User's Manual

2769
Portable Double Bridge

YOKOGAWA ◆

Yokogawa Test & Measurement Corporation

Introduction

Thank you for purchasing the 2769 Portable Double Bridge.

This User's manual contains useful information regarding the instrument's functions and operating procedures, as well as precautions that should be observed during use.

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 Document and 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. 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 this 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.

■ **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 or fuse.
    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.

■ **Since mishandling the instrument can result in an accident, such as an electric shock, that may injure the operator or damage the instrument, be sure to observe the following instructions.**

⚠ CAUTION

● **Batteries**

• Do not use a mixture of different types of batteries or a mixture of old and new batteries.
If the instrument will not be used for a prolonged period, remove the batteries before storage.
The battery fluid will leak more readily during long-term storage, resulting in an instrument malfunction.

CONTENTS

1. GENERAL

The Portable Double Bridge 2769 is quite convenient with low resistance measurement from
1 mΩ to 110 Ω.
This double bridge contains an electronic galvanometer and bridge power supply to
facilitate the operation.

2. SPECIFICATIONS

Measuring Range: 0.100 mΩ to 110.0 Ω

Accuracy: $\pm$ { 0.05 Ω × (multiplaying factor) + 0.01 mΩ }
at ambient temperature 5 to 35°C, and
the lead resistance between C_2 terminals and Rx is less than 20 mΩ.

Measuring Dial: 1.00 to 11.00 Ω, 0.05 Ω minimum division

Multiply	Measuring range	Standard Resistor		
		Resistance	Accuracy	Max. current
0.0001 *	0.1Ω mΩ to 1.1 mΩ	0.01 Ω	±0.1%	10 A
0.001	1 mΩ to 11 mΩ	0.1 Ω	±0.1%	3 A
0.01	0.01 Ω to 0.11 Ω	1 Ω	±0.1%	1 A
0.1	0.1 Ω to 1.1 Ω	10 Ω	±0.1%	0.3 A
1	1 Ω to 11 Ω	100 Ω	±0.1%	0.1 A
10	10 Ω to 110 Ω	1000 Ω	±0.1%	0.01 A

* with an external STANDARD RESISTOR 2771

Table 2.1   Multiply v.s. Standard Resistor

Electronic Galvanometer

    Voltage sensitivity: approx. 20 µV/div.

    Input resistance: approx. 11 kΩ

    Sensitivity dial:

        G_0 (input resistance: approx. 11 kΩ)

$$G_1 = \frac{1}{11} \ G_0 \ \text{(input resistance: approx.11 kΩ)}$$

$$G_2 = \frac{1}{110} \ G_0 \ \text{(input resistance: approx.11 kΩ)}$$

        GA, OFF and B check

    Power source: 9 V (dry cell Type 006P)

        Battery life: approx. 300 h

Bridge Power Source

    Voltage: 1.5 V

        (dry cell UM-1 or SUM-1, two cell are parallel connected.)

    Max. current supply: approx. 1 to 2 A

    Battery life: more than 1200 measurement

        (50% duty cycle, 15 sec maximum on-time)

Operating Temperature and Humidity Range:

        5 to 35°C, Less than 85%

Dimensions: Approx. 182 × 226 × 118 mm (excluding handle and rubber feet.)

        Approx. 196 × 226 × 130 mm (including handle and rubber feet.)

Weight: Approx. 2.6 kg (5.7lbs)

Accessories: Plug (A1025WX)

        User's Manual

        Carrying case (B9350AW)

Optional accessories: Standard Resistor 277100

        (0.01 Ω ±0.1%, with three leadwires)

        Approx. 30 × 175 × 63 mm

        Approx. 0.25 kg

3. COMPONENT NAMES AND FUNCTIONS

Front Panel

Fig. 3.1   Front Panel

[1] Measuring Dial

This dial is used to adjust the measuring arm.

[2] Multiplying Factor Switching Plug

The multiplying factor is selected by this plug.

[3] Battery Switch

This switch turns on/off the power to the bridge.

[4] Galvanometer Button Switch

The galvanometer is connected to the bridge by depressing this switch.
This switch is locked by turning it clockwise or counterclockwise while keeping it depressed.

[5] Galvanometer Sensitivity Dial

The galvanometer sensitivity is selected by this dial;
G_0 gives the highest sensitivity, G_1 is medium, and G_2 is lower than G_1.
With this switch, the galvanometer driving battery can be checked through observing the meter.
When the pointer is deflected to the blue zone, this shows that the battery is good.
Also, this switch turns on/off the galvanometer driving battery.

[6] INT. BA —(A)— Terminals

When the self-contained battery is used to supply power to the bridge,
these terminals are short-circuited by the short-bar.

[7] EXT. BA —(A)— Terminals

When an external power supply is used, these terminals are short-circuited by the short-bar.

[8] Rx Terminals

An unknown resistance is connected to these terminals.
The Rx terminals consist of current terminals C_1, C_2 and potential terminals P_1 and P_2.

[9] P_{2S} Terminal

This is one of the potential terminals to which the Standard Resistor 2771 is connected.

[10] EXT. BA Terminals

An external battery is connected across these terminals.
The minus (-) side of the terminals is one of the current terminals to
which the External Standard Resistor is connected.

Battery Replacement

The self-contained batteries are located in the bottom of the instrument case.

To open the battery cover, push the clamping plate thoroughly in the arrow direction,

and raise the foot of the cover.

While, to close the cover, push the clamping plate in the arrow direction, fit the edge A-A' with

the groove of the instrument body, and depress the cover.

The stopper will lock the cover in its place.

Since two batteries are used in parallel connection, replace them with two new ones at a time.

Note that use of old battery in combination with new one will result in short battery life.
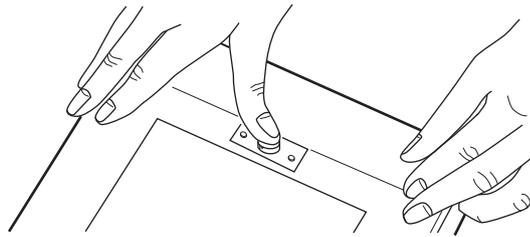
Fig. 3.2   Removal of the Battery Cover
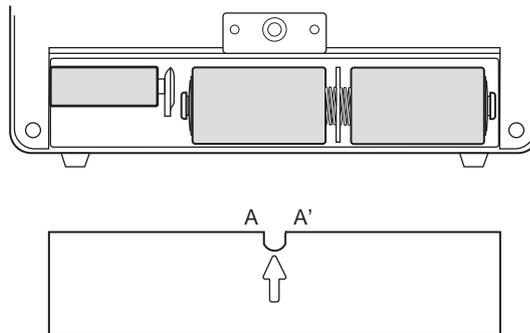
Fig. 3.3   Location of Batteries

Connection for External Battery

When an external battery is used, change the short-bar position
INT. BA —Ⓐ— terminals to EXT. BA —Ⓐ— terminals.
Regulate the current by connecting a slide resistor in series to the external battery so as not to allow current flow in the instrument exceeding the value indicated above the "MULTIPLY" jack and external standard resistor.

Fig. 3.4 (a)   Connection for External Battery

Fig. 3.4 (b)   Connection for Rx terminal

IM 2769-10E

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4. OPERATING INSTRUCTIONS

4.1 Preparation

(1) Make sure that the INT. BA as well as P_{2S} terminals are shorted securely.
Place the BA switch to OFF position, open the Rx terminals.

(2) Set the GA sensitivity dial to CH position.
By doing this, check that the galvanometer driving battery is good.
When the pointer of the galvanometer deflects to the blue zone on the scale,
this shows that the battery is good.
Note: It takes 1 to 2 seconds for stabilized indication.

(3) Set the GA sensitivity dial to G_2, and check that the galvanometer indication is in the zero position.
If deviated, turn carefully the zero adjusting screw of the galvanometer to obtain a true zero point.

(4) Connect an unknown resistance to the Rx terminal.
(Refer to Fig. 3.4 (b) Connection for Rx terminal.)

4.2 Operation for Measurement

(1) Select a multiplying factor by using the plug, to fit the approximating value of the unknown resistance, according to Table 4.1.

Rx	MULTIPLY	
0.1 to 1.1 mΩ	∗	0.0001
1 to 11 mΩ		0.001
10 to 110 mΩ		0.01
0.1 to 1.1 Ω		0.1
1 to 11 Ω		1
10 to 110 Ω		10
∗ When using 2771		

Table 4.1

(2) Turn the BA switch ON.

(3) Set the measuring dial to a position near the center, push the GA button switch momentarily,
and observe the galvanometer.
If the deflection is on the plus (+) side, increase the dial value to obtain zero indication by
repeating the above operation.
When the indication comes near the zero position, push and turn the GA button switch
either clockwise or counterclockwise, to lock the switch.
Then, move the measuring dial to obtain zero indication on the galvanometer.
If the indication is on the minus (-) side in the beginning of this adjustment, reduce the dial value and
obtain zero indication in the same manner as above.
If more sensitivity is required, select G_1 position first, and G_0.

(4) When the galvanometer indication comes to zero through adjustment of the measuring dial, the resistance value of Rx is calculated from the following equation.

$$Rx = \left(\begin{array}{c} \text{Indication on} \\ \text{the measuring dial} \end{array} \right) \times \left(\begin{array}{c} \text{Multiplying} \\ \text{factor} \end{array} \right) \quad [\Omega]$$

(5) When measurement is finished, first release the GA button switch.

Then, turn off the BA switch and set GA sensitivity dial to $\boxed{\begin{array}{c} GA \\ OFF \end{array}}$ position.

(6) When it is desired to measure the resistance below 1 mΩ to 0.1 mΩ, connect the 2771 standard resistor to the instrument as shown in Fig. 4.1. In this case, the plug should be removed. The unknown resistance Rx is calculated from the following equation.

$$Rx = \left(\begin{array}{c} \text{Dial} \\ \text{indication} \end{array} \right) \times \frac{1}{100} \left(\begin{array}{c} \text{Value of external} \\ \text{standard resistor} \end{array} \right) \quad [\Omega]$$
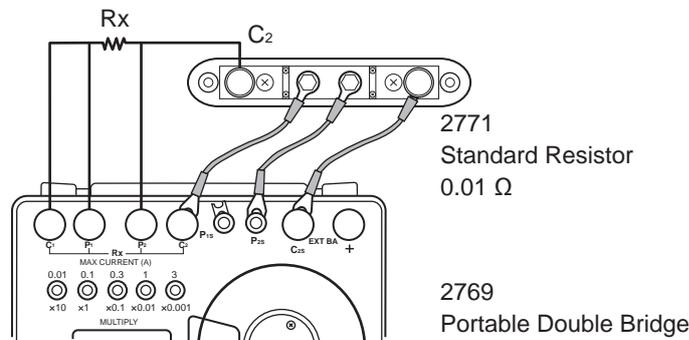
Fig. 4.1   Connection for External Standard Resistor

4.3 Accessories

(1) Measuring Cord (275300)

The following cords are provided for connection of an unknown resistance:

       Current Cord (two)   length: 2 m, resistance: approx. 3 mΩ

       Potential Cord (two) length: 2 m, resistance: approx. 8 mΩ

Current Cord

Potential Cord
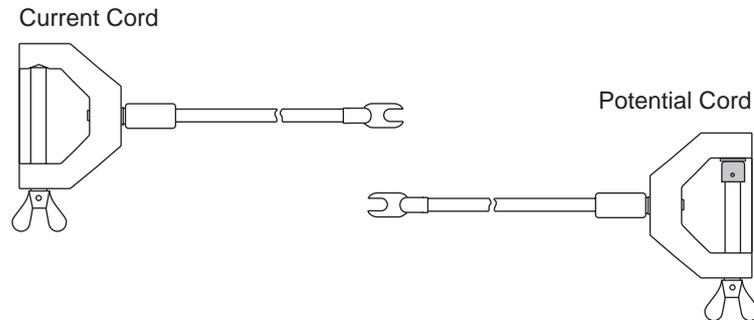
Fig. 4.2   Measuring Cords

(2) Clamping Device (275400)

This clamping device is used for the measurement of a bar resistance of unit length or conductivity.

[length from terminal (P_1) to terminal (P_2): approx. 500 mm]
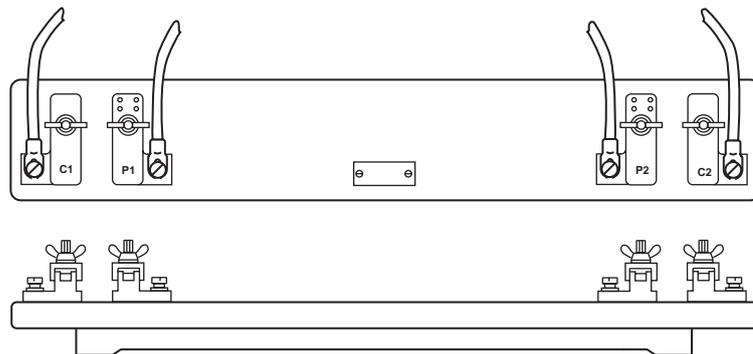
Fig. 4.3   Clamping Device

(3) Ammeter

When an ammeter is used for monitoring current through Rx,

remove the short-bar INT. BA —Ⓐ— (or EXT. BA —Ⓐ—) terminals and

the ammeter is connected to these terminals.

For current monitoring, DC Ammeter 2051 (0.3/1/3/10/30 A) is recommended.

5. CAUTIONS

5.1 Cautions for Operation

(1) Insert the multiplying factor switching plug securely into the jack.

(2) Be sure that the GA sensitivity switch is first set to G_2 position.
   Then, proceed to G_1, and to G_0.

(3) The maximum allowable current of each built-in resistor is indicated on the panel respectively.
   Be sure not to exceed this current value. (Refer to Table 2.1 of 2. SPECIFICATIONS.)

(4) Never fail to BA switch to $\boxed{\text{OFF}}$ and GA sensitivity dial to $\boxed{\substack{\text{GA}\\\text{OFF}}}$, when the measurement is completed.

5.2 Cautions for Maintenance

(1) When the instrument is used after a long period of time,
   clean carefully the multiplying factor switching plug, dial and
   the slide resistor of the measuring dial, with soft clean cloth.
   In this case, be careful not to change the contacting pressure of the slider of the slide resistor.
   (Avoid using sandpaper or the like when cleaning.)

(2) Remove the self-contain batteries when the instrument is stored for a long period.

(3) The panel and case of this double bridge are made of ABS resin and
   has sufficient mechanical strength.
   However, they are low resistive against heat and chemicals.
   An organic solvent, such as lacquer thinner, should be strictly avoided
   when cleaning the panel or case.

5.3 Calibration

Periodic calibration (once a year) is to be conducted in the following manner.

5.3.1 General Check

   (1) Check the dials, name plate, terminals, plug, switches, etc., and
      see if there are loose connections or defects.

   (2) Check if the self-contained battery is exhausted.

5.3.2 Check on Operation

   Measure the value of a standard resistor (100 Ω, 10 Ω, ..., 0.001 Ω), and check that
   the measured result is within allowable error of 0.5% at 1.0 and 10 on the dial scale.
   For this check, use of the 2792A or 2792 Series standard resistor is recommended.
   (2792 Series have been discontinued.)

5.3.3 Calibration of Standard Resistor

(R_1 to R_5, and 2771 standard resistor)

Based on a four-terminal resistor comprising a pair of current terminals C_2 and C_{2S},
and a pair of potential terminals P_{2S} and P_{1S} (same as C_2) as shown in Fig. 5.1,
measure R_1 to R_5 by the double bridge at an accuracy of higher than 0.1%.
Through this operation, obtain the calibrated resistance values of R_1 to R_5.
Then, calibrate the 2771 standard resistor in the same way.
In this case, the current value should be 1/3 the value indicated on the "MULTIPLY" jacks.
For this calibration, use of the 2752 precision double bridge is recommended.

5.3.4 Calibration of Measuring Arm Dial

Connect a calibrated resistor 1000 Ω as an external resistor and then
connect a variable standard resistor (10 Ω to 110 Ω) whose accuracy is 0.1% or better,
to the Rx arm in the ×10 range, and measure its resistance.
The calibrated value is obtained as follows:

$$\text{Calibrated value of measuring arm dial} = \frac{100 \times \left(\begin{array}{c} \text{Resistance value of} \\ \text{variable standard resistor} \end{array} \right)}{\left(\begin{array}{c} \text{Resistance value of} \\ \text{standard resistor 1000 Ω} \end{array} \right)}$$
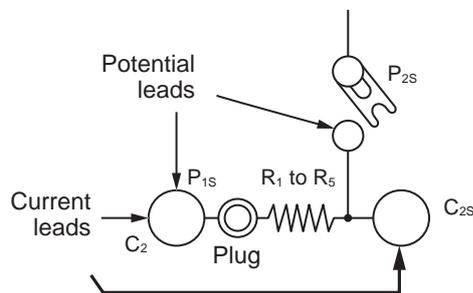
Fig. 5.1   Calibration of Built-in Standard Resistors

6. PRINCIPLE OF OPERATION

6.1 Basic Principles

Fig. 6.1 shows the theoretical diagram of the double bridge circuit.
When the resistances N and n are adjusted so that the current flowing in
the galvanometer G is reduced to zero, the unknown resistance X is expressed
by equation (6.1) as follows:

$$X = \frac{N}{M} \times S + \frac{m \times \ell}{m + n + \ell} \times \left(\frac{N}{M} - \frac{n}{m} \right) \quad \cdots \cdot (6.1)$$

Where ℓ is the lead resistance from the terminal Ps of S to the terminal Px of X.

The 2769 double bridge is designed so that the fixed resistors and
slide resistors have the following relationship:

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

Therefore, $\dfrac{N}{M} - \dfrac{n}{m} = 0$

From equation (6.1),

$$X = \frac{N}{M} \times S \quad \cdots \cdot (6.2)$$

In other words, the low resistance X can be accurately measured without influenced by
the lead resistance.
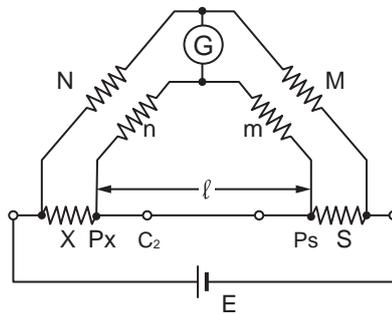
Fig. 6.1   Theoretical Circuit Diagram

6.2 Error

6.2.1 Error due to Current Lead

Practically, $\left(\dfrac{N}{M} - \dfrac{n}{m} \right)$ is not perfectly zero, but is approximately $\pm(10^{-3}$ to $10^{-4})$.

For example, $m + n \gg \ell$, $\dfrac{m}{m + n} \fallingdotseq 0.99$, $\ell = 10$ mΩ

Then, the second term of equation 6.1 is $\pm 1 \times 10^{-5}$ Ω.
If S = 0.1 Ω, the resistance value is X = 10^{-2} Ω $\pm 1 \times 10^{-5}$ Ω according to equation (6.1).
This means that the error is $\pm$ 1% of the dial reading.

When the value of S is small, namely, X is small, and if the value of ℓ /S is large,

a large error will cause no matter how small the value of $\left(\dfrac{N}{M} - \dfrac{n}{m}\right)$ may be.
In case of low resistance measurement, the lead resistance between
Ps and C_2 is designed to be nearly zero.
Therefore, the lead resistance from C_2 to Rx may be considered as ℓ .
In this view, when this double bridge is used in the × 0.0001 range,
arrange" ℓ " to be less than 10 mΩ.

6.2.2 Error due to Potential Lead

When the potential lead resistance is large and cannot be neglected, the lead connected across
the potential terminals P_1 and P_2 becomes an error of the M and N arms.
While, the individual resistance of M and N arms are not directly related to this error but
the ratio N/M has relation to the error.
Therefore, when the lead resistance $\triangle N$ is present on the N arm,
the influence of this $\triangle N$ can be cancelled by adding a lead resistance to the M arm.
This is expressed by the following equation.

$$X = \frac{(N + \triangle N)}{(M + \triangle M)} \times S = \frac{N}{M} \times S \left(1 + \frac{\triangle N}{N} - \frac{\triangle M}{M}\right) \quad \cdots\cdot (6.4)$$

on condition that, $\dfrac{\triangle N}{N} \ll 1$, $\dfrac{\triangle M}{M} \ll 1$

In Model 2796 double bridge, a resistance to act as $\triangle M$ can be connected to the terminals P_{2S}.
The error becomes minimum when $\dfrac{\triangle M}{M}$ is equal to $\dfrac{\triangle N}{N}$ based on equation (6.4).

Then, find the value of $\triangle N$ for the measurement where the error due to
the potential lead is 0.5% of the measured value without connecting a resistance
corresponding to $\triangle M$.

From equation (6.4),

$$X = \frac{N + \triangle N}{M} \times S = \frac{N}{M} \times S \left(1 + \frac{\triangle N}{N}\right) \quad \cdots\cdot (6.5)$$

The value of $\left(1 + \dfrac{\triangle N}{N}\right)$ should be 1.005.   Therefore,

$$\triangle N = 0.005N \quad \cdots\cdot (6.6)$$

Model 2769 bridge is designed so that the N = 21 Ω
when the measuring dial scale is minimum (1.0).
Substituting N = 21 Ω for equation (6.6),

$$\triangle N = 110 \text{ mΩ}$$

Also, the allowable error of $\triangle N$ is changed according to the ratio of N/M.

This relationship is expressed by the graph as shown in Fig. 6.2.

For the m and n arms, there are provided no terminals such as corresponding to P_{2S}.

The influence of the lead resistance $\triangle m$ and $\triangle n$ upon the m and n arms can be neglected if the value of ℓ is determined sufficiently smaller than that of S.
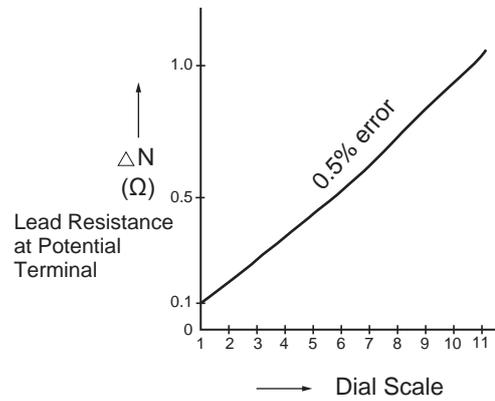
Fig. 6.2   Error due to Potential Lead

7. CIRCUIT DIAGRAM AND PARTS LIST