value: approx. 1 m Ω

Voltage cord (two): 500 mm long,
resistance value: approx. 2.5 m Ω

3. COMPONENT NAMES AND FUNCTIONS

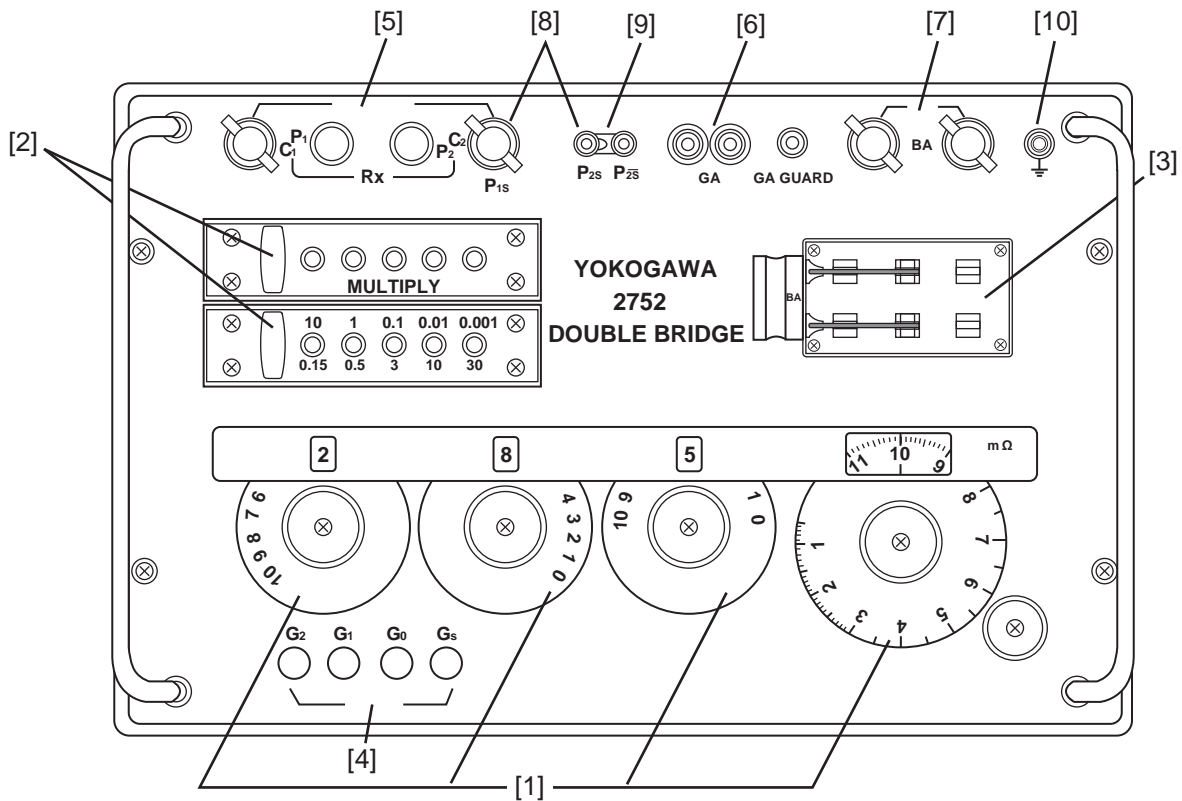


Fig. 3.1 Front Panel

Fig. 3.1 shows dial and terminal arrangement of this instrument.

[1] DIALS: I, II, III, IV

for use in adjustment of measuring arms

[2] MULTIPLYING FACTOR SWITCH PLUG:

to changeover the multiplying factors, by replacing two plugs at the same time.

[3] BA KNIFE SWITCH:

to be used as ON – OFF, or to reverse the circuit current

[4] GALVANOMETER BUTTON SWITCH:

to select sensitivity; on G₂ or G₁ or C₀ gives the highest sensitivity, and G₁ is more sensitive than G₂.

The use of G_s is to short circuit the galvanometer.

These G switches are clamped by turning them clockwise or counter-clockwise, after pushing them down.

[5] Rx TERMINAL:

consisting of C₁, C₂, P₁, P₂ terminals, for the connection to an unknown resistance.

[6] GA TERMINAL:

for the connection to the galvanometer.

[7] BA TERMINAL:

for the connection to the DC Power source (Battery).

[8] P_{2s} – P_{2s̄} and P_{1s} TERMINAL:

These are the potential terminals to be used for the connection external standard resistance.

[9] P_{2s} and P_{2s̄} TERMINAL:

for the connection to the compensation resistance (ΔM)

[10] EARTH TERMINAL:

being connected to the panel.

4. ACCESSORY COMPONENTS

The following accessories are required for the operation of 2752.

4.1 Galvanometer (Null-Detector)

The galvanometer should have high sensitivity and a stable "0" position.

Sensitivity of the galvanometer depends upon the amount of unknown resistance and current flowing through this unknown resistance.

For this, refer to Table 4.2 below.

The 2709 DC Electronic Galvanometer of its sensitivity of 0.2 μV is recommended for use.

When measuring resistance for a larger range than $\times 1$, the handy Electronic Galvanometer 2707 is recommended.

| Item \ Model | 2707 | 2709 |
|---------------------|------------------------------------|------------------------------------|
| Sensitivity | $10 \times 10^{-6} \text{ V/div.}$ | $2 \times 10^{-10} \text{ A/div.}$ |
| Internal Resistance | 9 k Ω | 1 k Ω |
| Period | 3 sec. | 0.5 sec. |

Table 4.1

Note:

Model 2707 and 2709 have been discontinued.

4.2 Battery and Current Adjusting Resistor

The capacity of the battery depends on the resistance value of an unknown resistance, however, its capacity is required to be, in general, more than 20 Ah at the voltage 2 V to 4 V. A battery having large capacity is needed particularly for the measurement of low resistance at heavy current. A slide resistor may often become useful.

It is connected in series to the battery for the control on the circuit current.

YOKOGAWA provides a group of slide resistors. The 2791 for such uses.

They are supplied in: 4.7 Ω (6 A max.), 10 Ω (4 A max.), 39 Ω (2 A max.).

For current monitoring, 2012 DC volt-ammeter (class 0.5) or 2051 (miniature DC ammeter (0.3 to 30 A, class 1.0) are recommended.

Table 4.2 shows the approximate current by which 1/10000 of unknown resistance change can be detected with deflection of more than one scale division when this instrument is used with a galvanometer.

Note:

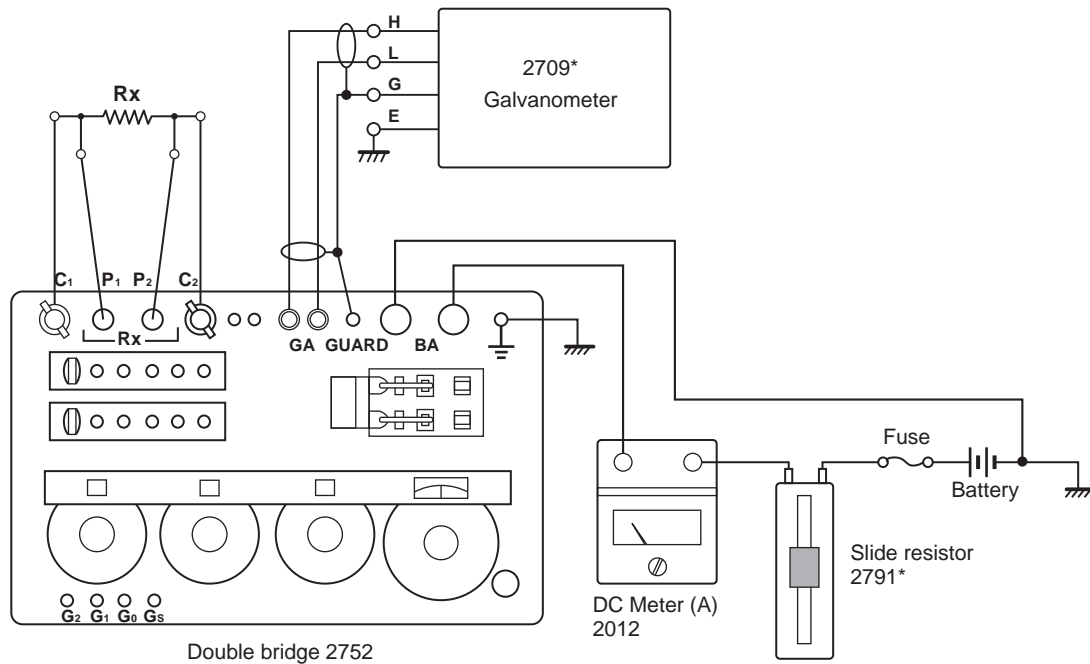
Model 2791 and 2709 have been discontinued.

| Unknown resistance (Ω) | Magnification | Current Value (A) | | Current Rating with 2752 |
|---------------------------------|----------------|-------------------|---------|--------------------------|
| | | 2708 | 2709 | |
| 100 | $\times 100$ | 0.0022 | 0.00008 | 0.05 |
| 10 | $\times 100$ | 0.011 | 0.00026 | 0.05 |
| 10 | $\times 10$ | 0.022 | 0.0008 | 0.15 |
| 1 | $\times 10$ | 0.11 | 0.0026 | 0.15 |
| 1 | $\times 1$ | 0.22 | 0.008 | 0.5 |
| 0.1 | $\times 1$ | (1.1) | 0.026 | 0.5 |
| 0.1 | $\times 0.1$ | 2.2 | 0.08 | 3 |
| 0.01 | $\times 0.1$ | | 0.26 | 3 |
| 0.01 | $\times 0.01$ | | 0.8 | 10 |
| 0.001 | $\times 0.01$ | | 2.6 | 10 |
| 0.001 | $\times 0.001$ | | 8 | 30 |
| 0.0001 | $\times 0.001$ | | 26 | 30 |

Table 4.2
Relationship of Measuring Sensitivity and Current

5. HANDLING

This instrument and accessories should be correctly connected in accordance with the diagram shown in Fig. 5.1 and the following instructions.



*: Model 2709 and 2791 have been discontinued.

Fig. 5.1 Connecting Diagram

5.1 Preparation

5.1.1 Connection for Battery

- (1) Capacity of the leads to be used for this connection should be large enough to sustain heavy current flow.
It is desirable for the leads to be of copper with the diameter about 3.6 mm or equivalent covered with suitable insulation material.
- (2) The battery should have a fuse.
- (3) Try to make use of an ammeter to check over-current flow in a measuring object.
Be careful not to overload the battery.
- (4) Put the leads together.
This will minimize the forming of magnetic field around them.

5.1.2 Connection for Galvanometer

- (1) When using the Electronic Galvanometer, 2709
 - (a) Warm up for several minutes.
 - (b) Use the attached low thermoelectromotive force type cord as the input cord, avoiding the effects of thermoelectromotive force.
 - (c) Equip the input cord with a guard to prevent DC leakage.
Ground the ground terminal of the galvanometer case in order to eliminate induction by commercial power.
 - (d) When installing this galvanometer, no special care is needed since design isolates the effects of vibration.
 - (e) For details, refer to the user's manual for 2709 Electronic Galvanometer.

5.1.3 Connection for Unknown Resistance

- (1) As shown in the Fig. 5.1, four pieces leads are used.
An unknown resistance is measured between the terminals P_1 and P_2 through leads which should be connected at its most reasonable points.
- (2) The leads to the current terminals C_1 and C_2 should have enough current capacity, particularly the resistance of the lead to C_2 must be sufficient enough for low where the resistance value should be less than (1 × each of the multiplying factors) ohms.
- (3) Since the difference in resistance between the two leads of the potential terminals P_1 and P_2 makes the error in the measuring arms, the value of resistance of the leads should be less than 10 mΩ or compensated by any reasonable means. The value of the resistance in each of the leads should be balanced before-hand.
- (4) YOKOGAWA provides the following leads designed for the use in the connection between an unknown resistance and the bridge.

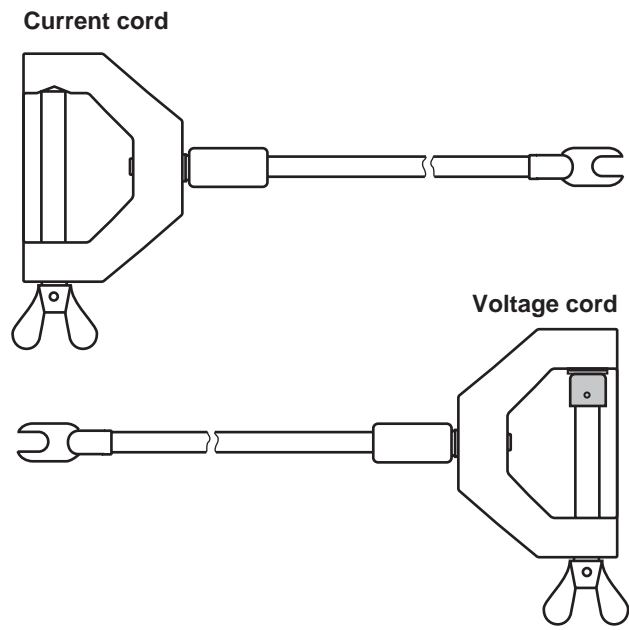


Fig. 5.2 2753 Measuring Cords

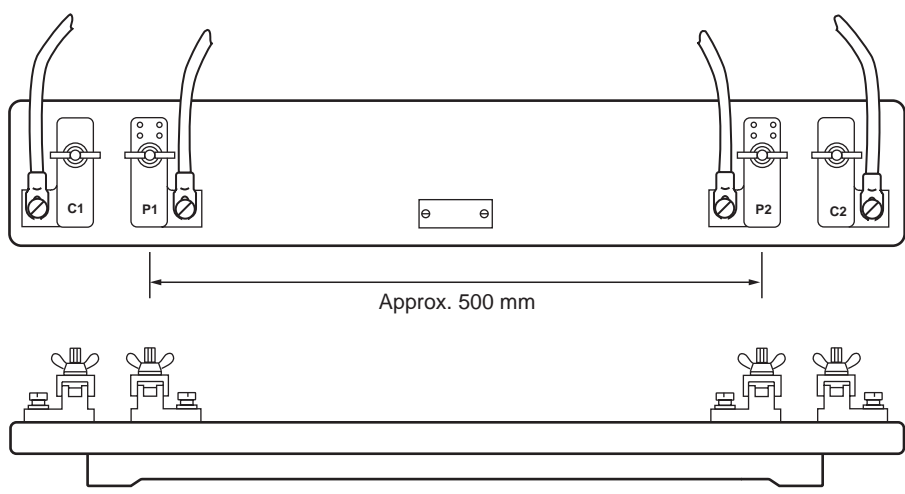


Fig. 5.3 2754 Clamp and Connecting Cords

5.1.4 Connection for External Standard Resistor

Use the terminals P_{1s} and P_{2s} , $P_{2\bar{s}}$ as shown in Fig.5.4 when a range of measurement exceeds the current capacity of the self-contained standard resistor or the measurement of the ratio against a certain standard resistor.

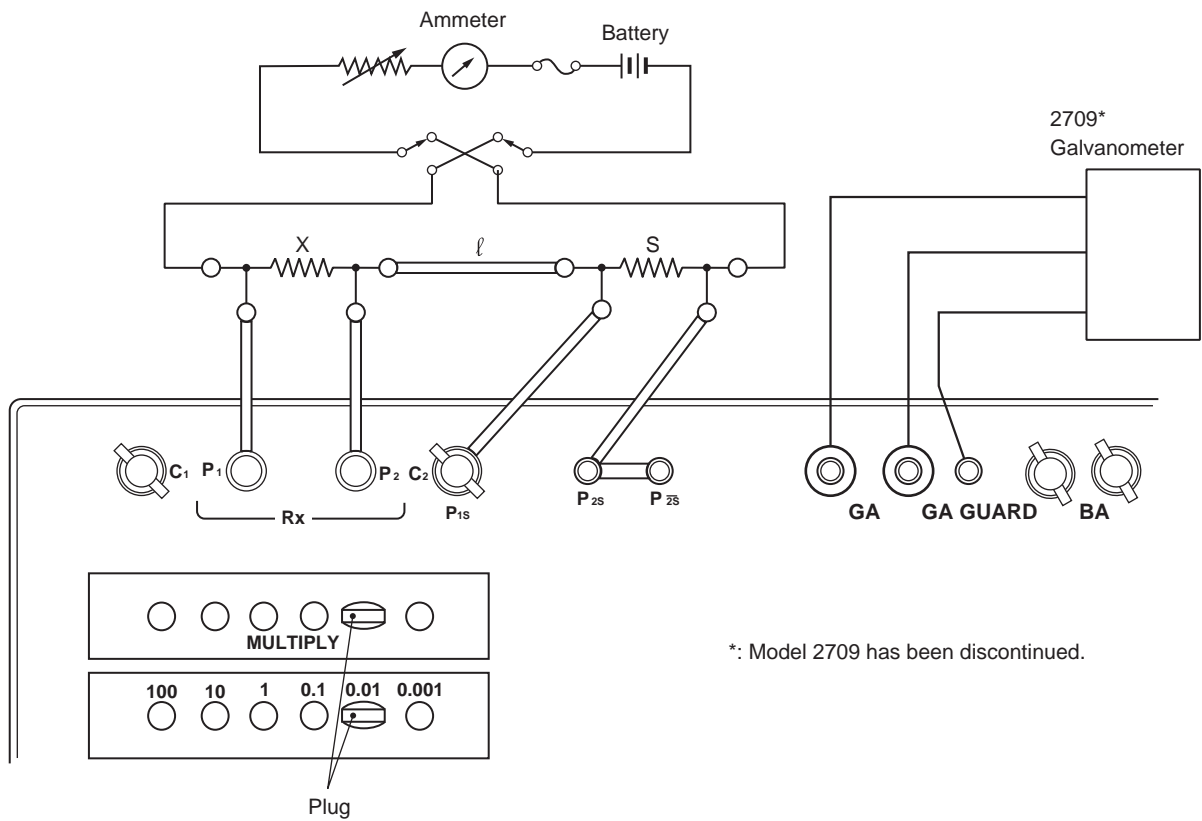


Fig. 5.4
Connection for External Standard Resistance

For this connection, the same care should be taken as described in Paragraph 5.1.3. The lead connecting an unknown resistance and the standard resistance marked l in the Fig. 5.4 is desirable to be short, and the lead resistance must be small than standard resistance. Try to wire it as short as possible.

When using an external standard resistor, pull out the (multiplying) plug from "MULTIPLY" side and put it into any position on the other (lower) side.

5.1.5 Grounding

The terminal G is to be first connected to the common side of the battery then it is grounded. For 2752 Precision Double Bridge, the value of resistance of each of the bridge components are made low enough and good insulating materials are used.

Therefore, the leakage current to the bridge can be negligible.

In case any leakage current to the galvanometer is observed, place the galvanometer on a plate of conductor, to which the ground terminal is connected.

5.2 Operation

- (1) Press and lock the short switch "Gs" of the galvanometer.
- (2) Locate the "KNIFE SWITCH" at neutral position.
Put the plug into a jack of the multiplying factors according to the range of measurement.
- (3) Connect the battery and turn the "KNIFE SWITCH" to the right or left to switch on and give a flow of a desired value of current, monitoring with the ammeter.
Note that in the measurement at a relatively heavy current, start with smaller current value and get a rough balance, then increase the current by steps to reach the planned current.
This process will protect the instruments or a measuring object from damage.
- (4) Unlock the switch "Gs" and turn the Dial I ($\times 0.1$ ohm), then proceed to Dials II and III and IV in order, as switching on or off the switch G_2 , to balance the zero indication on the galvanometer.
In the same process, proceed zero balancing at G_1 and G_0 to a higher range of sensitivity.

- (5) The measured value R_1 in the above process shall be expressed in the equation:

$$R_1 = (\text{the total indications read on the measuring dials}) \times (\text{multiplying factor})$$

Then, turn the KNIFE SWITCH to the other side to reverse the current and get the balance in the same manner as described in the sub-clause (4) above.

The measured value R_2 shall be the mean value of R_1 and R_2

$$(R_1 + R_2) \times 1/2$$

- (6) In case using a external standard resistor of S ohms, the measured value R_1 shall be

$$R_1 = S \times (\text{the total indications read on the measuring dials})$$

In order to remove the influence of thermo emf reverse the current by turning the knife switch in the manner as said in the sub-clause (5) above, where the mean value of R_1 and R_2 shall be considered as the measured value.

- (7) When having finished the measurement, place back the knife switch at neutral point to cut off the current and loosen the plug of the multiplying factor selection.

6. MAINTENANCE

6.1 Precaution for handling

- (1) The plug of the multiplying factor selection is required to be tightly inserted into the plug-in hole when taking measurements, but when being not used, it should be loosen.

- (2) Turn around the measuring dials thoroughly beforehand.
This will make its contact better conductive.
When turn the dial IV, please turn it gently especially because the dial IV belt is made of fragile poly urethane. (belt is spare part.)
If the bridge is used after a long interval of time, it is necessary to clean the contact surface of the plug switch and slide resistors with clean soft cloth.
Use care in cleaning the slide resistors.
Do not change slide resistor brush pressure. (Do not use sandpaper on the brush surface.)

- (3) The galvanometer switches G_2 , G_1 , G_0 should be used in order from G_2 , G_1 and G_0 .
If G_0 be first switched, heavy current will flow in the galvanometer and it may damage the instrument.

- (4) In case of a precision measurement using a highly sensitive galvanometer, it is required from the operator not to touch the galvanometer switch for long time, least the human heat should be conveyed to the galvanometer circuit causing the effect of the thermo emf.
The ideal temperature for the measuring room shall be at $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$.
Avoid to take a measurement by the side of windows where the temperature may often be most changeable.

- (5) The current flowing in the self-contained standard resistor should be kept within the rated value engraved on the plug board.
The temperature rise at the continuous rated current shall be about 10 deg. C.
As shown in Fig. 7.2 the resistors are of selected quality, which has less temperature co-efficient and made under careful heat treatment and aging.
This assure stability in measurements.

In case of the measurement where the temperature co-efficient can not be negligible, for instance, at $\pm 0.01\%$ with the limit of repeatability, get the balances by steps as described in Para. 5.2. (3).
The measurements at a heavy current should be made in a shortest possible time and, as soon as finished the measurement, reduce the current and avoid the temperature rise both in measuring object at the standard resistance.

If the measurement can be finished in a very short time (2 or 3 minutes) at the multiplying factor $\times 0.01$ or $\times 0.001$, the current may be increased to about the value 1.4 times as much as the rated value or twice as much in the value or power.

- (6) An unknown resistance generally has a large temperature co-efficient in comparison to the measuring accuracy of this bridge.

For instance, in copper wire it changes about 0.4% at 1 deg. C, change of temperature. Therefore, the current flow in the measuring object causes temperature rise of the object and varies its resistance value.

Note that this will mark the balancing difficult. (Refer to the Para. 5.2 (3).)

- (7) The breaking capacity of the knife switch is 30 amperes.
Reduce the value of current before changing the switch.

6.2 Inspection

The following inspections should be made periodically (at least once par year).

6.2.1 Preliminary inspection

- (1) Check external parts such as dials, nameplate, terminals, plugs, knife switch, and galvanometer sensitivity switch.
- (2) Check the dial switch, battery switch, and plug for proper contact.

6.2.2 Inspection of standard resistors (R11 to R16)

As shown in Fig. 6.1, measure the 4-terminal resistor consisting of C₂ and BA (current terminals) and P_{1S} and P_{2S} (voltage terminals) with a double bridge or potentiometer, making sure that the value is within the specified tolerance range ($\pm 0.02\%$) as compared to the standard resistor (Standard Resistors 2792A or 2792 are recommended).

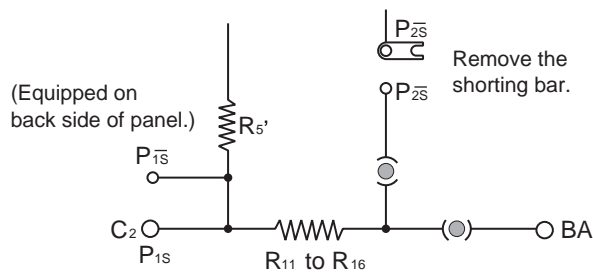


Fig. 6.1

In this case, current flow should be one-third of the value described on the plug board.

6.2.3 Overall inspection

In each range, connect the standard resistor to Rx and measure the resistance value, thus checking overall performance.

Insure that the condition satisfies specifications.

7. CIRCUIT PRINCIPLE

7.1 Basic Principle

The circuit principle of the double bridge is given in Fig. 7.1.

If the current flowing through the galvanometer G becomes zero by adjusting the resistance N and n , the unknown resistance X is expressed in the equation (7.1) where ℓ represents the resistance of the lead across the terminals P_s of S and P_x of X .

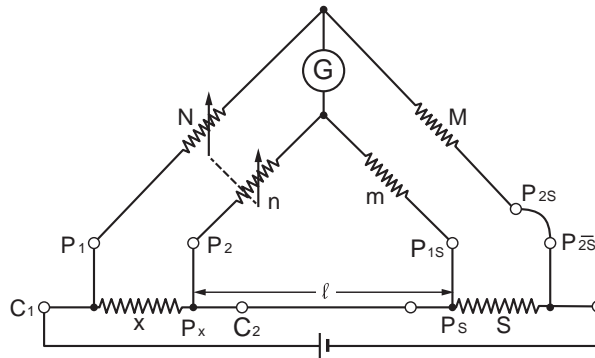


Fig. 7.1 Principle Circuit

$$X = \frac{N}{M} S + \frac{m \cdot \ell}{m + n + \ell} \left(\frac{N}{M} - \frac{n}{m} \right) \quad \dots\dots (7.1)$$

In this double bridge, the resistance arms N and n are equally variable by means of interlocked dial, and the relation between N , n and M , m are made to be

$$N = n \text{ and } M = m,$$

then

$$\frac{N}{M} - \frac{n}{m} = 0 \quad \dots\dots (7.2)$$

therefore, the equation (7.1) leads

$$X = \frac{N}{M} S \quad \dots\dots (7.3)$$

It is thus possible to measure "X" (low resistance) precisely without being affected by " ℓ " (resistance of leads).

An unknown resistance X can be read on the N arm dial at the multiplying factor determined from the ratio of the resistance M against the standard resistance S as $\frac{S}{M}$.

7.2 Error

7.2.1 Error due to current lead resistance

In a practical circuit, the equation (7.2) does not become zero, but shall be about 10^{-4} to 10^{-5} , even though in such a highly accurate bridge as 2752.

For example, $m = n$, ($m = 1000$ ohms, $n = 1000$ to 100 ohms) and $\ell \ll (m + n)$.

Then the equation (7.1) shall be

$$\frac{m \cdot \ell}{m + n + \ell} \left(\frac{N}{M} - \frac{n}{m} \right) \doteq \frac{m}{m + n} \cdot \ell \left(\frac{N}{M} - \frac{n}{m} \right) = \pm 0.5 \ell \times 10^{-4} \dots (7.4)$$

If $\ell = 0.1$ ohm, the equation (7.4) shall become $\pm 0.5 \times 10^{-5}$ ohms and if $S = 10^{-3}$ ohms, (7.1) shall be

$$X = \left(\frac{1000}{1000} \times 10^{-3} \right) \pm 0.5 \times 10^{-5} \text{ ohms}$$

Thus, the error is 0.5% against the reading on the dial.

This means that if the value of $\frac{\ell}{S}$ is large, the error shall become

large accordingly, regardless how shall the value $\left(\frac{N}{M} - \frac{n}{m} \right)$ may be.

Therefore, care should be taken to the value of ℓ .

The resistance in the part of ℓ corresponding to the distance between P_1 and C_2 in this bridge is designed to be nearly zero.

Therefore, the resistance of the lead from C_2 to P_x may be considered as ℓ .

7.2.2 Error due to potential lead

In this bridge, the arms M , m , N , n are determined in the range of resistance 1000 ohms and 100 ohms, so that the influence from lead resistance can be negligible in ordinary measurements.

However, if the lead resistance is too large to neglect, the lead resistance connected the terminals P_1 and P_2 becomes the error of the arms M and N .

While, the values of the arms M and N are only influential upon the measuring result in the form of the ratio $\frac{N}{M}$.

Therefore, if there is a resistance ΔN in N , the addition of a resistance ΔM to M can offset the side influence.

$$X = \frac{(N + \Delta N)}{(M + \Delta M)} S \doteq \frac{N}{M} S \left(1 + \frac{\Delta N}{N} \right) \left(1 - \frac{\Delta M}{M} \right) = \frac{N}{M} S \left(1 + \frac{\Delta N}{N} - \frac{\Delta M}{M} \right)$$

on condition that,

$$\frac{\Delta N}{N} \ll 1, \quad \frac{\Delta M}{M} \ll 1, \quad \dots \dots (7.5)$$

The 2752 provides the terminals P_{2s} and $P_{\bar{2s}}$ for this purpose.

The resistance corresponding to the value ΔM can be connected between P_{2s} and $P_{\bar{2s}}$ in place of the short bar.

The relation between ΔM and ΔN to minimize such error is introduced from the equation (7.5) as follows:

$$\frac{\Delta M}{M} = \frac{\Delta N}{N}$$

Usually, the ΔM is less than 0.1 ohm and it is difficult to be replaced with a variable resistor. In practice the same sort of lead as ΔN is recommendable to put to use as ΔM , where the length of M is adjusted to an appropriate amount.

There is no terminals provided for the arms m and n as in the case of M and N, however, the lead resistance can be negligible if the value of l is made less than S. The influence of the lead resistance Δm and Δn has relation to the equation (7.1) as described in Para. 7.2.1.

7.2.3 Error of standard resistor

YOKOGAWA manufactures the standard resistor under a strict quality control, since such resistance give influences direct upon errors in measurement.

The quality of manganin to be used as the resistance material is of AA class prescribed in Japanese Industrial Standard, JIS 2522, or of even better than standard.

The tolerance of its resistance error at 20°C is made to be within 0.02%.

One of the most importance point to note for the use of this bridge is the change of resistance by temperature rise.

Follow Para. 6.1 (5) again for an accurate measurement.

Fig.7.2 shows a typical example of temperature characteristics for manganin resistor used in this bridge.

Accuracy of this resistor is largely depended on the temperature coefficient.

The extent of accuracy drop may be assumed from the example shown in Fig.7.2.

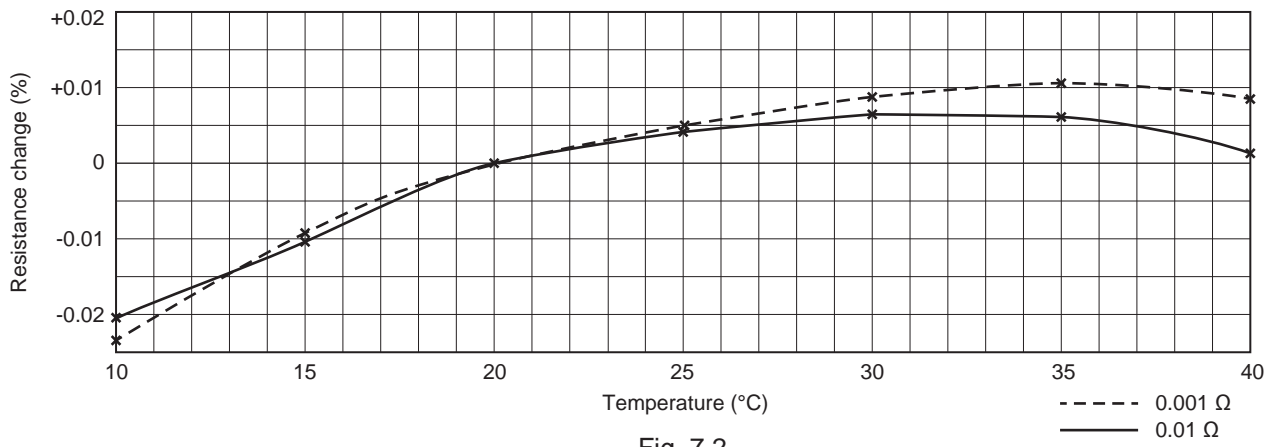
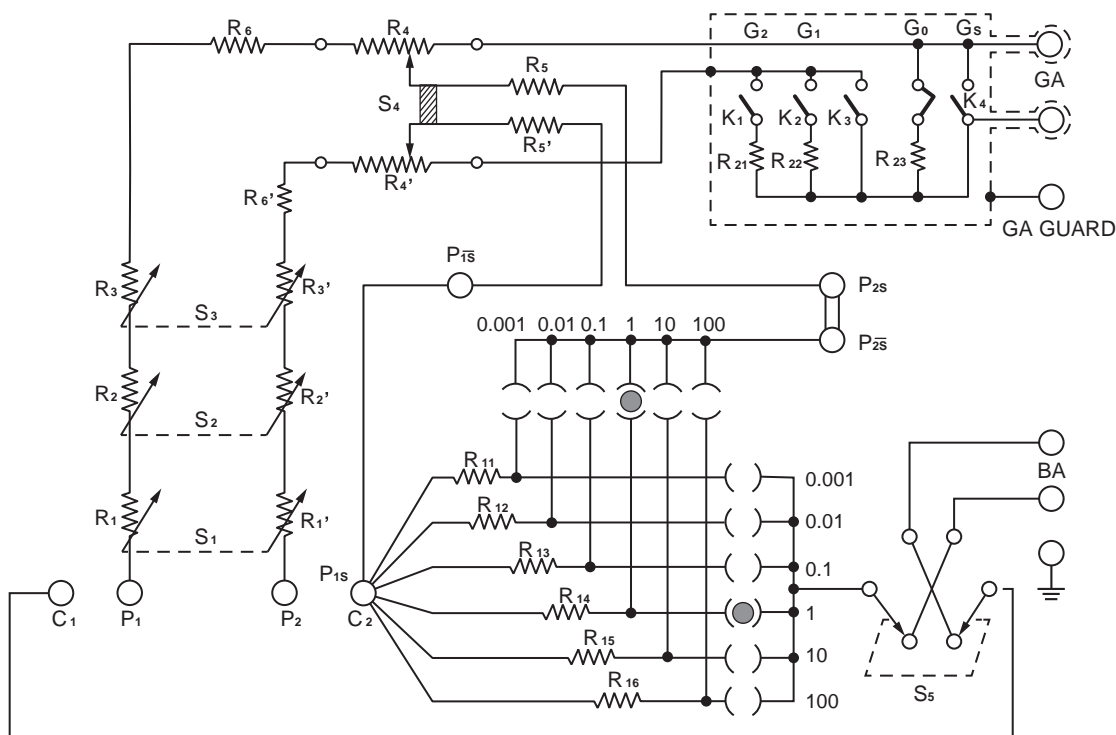
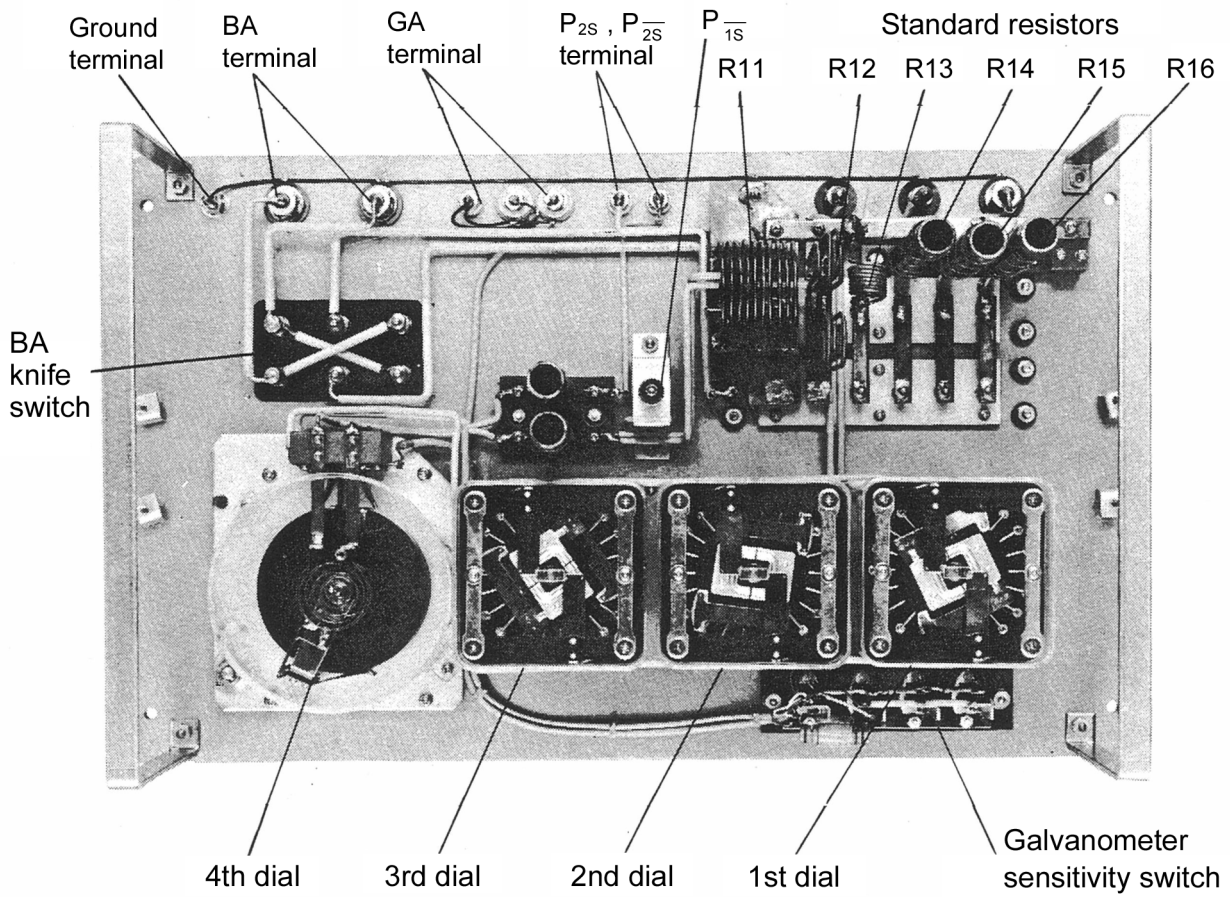


Fig. 7.2
 Typical Example of Temperature Characteristics for
 Built-in Standard Resistor

8. CIRCUIT DIAGRAM



| | | | |
|------------|--------------------------------|----|----------------------------------------|
| R1, R1' | Resistor: 1st dial (element) | S1 | Switch: Rotary 1 |
| R2, R2' | Resistor: 2nd dial (element) | S2 | Switch: Rotary 2 |
| R3, R3' | Resistor: 3rd dial (element) | S3 | Switch: Rotary 3 |
| R4, R4' | Resistor: 4th dial (element) | S4 | Switch: Rotary 4 |
| R5, R5' | Resistor | S5 | Switch: Knife (Battery) |
| R6, R6' | Adjusting resistor | K1 | Switch : Push button (G ₂) |
| R11 to R16 | Resistor | K2 | Switch : Push button (G ₁) |
| R21 to R23 | Resistor (for Galvanometer) | K3 | Switch : Push button (G ₀) |
| | | K4 | Switch : Push button (G _s) |



Internal Construction of 2752 Double Bridge

