AUTOMATIC SYSTEMS LABORATORIES

F700 Precision Thermometry Bridge Operator's Handbook

F700-14-002 Issue 3

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ENGLISH **IMPORTANT SAFETY INFORMATION** 22/1/97

GENERAL

This instrument has been designed and tested to comply with the Electromagnetic Compatibility Directive 89/336/EEC and Low Voltage Directive 93/68EEC in accordance with EN 61010 -1 :1995 relating to the safety requirements for electrical equipment for measurement, control and laboratory use.

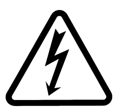
Before connecting the instrument to the mains supply please ensure the following safety precautions have been read and understood.

SAFETY SYMBOLS

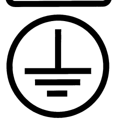
The following symbols are used to describe important safety aspects of this instrument, these symbols appear on the instrument and in the operation instructions.

Attention Symbol: Indicates a potentially hazardous condition exists and that it is necessary for the operator to refer to the instruction manual to ensure the safe operation of this instrument.

Hot Surface Warning: Indicates a hot surface that may be at a temperature capable of causing burns, refer to the instruction manual for further safety information.



Caution Risk of Electric Shock: Indicates hazardous voltages may be present, refer to the instruction manual for further safety information.



Protective Conductor Terminal: For protection against electrical shock during a fault condition. This symbol is used to indicate terminals that must be connected to electrical ground before operating equipment.

SUMMARY OF SAFETY PRECAUTIONS

The following general safety precautions must be observed while operating or servicing this instrument. Failure to comply with these precautions may result in personnel injury or death.

INSTRUMENT ELECTRICAL EARTH

This instrument is designed as a Class 1 electrical safety insulation device. To ensure continued protection from electric shock the instrument chassis must be connected to an electrical ground. The instrument is supplied with an AC power cable with an earth connection.

LIVE CIRCUITS DANGER

Do not connect the power supply to or operate this instrument with the protective covers removed. Component replacement and internal adjustments must be made by qualified service personnel. Do not replace components with the power cable connected. Under certain conditions, dangerous voltages may exist with the power cable removed. To avoid injuries always disconnect power and discharge circuits before touching them.

DO NOT MODIFY THIS INSTRUMENT OR SUBSTITUTE PARTS

Because of the danger of introducing additional hazards; do not perform any unauthorized modification or install substitute parts to the instrument. Only fuses with the rated current, voltage and specified type should be used, failure to do so may cause an electric shock or fire hazard. Return the instrument to Automatic Systems Laboratories for service and repair to ensure the safety features are maintained.

DO NOT OPERATE IN EITHER DAMP OR EXPLOSIVE ENVIRONMENTS

This instrument is not designed to operate while wet, in an environment of condensing humidity or in the presence of flammable gases or vapors. The operation of this instrument in such an environment constitutes a safety hazard.

HOT SURFACES DANGER

Equipment marked with a Hot Surface warning symbol should be regarded as operating at temperatures capable of causing burns. Do not touch, handle or transport hot components or liquids until they are at safe temperatures. Care should be taken not to spill or splash water or volatile fluids on or into hot surfaces or liquids.

CERTIFICATION

Automatic Systems Laboratories certifies that this product met its published specifications at the time of shipment from our factory. All calibration measurements performed in the manufacture of this instrument are traceable to the National Physical Laboratory (London).

ASSISTANCE

For after sales support and product service assistance please contact Automatic Systems Laboratories Customer Support Group. Contact information is provided in the operation instruction manual.

Table of Contents

1. Introduction

The Model F700 is an advanced multi stage ratio transformer potentiometer for comparing two, four terminal resistors. It can be used with a variety of PRTs to achieve precise temperature measurement or control.

External control of all functions is possible using the optional computer interfaces (RS232, IEEE-488).

Overall system accuracy will depend on the quality of PRT used.

The bridge design is such that it can be connected to a number of different types of PRT. The system can be set up so that absolute, relative or differential temperature measurements may be made, even with long thermometer leads.

Temperature Equivalents:

1 milli-degree C = 0.001°C = 1m°C = 1mK = 1.8m°F

1 milli-degree F = 0.001°F = 1m°F = 0.56mK = 0.56m°C

1.1. Definitions and Terminology used in this Manual

i) 1°C = 1K

ii) 1 mK (milli-Kelvin) = 0.001°C (one milli-degree Celsius)

iii) Alpha, or α, is the temperature coefficient, or temperature sensitivity, of the Platinum wire used in PRTs. Generally speaking, the higher the alpha value, the better the PRT.

iv) PRTs are regularly referred to with several alternative abbreviations as follows:

PRT (Platinum Resistance Thermometer)

Pt100 (PRT with nominally 100Ω resistance at 0°C)

RTD (Resistance Temperature Device)

Platinum resistance thermometers may also be referred to as probes or sensors.

v) System accuracy refers to the overall, combined accuracy of the F700 and the PRT in use.

2. Controls and Connections

2.1. Front Panel

Figure 2-1 shows the F700 front panel.

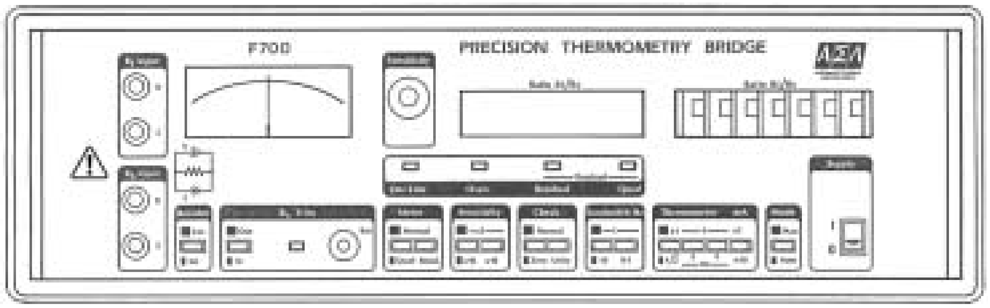


Figure 2-1. Front Panel.

2.1.1. Supply

Power ON/OFF switch

I = Power ON 0 = Power OFF

The power switch itself will be illuminated (green), when the F700 power is switched ON. Care should be taken not to limit access to the power ON/OFF switch.

2.1.2. Thermometer mA

Four push buttons to select the current in the bridge resistors (or resistance thermometer). When all the buttons are out 1mA is selected. The second and third buttons select 5mA and 2mA respectively, and 10mA both selected. The left-hand button is a √2 multiplexer for each setting and the right-hand button is a by 10 divider for each setting.

2.1.3. Bandwidth Hz

Two push buttons to select the meter and analogue output bandwidth. Both buttons out give a 1Hz bandwidth. Selecting the left-hand button gives 10Hz and the right-hand button gives 0.1Hz bandwidth.

2.1.4. Check

Two push buttons normally left out. Selecting the left-hand push button connects the bridge internally for a zero check. Selecting the right-hand button connects the bridge internally for a unity ratio measurement check.

2.1.5. Sensitivity (Push Buttons)

Two push button switches giving relative sensitivity selection of x 1 when they are out, x 10 if either one is selected and x 100 if both are selected.

For 100 Ohm R_S at 1mA current operation

A x10 sensitivity setting and the sensitivity potentiometer set at 7 gives and approximate meter FSD equal to 10 least significant digits of the thumb-wheel switches, precise gain adjustments can be set via the sensitivity potentiometer.

For 1 ohm R_S at 10mA current operation

The x 100 sensitivity setting and a sensitivity potentiometer set at 7 gives an approximate meter FSD equal to 10 least significant digits of the thumb-wheel switches, precise gain adjustment can be set via the sensitivity potentiometer.

2.1.6. Sensitivity (Potentiometer)

The 10 turn sensitivity adjustment potentiometer gives a relative sensitivity overlap on the nominal push button settings of about 100 to 1.

2.1.7. Meter

Two push buttons to select the meter function. The buttons are normally out to select a display of bridge imbalance. The left-hand button selects the bridge quadrature signal and the right-hand button selects the residual check signal. The meter is scaled ±10 and ±2.5 with a center zero.

2.1.8. R_S Trim

A push button switch to select the R_S Trim facility. An indicator lights up when the R_S Trim is selected. The R_S Trim adjustment is made with a ten turn potentiometer using a screw-driver. The position of the potentiometer can be locked by setting a small grub-screw.

2.1.9. Bridge Resistors

2.1.9.1. R_S

Two co-axial connectors which supply the current drive and voltage sense to an external standard resistor. There is a temperature controlled 100 ohm standard resistor within the Model F700. Either internal or external standard resistor may be selected using the INT/EXT push button.

2.1.9.2. R_t

Two co-axial connectors which supply the current drive and voltage sense to the resistor or thermometer being measured.

WARNING

These are isolated connectors and are <u>NOT</u> to be used as earth connections.

2.1.10. R_t/R_S (Display)

Seven digit display indicating R_t to R_S ratio.

2.1.11. R_t/R_S (Thumb-wheel switches)

Seven thumb-wheel switches which allow the operator to change the R_t to R_S ratio in the range of 0 to 3.999999.

2.1.12. Oven

A front panel indicator which lights when the internal standard resistor temperature control oven is out of temperature limits.

2.1.13. Overload Residual

A front panel indicator which lights when the residual signal exceeds preset limits.

2.1.14. Overload Quad

A front panel indicator which lights when the quadrature signal exceeds preset limits.

2.2. Rear Panel

Figure 2-2 shows the F700 rear panel.

Figure 2-2. Rear Panel.

2.2.1. AC Power Input Socket

The AC Power input unit incorporates a voltage selection tumbler, to enable the user to match the F700 to the local AC voltage supply, and two fuse holders. The correct 20mm fuses to install are as follows:

Voltage	Fuse
220/240V	T1A (250V AC)
100/120V	T2A (250V AC)

2.2.2. Analogue Output

A BNC connector carrying the bridge out of balance signal. A positive voltage indicates that the bridge setting is high. The outer conductor is earthed.

2.2.3. SKT 1 (AC output)

Unfiltered bridge output from the phase sensitive detector.

2.2.4. SKT 2 (dc output)

1 Hz bandwidth DC output proportional to bridge imbalance.

2.2.5. Earth Terminal

A jack/binding post which is connected to the main instrument earth point. It can be used for the PRT or resistor screens only if they are not earthed through another connection.

3. Initial Operation

3.1. Power Supply Connection

Checking Voltage and Fuse Rating

WARNING: DO NOT CONNECT THE POWER CABLE OR SWITCH THE UNIT ON UNTIL THE VOLTAGE AND FUSE RATING OF THE INSTRUMENT HAVE BEEN CHECKED AND CHANGED IF NECESSARY.

The supply voltage setting of the F700 is shown on the power inlet socket on the rear panel. Check that this corresponds to the local voltage and that the fuse installed is as specified in section 2.2.1.

Figure 3-1. Power Input Unit and Fuse Rating Block.

3.1.1. Setting the Voltage and Fuse Rating

Lever open the power input unit from the top with a flat bladed screwdriver. Inside is a plastic cam: remove this and replace it so that the voltage to be set is displayed through the window.

Where fused power plugs are connected to the supply cable provided, the correct fuse rating is 3 Amps. The supply cable provided with the F700 is color coded as follows:

Ground	Green/Yellow (Protective Conductor Terminal)
Live	Brown
Neutral	Blue

3.2. Initial Checkout

The purpose of these initial checks is to verify correct operation of the Model F700 controls and circuits. The logical sequence of checks is zero check, unity check, Ratio of two resistors and finally signal output checks. However, for those operators who are completely unfamiliar with the Model F700, it is recommended that the ratio of two resistors section is studied first as this will familiarize him/her with most of the controls and their use. The normal mode of connecting two and four terminal resistors, as shown in Figures 3.2 and 3.3, is changed in some of these tests.

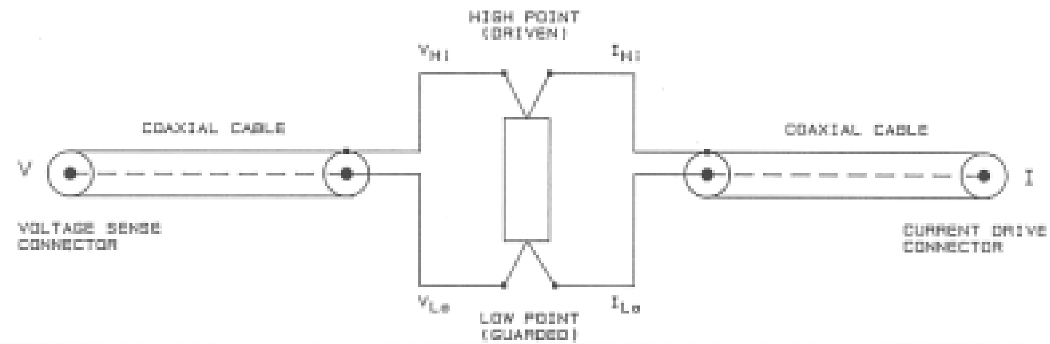


Figure 3-2. Normal Four Terminal Resistor Connection Arrangement.

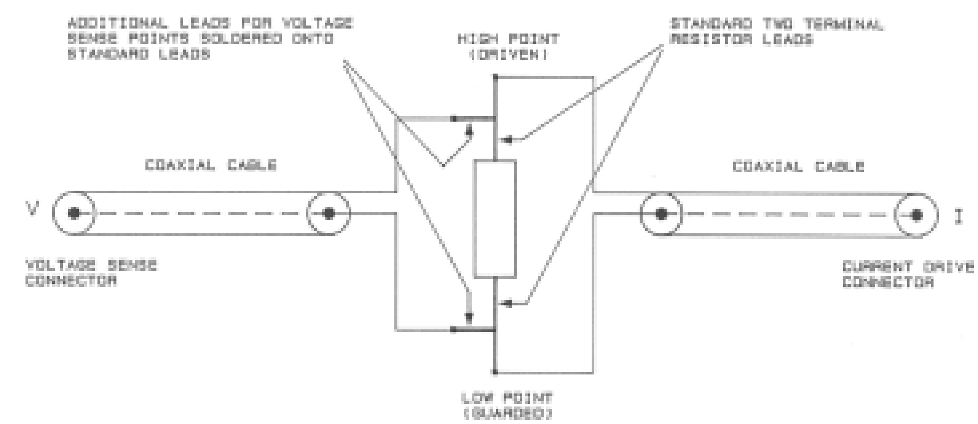


Figure 3-3. Modification of a Two Terminal Resistor for use with the F700.

3.2.1. Zero Check

The Model F700 bridge has an internal zero check facility. The R_S resistor need not be fitted if the internal reference is used, but a resistor should be fitted to the R_t terminals. The bridge is designed to work with the existing measurement connections left in situ while checks are being made. However, the voltage across R_S should not exceed 0.7 volts. R.m.s. Select the following front panel push buttons and controls:

1mA thermometer (bridge resistor) current

1Hz Bandwidth

Zero check mode

x10 sensitivity

Normal meter display

R_S Trim out

R_S INT

R_t/R_S ratio on thumb-wheel set to 0.000000

Sensitivity dial set to 9.00

The meter should display zero ±10% of FSD.

The two overload lights and the oven control warning lights should be off.

3.2.2. Unity Check

The Model F700 bridge has an internal unity check facility. The conditions and limits described for the zero check facility above apply except that the unity check push button should be selected and the thumb-wheel switches set to 1.000000.

The meter should display zero ±10% of FSD.

The two overload lights and oven warning light should be off.

3.3. Ratio of Two Resistors

3.3.1. Internal Reference Resistor

Connect a four terminal test resistor to the R_t sockets for the Model F700 Bridge, as shown in Figure 3.4 using the connection arrangement shown in the detail of Figure 3.2. If a two terminal resistor is to be used, convert it to a four terminal arrangement, as shown in Figure 3.3. For the purposes of initially checking the bridge operation, almost any resistor in the range 1 to 399 ohms could be used, but a nominal 100 ohms resistor is preferred. The stability and repeatability of measurement will depend on the nature of resistor used and a high quality component is preferred.

Bridge balance:

Select the front panel push buttons and controls, as follows:

1mA thermometer (bridge resistor)

1Hz Bandwidth

Check switches for normal operation

Sensitivity x1

Meter switches for normal display

R_S Trim out of circuit

R_S for Internal

Sensitivity dial to 9.00

Adjust the thumb-wheel switches to approximately balance the bridge, that is bring the meter display to zero within 10% of FSD. Increase the sensitivity to x10. The meter should remain on scale. Rebalance to within 10% of FSD. For 1 ohm R_S increase the sensitivity to x100, the meter should remain on scale. Rebalance the bridge using the thumb-wheels. It should be possible to zero the meter to within 10% of full scale deflection.

Note: In normal operation, the sensitivity switches can be left in the x10 / x100 position. The meter is protected from overload. The procedure above verifies the operation of the x1 and x10 switches.

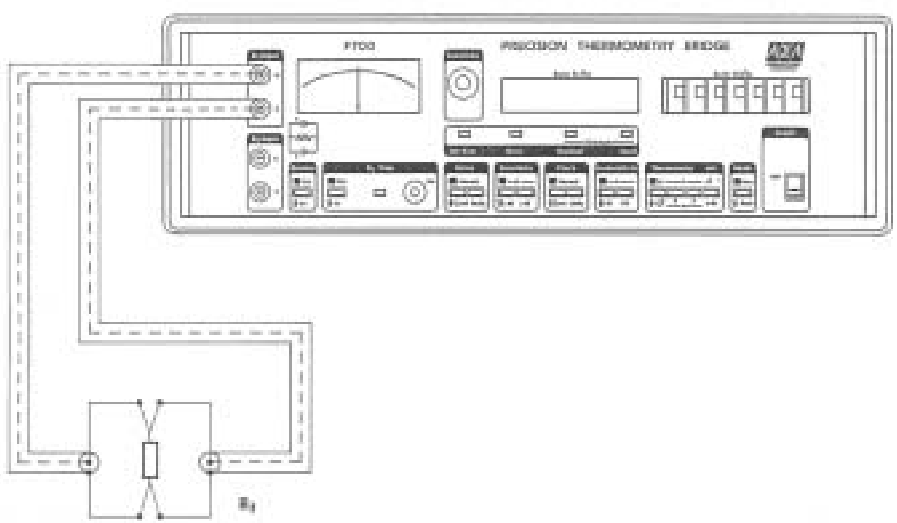


Figure 3-4. Resistance measurement Internal Reference.

3.3.1.1. Bridge Current:

Confirm that the bridge can be balanced with all combinations of the current switches. Note that the voltage across the resistors connected to R_S must not exceed 0.7 volts rms. Reset the bridge current to 1mA.

3.3.1.2. Sensitivity variable control and calibration:

Adjust the bridge balance so that there is about 20% deflection on the meter. Adjust the sensitivity variable control from 0.00 to 10.00 and verify at least 10 to 1 range of sensitivity, as indicated by the meter reading. Set the sensitivity variable control to about 9.00. Rebalance the bridge with x10 sensitivity on switches. Change the R_t/R_S ratio on the thumb-wheel switches by 10ppm, ie. change the second from last switch by one digit. Adjust the variable sensitivity to set the deflection of the meter to exactly full scale. Lock the counting dial.

This calibrates the meter display to the thumb-wheel switches. The variable sensitivity control may be altered at any time to give a convenient deflection on the meter, but it is worth noting the calibrated setting so that it can be easily reset.

3.3.1.3. R_S Trim:

Calibrate the meter to the thumb-wheel switches as described above. Set the sensitivity switches to x10. Rebalance the bridge by adjusting the R_t/R_S ratio thumb-wheels. Set the R_S trim push button. The R_S trim indicator should light and the meter should move to full scale right-hand deflection corresponding to 100ppm reduction in R_S. Adjust the R_S trim control slowly clockwise. The meter display should move from the right-hand full scale deflection for the ten turns of the R_S trim corresponding to a change in R_S from -100ppm to +100ppm.

3.3.2. External Reference Resistor

Connect two, four terminal resistors R_t and R_S to the Model F700 bridge, as shown in Figure 3.5. The resistors may be any value in the range 0 to 4K ohms, and the ratio R_t to R_S must not exceed 4 to 1. Note, the resistor IR volts drop must not exceed 0.7 volts rms and the bridge (thermometer) current must be set accordingly.

Confirm the operation of the bridge, following the procedure outlined above, but with the R_S EXT push button selected and an appropriate current set.

Note: The purpose of these ratio checks is to verify normal operation of the Model F700 Bridge controls and to familiarize the operator with their use. The actual ratios measured will depend on the quality of resistors used, and the tests can only be relied on as a specification check if high precision, standard quality, resistors are used.

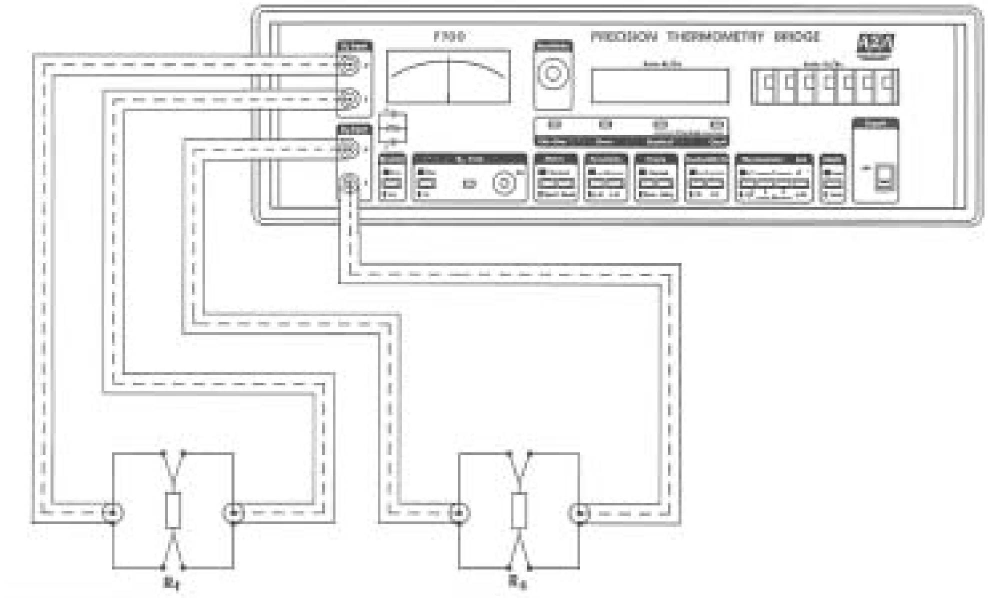


Figure 3-5. Resistance Measurement External Reference.

3.4. Warning Indicators

3.4.1. Quadrature and Residual Check

The Model F700 Bridge has a quadrature detector with a quadrature servo circuit which integrates the quadrature error and applies a correction signal to the bridge. If the quadrature error exceeds the range of the compensation circuitry the quadrature fault indicator will light.

The unit also has a residual AC detector which monitors the level before the phase sensitive detector. If this exceeds limits the residual warning indicator lights.

These two indicators can be checked, as follows:

Balance the bridge using the procedures as described in section 3.3 1 or 3.3.2.

Grossly unbalance the bridge by switching the most significant thumb-wheel switch.
The residual warning indicator should light immediately. The quadrature warning light will light after a few seconds delay. The residual and quadrature signals can be displayed on the meter by selecting the appropriate meter display push button.

3.4.2. Oven Warning Indicator

The oven control indicator lights only when the internal reference resistor oven is outside it's temperature limits. The bridge may not operate at the specified level of performance if the indicator is illuminated. The operation of this indicator can be checked at switch on of the Model F700 bridge. At this time, the oven will not have warmed up, and the indicator should light immediately. After a few minutes, dependent on ambient temperature and how long the instrument has been switched off, the oven warning indicator will go out showing that the internal reference resistor is at working temperature.

WARNING

If the Oven light stays on, a fault in the Oven control circuit has occurred.

3.5. Analogue Output

Set up the Model F700 bridge as in Section 3.3 1 or 3.3.2. Connect a strip chart recorder to the analogue DC output, SKT2. Balance the bridge and set the recorder pen to mid point of the recorder paper. Unbalance the bridge by changing the thumb-wheel switches and note the change in recorder response.

Confirm the relative effect (factors of 10) of each thumb-wheel in sequence. Note that the output will saturate for gross bridge imbalance. Reduce the sensitivity in factors of 10 using the sensitivity select push button.

Verify the relative change in response on the recorder output. Socket SKT2 gives a filtered 1Hz bandwidth signal, which is unaffected by the front panel (meter) bandwidth setting. A raw DC signal without any filtering corresponding to the output of the phase sensitive detector, before the output filter can be seen at SKT1. This can be checked in a similar way to the SKT2 output, but a high speed monitor, such as an oscilloscope, should be used instead of a strip chart recorder.

4. Theory of Operation

4.1. Basic Principles of Operation

The Model F700 is an AC Bridge instrument designed to measure the ratio of two R_t/R_S to a high level of accuracy. The basic bridge arrangement is shown in Figure 4.1. A stable AC signal is produced by the carrier generator. This drives current through the standard resistor, R_S, and the unknown resistor, R_t which are connected in series. The voltage generated across R_S is used as a reference signal to excite the input windings of a multistage inductive divider.

The inductive divider secondary winding output is compared with the voltage appearing across the unknown resistor R_t by the detector circuitry. The inductive divider acts as a precision ratio transformer. It's tappings are adjusted to balance, that is bring to zero, the output to the detector circuit. At balance the voltage from the inductive divider is exactly equal and opposite to that appearing across R_t.

The output of the inductive divider is also a precise ratio of the voltage across the R_S. Since the current flowing through R_S and R_t is identical, the ratio set on the inductive divider will be equal to the ratio R_t/R_S.

Obviously, this description is simplified to explain the basic operating principles. Detailed discussion of the various elements making up the Model F700 Bridge, are discussed in more detail below.

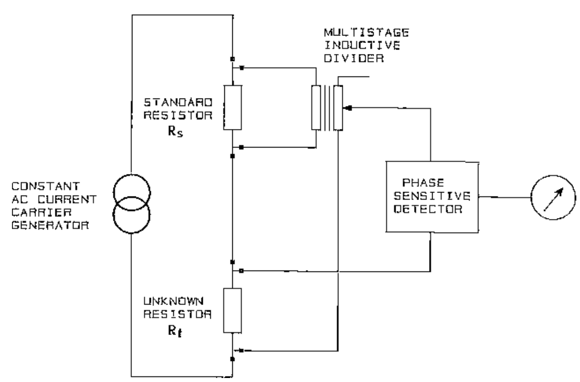


Figure 4-1. Basic F700 Bridge Arrangement.

4.1.1. Carrier Generator

The carrier generator consists of a Wien Bridge oscillator with feed-back level control, as shown in Figure 4.2. The output voltage level is fed back through a detector circuit and compared with a reference voltage in the level control circuit. The reference can be switched between two levels providing $\sqrt{2}$ ratio in the generator output. The oscillator also incorporates a DC bias control. This senses a signal from the inductive divider and biases the oscillator output level to compensate, ie. remove, standing DC currents from the inductive divider.

The output of the oscillator provides a very stable AC voltage. This is fed through a switched attenuator to a voltage to current converter. The attenuator sets the input level to the voltage to current converter and hence defines the output current to the bridge resistors R_S and R_t. The output current is selected by the operator from the front panel push button switch selection, 1mA ,2mA, 5mA, 10mA, 10 and √2.

The bridge operating frequency is set to 1.5 times the local supply line frequency. This is 75Hz in the UK, and some parts of the world with a 50Hz line frequency and 90Hz in the rest of the world where a 60Hz line frequency is standard. This frequency relationship is chosen to achieve the required loop gain and bandwidth in the system consistent with a high level of noise rejection at the line frequency and it's harmonics. The operating frequency is sufficiently low to avoid significant quadrature effects, due to cable capacitance, but not so high that the sensor resistances compared with their DC levels are significantly different. The use of an AC carrier has the advantage over DC techniques in that thermal emf's due to the various metal junctions of the circuits are cancelled out and the effects of certain types of low frequency are minimized.

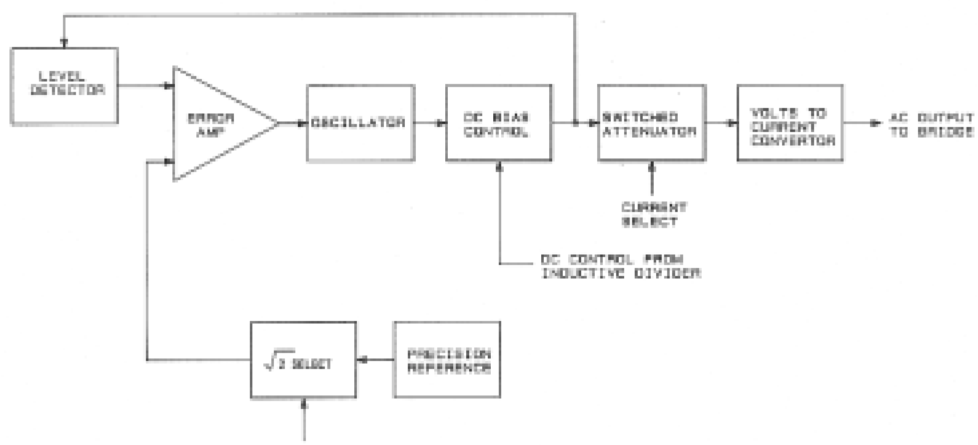


Figure 4-2. Carrier Generator Block Diagram.

4.1.2. Bridge Input Arrangement

The output from the carrier generator is connected to the standard resistor. R_S, and unknown resistor, R_t, as shown in Figure 4.3. R_S may be selected as either an external or an internal standard resistor. Connections are provided for current drive and voltage sense to the externally connected resistors allowing true four terminal operation.

The internal standard resistor is housed in a temperature controlled oven so that a high degree of stability may be achieved. An oven warning circuit drives a LED when ever the oven is outside it's temperature limits.

To provide adequate screening, and to reduce common mode input signals to preamplifier, a guard circuit is connected around R_t. The output drive from the carrier generator circuit is essentially a floating voltage supply because of it's constant current output characteristics. The voltage developed at the junction R_S with R_t is sensed by the guard amplifier and is compared with the bridge reference ground potential. The guard amplifier drives the "tail" of the bridge in an opposite sense to the voltage developed across R_S. The voltages across R_S and R_t are then of opposite polarity and their junction is driven to a virtual ground potential.

The voltage across the reference resistor, R_S, is sensed by the inductive voltage divider. The very high input impedance of the inductive voltage divider ensures that the voltage developed across the divider primary is a faithful reproduction of the voltage across R_S accurate to better than 1ppm of FS. The input impedance is very high compared with the allowed range of R_S and so does not load the bridge. Hence the current flowing R_S will be equal to the current flowing in the unknown resistor R_t.

A trim circuit can be switched in series with the divider input. This carries a voltage in phase with that across R_S, and is derived from a winding on the inductive divider. A front panel control allows the operator to adjust the magnitude and polarity of this voltage by means of a 10 turn potentiometer. This gives an apparent change in the resistance of R_S equivalent to ±100ppm allowing the operator to trim an actual resistor value so that in the bridge it appears as its nominal value.

The output of the inductive divider is a precise ratio of the voltage appearing across R_S. The common point of the inductive divider secondary is connected to the "tail" point of the unknown resistor, R_t. In this arrangement the voltage across R_t and the divider are in opposite sense and will tend to sum towards zero. The difference voltage will appear at the output of the inductive divider secondary and this is connected to one input of a differential preamplifier.

The other input of the preamplifier is connected to the common point of R_S and R_t. At balance both inputs to the preamplifier will be equal and at virtual ground potential. This allows a very high level of common mode rejection at the preamplifier and detector input circuitry in line with the requirements of a very precise ratio measurement. When balanced the inductive divider ratio will be equal to the ratio of:

$$\frac{Rt}{Rs}$$

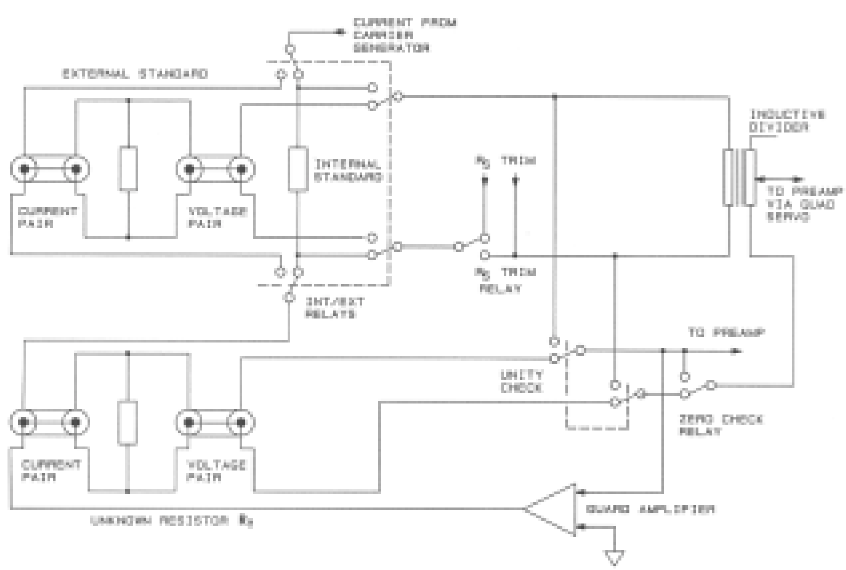


Figure 4-3. Bridge Input Arrangement.

4.1.3. Zero and Unity Check

The bridge input arrangement incorporates two operator check features; zero check and unity check. Both can be selected by front panel push button switches. For zero checking, the common point of the inductive divider is disconnected from R_t and connected to R_t/R_S common point. Setting the inductive divider ratio to zero in all decades should give zero potential output to the preamplifier. Any errors due to standing currents, pick up, or offsets in the inductive divider and it's selector switches will be compared with the virtual ground on the other input to the preamplifier and will give rise to a displayed signal on the meter. At x10 and volume sensitivity set to 7 with the internal reference resistor selected, a current of 1mA and an unknown resistor, R_t, that is within limits the meter should be set at zero ±10% FSD when the meter switches are set to 0.000000.

Selecting the unity check push button causes the common point of the inductive divider secondary to be connected to the R_t side of R_S. Since the voltage across R_S is used to define the voltage across the inductive divider the output of it's secondary should be equal to the voltage across R_S when a ratio of unity is set. The switch arrangement also causes the reference input of the preamplifier and the monitoring input of the guard amplifier to be connected to the carrier generator side of R_S. This causes the generator side of R_S to be driven to virtual ground. The polarities and virtual grounding of the inputs of the two precision followers are therefore reversed providing a check of their characteristics, as well as setting the bridge up for a unity ratio check. The preamplifier will have one input at virtual ground, and the other input will be equal to the volts drop across R_S less the volts drop across the inductive divider secondary. These two voltages should be the same when a ratio of 1.000000 is set on the front panel thumb-wheel switches, the other parameters being set as described above. Hence the preamplifier inputs should both be at virtual ground giving a high degree of common mode rejection, and the output displayed on the meter should be zero ±10% FSD.

4.1.4. Inductive Divider

The inductive divider arrangement is shown in Figure 4.4.

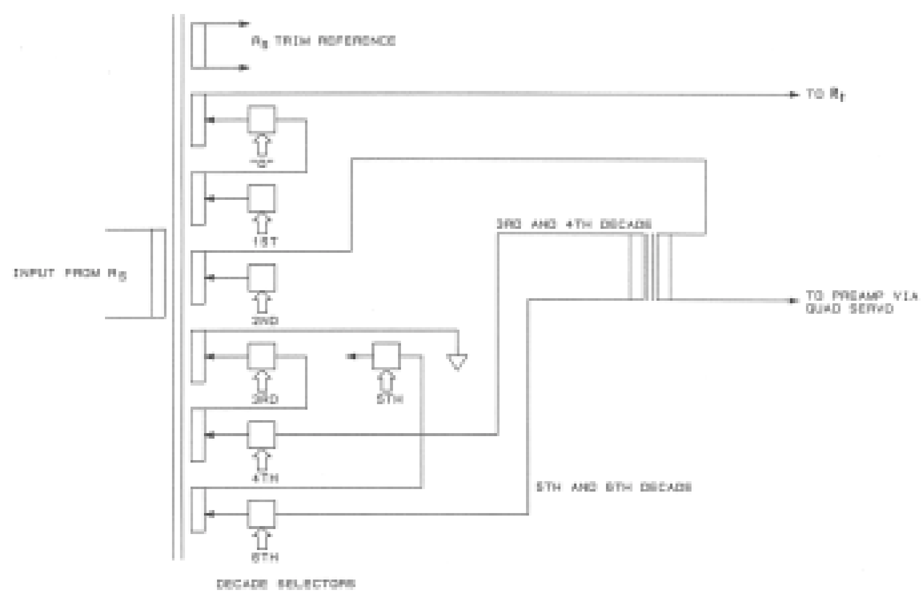


Figure 4-4. F700 Inductive Divider.

4.1.5. Phase Sensitive Detector

The output of the inductive divider is referenced to the driven "tail" side of the resistor R_t but of opposite polarity. Consequently the output tends to virtual ground when the bridge is balanced. This output is connected to one input of a differential preamplifier.

The other input of the preamplifier is connected to the virtual ground common point between R_S and R_t. (As discussed above, these input connections change in the unity and zero check modes). The output of the preamplifier becomes an extremely low level signal as the bridge is adjusted nearer to balance and significant noise rejection and signal detection techniques must be used. The preamplifier is an extremely low noise amplifier followed by a supply frequency notch filter. This passes signals at the carrier frequency, but shows a high degree of attenuation for signals at the supply line frequency and it's 3rd harmonic. The filter circuit also shows significant roll off for frequencies above and below the carrier frequency. In this way a high level of noise rejection is achieved before the detector circuit. Figure 4.5 shows a block diagram of the signal detector arrangement.

Following the supply frequency notch filter the signal is amplified by a gain control circuit. The gain is selected by the operator using the front panel selector switches.
The filtered, amplified, signal is then passed to a phase sensitive detector. The reference signals for the phase sensitive detector are derived from the inductive divider excitation voltage. The inputs to the inductive dividers are fed through the buffer amplifier to a squaring circuit. This produces a square wave in phase with the carrier waveform. The output of the squaring unit is used as a control input to a phase locked reference generator. This produces four waveforms synchronized to the carrier generator waveform. The phase relationships of these waveforms are therefore precisely controlled. The detector pair are at 0° and 180° with respect to the carrier and drive the phase sensitive detector. The quadrature pair are at 90° and 270° to the carrier and provide the reference signals for the quadrature detector.

The detected in phase signal from the phase sensitive detector is DC level and is fed through low pass filters of 0.1, 1 and 10Hz bandwidths which can be selected by the front panel bandwidth selector switches. This signal can be selected for display on the front panel meter by the operator using the front panel meter select push buttons.
The 1Hz bandwidth signal is available at the rear panel connector SKT2. The unfiltered DC signal from the phase sensitive detector is also available at the rear panel from connector SKT1.

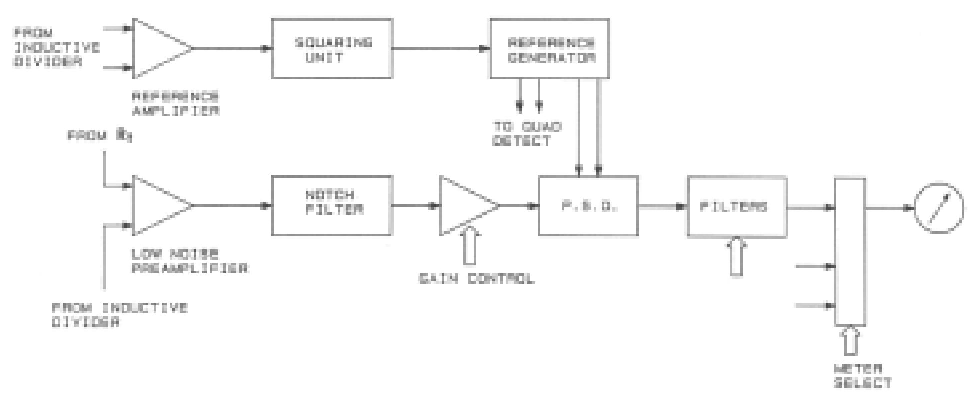


Figure 4-5. Phase Sensitive Detector.

4.1.6. Quadrature Servo Control

The amplified bridge signal from the supply frequency notch filter is fed to a quadrature phase sensitivity detector as shown in Figure 4.6. This produces a DC output proportional to the signal level that is in quadrature to the carrier signal.

Quadrature signals arise due to reactive loading of the bridge by the sensing elements R_S and R_t which may not be perfect resistors and by the series and stray loads associated with their connecting cables.

The output of the quadrature detector is passed through an integrator to give a DC level of limited bandwidth. This signal is available for display on the front panel meter and is used as the input to an overload detect circuit. This circuit triggers, turning on a front panel indicator if the quadrature signal exceeds preset levels.

The detected quadrature signal is also used to drive the quadrature control servo circuit. The integrated DC level is applied to one input of an analogue multiplying unit. The other input is taken from the reference amplifier and is the buffered carrier generator signal. The output of the multiplier is therefore an AC signal proportional to the quadrature level. This is fed to one side of a mutual inductor which is in series with the signal from the inductive divider. The effect of the mutual inductance is to reduce the quadrature loading on the bridge by pulling the phase of the detected signal. The mutual inductor appears as a reactive load that cancels the other reactive loads on the bridge. The effect of the integrator in the circuit is to drive the multiplier/mutual inductor in a direction to reduce the net quadrature load in the bridge and to hold the drive level once the quadrature level is reduced to zero.

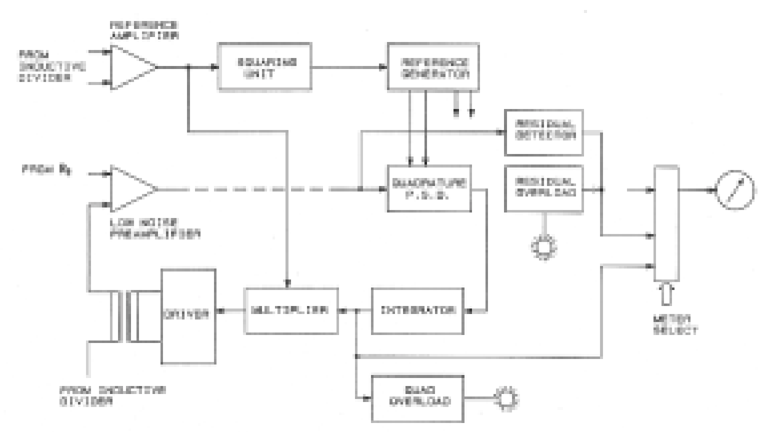


Figure 4-6. Quadrature Servo-Control.

4.1.7. Residual Overload Detector

The residual overload detector is a non-synchronous level detector. It monitors the signal level at different points in the preamplifier to phase sensitive detector filter-amplifier chain. If the signal level at any frequency exceeds preset limits, the overload detector will trigger, and the front panel indicator will light. If the overload warning light shows check the balance and gain settings. Balancing the bridge and/or reducing the gain should clear the problem. If the fault light continues to glow there may be excessive noise entering the system. Normal operation of the bridge can be verified using the unity and zero check facilities. If the overload light persists in these modes the unit either has a fault or is subject to an excessively noisy environment. On the other hand, satisfactory operation implies that the fault lies in the thermometer and it's connections and screening should be checked.

4.2. Resistor Connection

The Model F700 Bridge is designed to operate with four terminal resistors or four terminal resistance thermometers and includes comprehensive guarding circuits.
Two terminal resistors should be converted to four terminal devices to take full advantage of the unit's features.

4.2.1. Connection and Guarding

Coaxial connectors are provided for connections to each resistor. The normal four terminal connection arrangement is shown in Figure 3.2. As shown in the diagram the right-hand cable is the current drive and should be connected to the "I" connector of the Model F700 Bridge. (The lower coaxial connector of the R_S and R_t connector pairs). A single outer conductor is driven from a low source impedance and effectively screens the returning current on the inner line.

The left-hand cable in Figure 3.2 is the voltage sense line and should be connected to the "V" connector of the Model F700 Bridge. (The upper coaxial connector of the R_S and R_t connector pairs). The inner conductor is connected to the 'low' point and the outer to the 'high' point of the resistor, i.e. the screen connects to the voltage terminal on the same side of the four terminal resistor as the screen of the current drive cable. This point is the driven, 'high' point of the resistor. The inner conductor is connected to the 'low' point of the resistor and is the same end as the inner conductor from the current drive cable. In this way, the outer cable screens are driven and provide screening for the low side of the resistor and cable inner conductors.

Additional guarding is provided by the guard circuit. This drives the "tail" of the bridge so that the common point of R_S and R_t is held at virtual ground potential. This common point is the low point of each resistor. Hence the high points are at opposite ends of the bridge and are each driven, but with opposite polarity. Although the low point of the resistors are held near earth potential by the guard amplifier, this is not a true earth and electrical connection other than the two bridge cables should be avoided. Where connections cannot be made directly to the resistor assemblies it is recommended that the join between the resistor leads and the coaxial cables is made with the FA-3 adaptor box. Flying leads from the resistor assemblies should be twisted in two pairs, the current "I" leads together and the voltage "V" leads together.

4.2.2. Use of two Terminal Resistors

Two terminal resistors can be used with the Model F700 Bridge, if they are first converted to four terminal devices. An extra lead should be soldered on to each lead of the two terminal resistor, as shown in Figure 3.3. In the case of a two terminal thermometer an FA-3 adaptor box should be used. The thermometer leads should be connected so as to link the two high terminals together and likewise for the two low terminals. Standard coaxial cables should be used for connection to the Model F700 Bridge.

4.2.3. Resistor Current Selection

The normal resistor current setting is 1mA higher and lower setting can be used. To maintain the bridge within operating limits the IR volts drop on the standard resistor should not exceed about 0.7 volts rms. This limits the R_S resistor to about 400 ohms when using the 1mA current setting so that the $\sqrt{2}$ multiplier will still be effective. High value resistors must be operated with a lower current setting. The R_t resistor value is limited to about 4 times the R_S resistor value. On the other hand, low value resistors (below 10 ohms) may develop too small a voltage to give an adequate signal to noise ratio and higher current settings may be required. Inevitably, for a given resistor higher currents lead to higher self heating effects. The √2 current multiplier will cause a doubling of the power developed across each resistor and can be used with the other current settings to estimate the effect of self heating on the resistor being measured.

4.3. Applications

The Model F700 bridge finds applications in resistance measurement, temperature measurement and temperature control. Typical connections and operating procedures for these modes of operation are discussed below.

4.3.1. Resistance Measurement

4.3.1.1. Ratio of Two Resistors R_t/R_S

Connect the standard to the R_S connectors and the unknown resistor to the R_t connectors, as shown in Figure 4.7. Depress the Internal/External push button switch to select external mode. Set R_S Trim push button switch to switch the R_S Trim potentiometer out of circuit. Set meter sensitivity to x10, (x100 for 1 ohm R_S), variable sensitivity 7 and the current as required. Balance the bridge, that is bringing the meter needle as near to zero as possible by adjusting the thumb-wheel switches. The ratio R_t to R_S can now be read directly from the digital display and an estimate of the next decimal place made from the meter zero error.

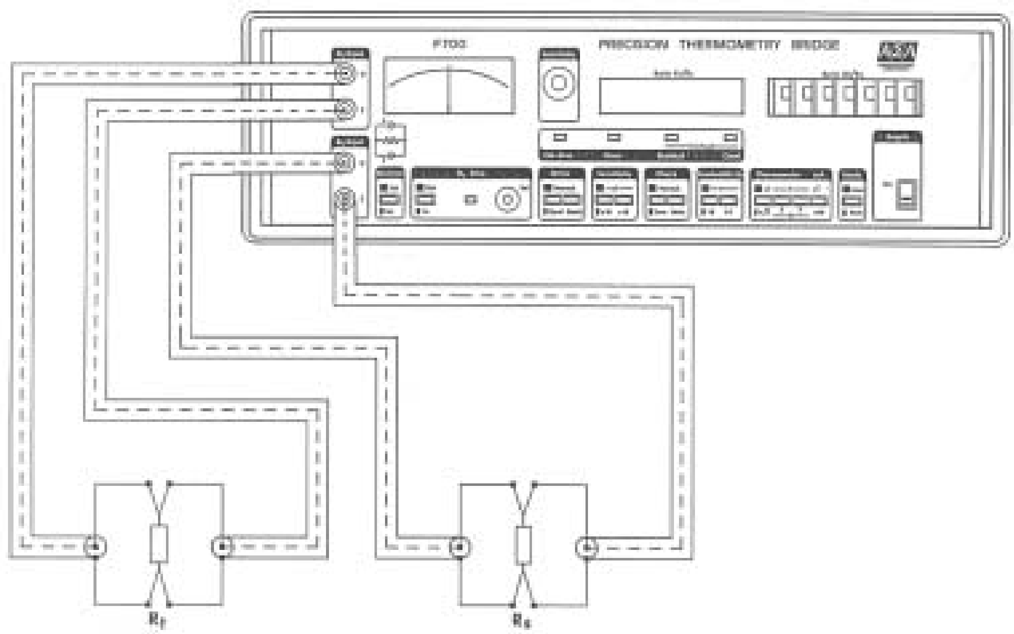


Figure 4-7. Ratio of Two Resistors.

4.3.1.2. Measurement of Unknown Resistance Relative to Internal Standard

Connect the unknown resistor to the R_t connectors as shown in Figure 4.8. No connections are needed to R_S connectors, but an external resistor could be left connected. Select the internal reference resistor, the INT/EXT push button switch should be depressed. Depress the R_S Trim push button to switch out the R_S Trim potentiometer. Set the meter sensitivity to x10, variable sensitivity 7. Set the bridge current as required. Balance the bridge using the thumb-wheel switches. The ratio of the unknown resistor to the 100 ohm internal reference resistor can now be read from the digital display and the meter error gives an indication of the next decimal place.

The actual resistance can be obtained by moving the indicated decimal point two places to the right, and is accurate to better than 0.01% of the internal 100 ohm resistor, i.e. better than 0.01 ohm. This accuracy is equivalent to 100ppm, but the precision and temperature coefficient of the Model F700 Bridge is better than 1ppm of FS. Absolute accuracy of this order can be achieved if the internal resistor and bridge indicators are first calibrated against an external standard and corrected using the R_S Trim facility.

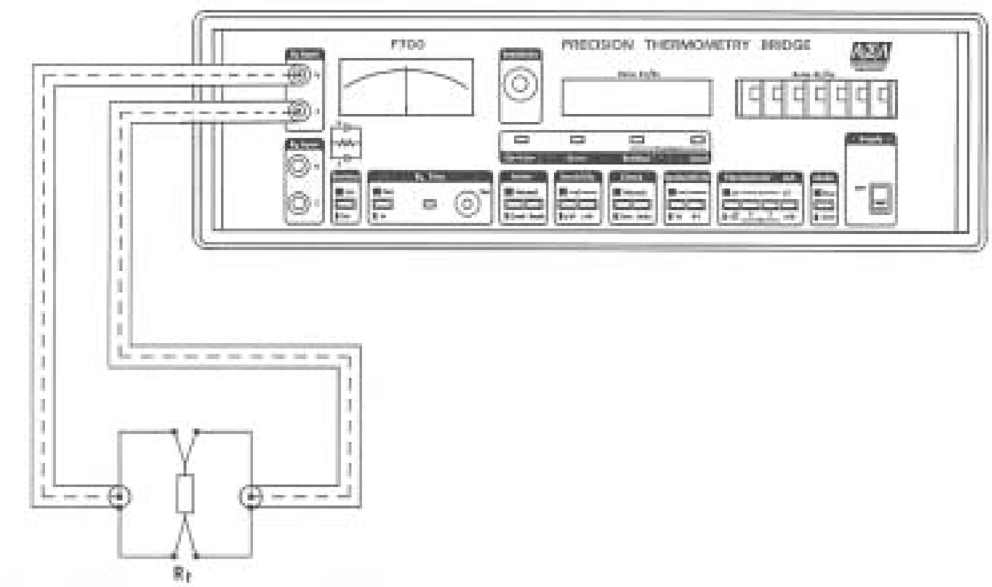


Figure 4-8. Ratio of a Resistor to the Internal Reference Resistor.

4.3.1.3. Calibration of the Bridge for Absolute Resistance Readout

Connect a known standard resistor R_F to the unknown resistor connectors labelled R_t, as shown in Figure 4.9. R_F may be in range 1 to 399 ohms, but a nominal 100 ohms is preferred. Set the thumb-wheel to the value of R_F/100. Set R_S Trim potentiometer to mid point, 5.0 turns from the end stop and selected with the front panel push button in. Select the internal reference resistor, the INT/EXT push button switch should be depressed.

Set the meter sensitivity to x10. Set the bridge current, as required, for the standard resistor. Balance the bridge, i.e. bring the meter needle to zero, by adjusting the R_S Trim potentiometer. Lock the potentiometer taking care to maintain the bridge balance. The internal reference is now calibrated to 100 ohms to better than 1ppm
$\pm$ the uncertainty of calibration of the standard R_F providing the R_S Trim facility is selected.

4.3.1.4. Absolute Resistance Measurement

Calibrate the internal reference resistor as in 4.3.1.3. The thumb-wheel switches are now calibrated in absolute terms. Disconnect the reference resistor R_F and connect the unknown resistor R_t. Leave the R_S Trim circuitry selected, and then balance the bridge as in section 4.3.1.2. Multiply the indicated ratio by 100 to obtain the resistance of the unknown resistor R_t.

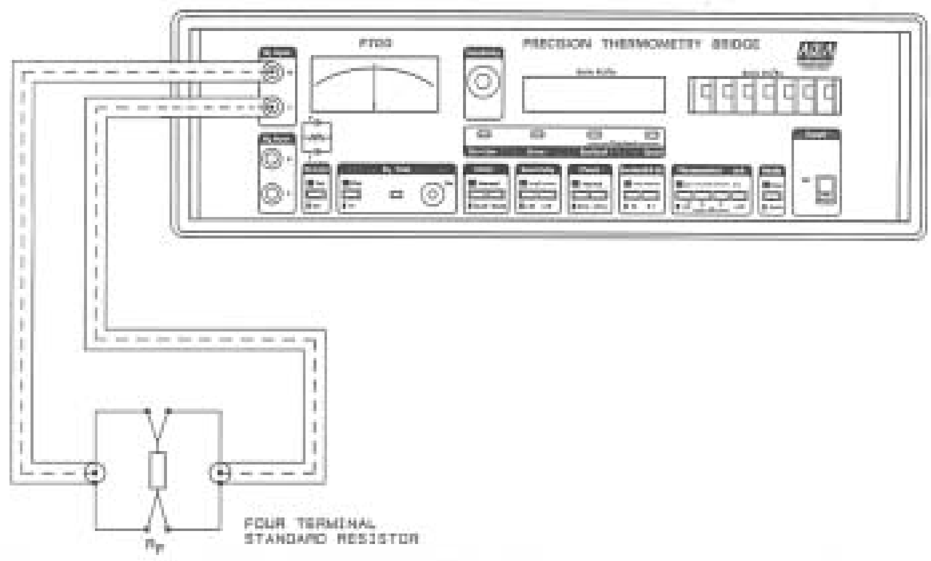


Figure 4-9. Calibration of F700 for Absolute Resistance Readout.

4.3.2. Temperature Measurement

The Model F700 Resistance Bridge is designed for use with a range of resistance thermometers. Calibration information for the resistance thermometer usually provides the following information:

R_O the actual resistance of the thermometer at 0°C.

R_t/R_O against T. Calibration data for the working temperature range of the thermometer. Preferred operating current of the thermometer. Self heating effect of the operating current.

Using this information, the Model F700 Bridge can be configured for temperature measurement in a number of ways dependent on the degree of accuracy required.

4.3.2.1. Temperature Measurement Against Internal Reference Resistor

Connect the four terminal thermometer to the R_t connectors of the bridge, as shown in Figure 4.10. The thermometer should be established in the experimental set-up as required. If long leads are required, it is recommended that an option FA-3 adaptor box be used in conjunction with low loss coaxial cables. Measurements are made using the following procedure:

Select the internal reference resistor, the INT/EXT push button switch should be dressed. Set the R_S Trim push button switch so that the R_S Trim potentiometer is out of circuit.
Select the appropriate push button switch for the thermometer current.
Select x10 100 ohm R_S meter sensitivity. Balance the bridge, i.e. set the meter to zero using the thumb-wheel switches.

The ratio of R_t to the internal R_S can now be read directly from the digital display. If the nominal resistance of the thermometer is 100 ohms, the same as the internal resistor, then the measured ratio can be used directly to obtain the temperature from the thermometer calibration data. For other values of nominal resistance of scaling factor must be applied to the measured ratio. Also accuracy by the above method is limited because the actual zero point resistance, R_O, for the thermometer may be significantly different from the nominal value. A more accurate measurement can be obtained for all thermometers by scaling the indicated ratio to take account of the true thermometer R_O value.

Hence: $$\text{True Ratio} = \text{Indicated ratio} \times \frac{100}{R_O}$$

The value of R_O can be obtained from the thermometer calibration data. Unfortunately, it may vary during the life of the thermometer and is a cause of error in temperature measurement. Furthermore, the above calculation assumes that the internal resistor is exactly 100 ohms. This is not so and an additional error is introduced. These errors can be overcome by first calibrating the thermometer and bridge using R_S Trim facility.

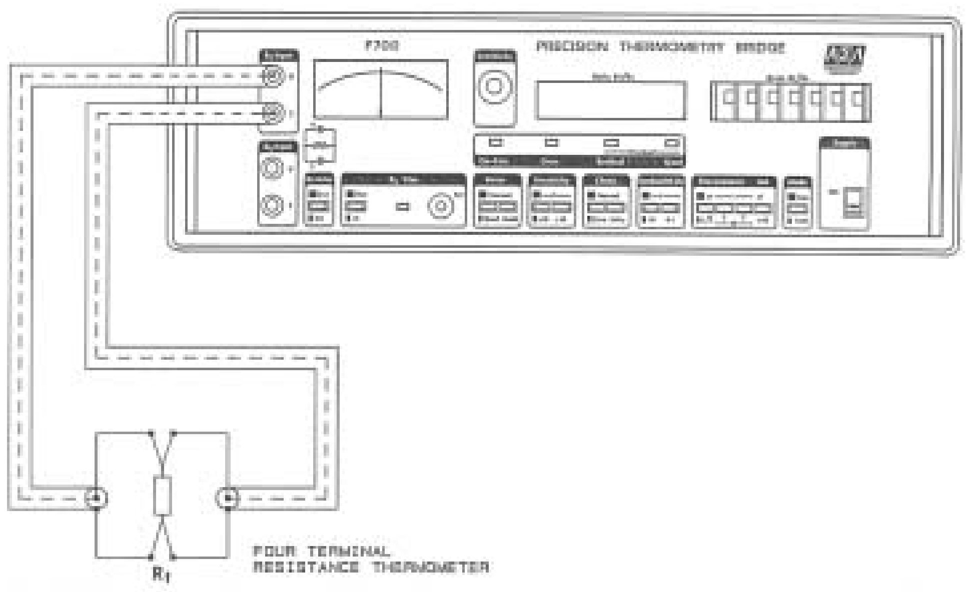


Figure 4-10. Temperature Measurement using the Internal Reference Resistor.

4.3.2.2. Calibration of the Model F700 Bridge using the R_S Trim

Connect the resistance thermometer to the R_t connector, as shown in Figure 4.10. Establish the thermometer in a test apparatus set up for temperature measurement at a known temperature such as the triple point of water and allow the system to stabilize.

Select the internal reference resistor, the INT/EXT push button should not be depressed. Set the thumb-wheel switches to the R_t/R_O ratio as given in the thermometer calibration certificate for the selected temperature. The ratio must be modified if the nominal R_O value of the thermometer is not 100 ohms. In this case the thumb-wheel switches should be set to:

$$\text{Ratio} = \frac{R_t}{R_O} \times \frac{R_N}{100}$$

Where R_t/R_O is given in the calibration certificate for the selected temperature and R_N is the nominal, 0°C, resistance of the thermometer. It is important that the calibration apparatus can be accurately set to the selected temperature, otherwise calibration errors will arise.

Select the appropriate thermometer current. Set the meter sensitivity to x10. Select the R_S Trim facility by depressing the R_S Trim push button. Adjust the R_S Trim potentiometer to balance the bridge, i.e. set meter to zero. Lock the R_S Trim potentiometer taking care not to disturb the bridge balance.

The bridge is now calibrated and can be used for temperature measurement. The calibrated bridge and thermometer assembly should be operated as in section 4.3.2.1, but the R_S Trim circuitry should remain selected. The true ratio is now given by:

$$\text{True Ratio} = \text{Measured Ratio} \times \frac{100}{R_N}$$

where R_N is the nominal resistance of the thermometer. For 100 ohm nominal resistance thermometer the ratio readout from the digital display can be used directly to obtain the temperature from the calibration data.

For a 25.5 ohm nominal resistance thermometer a scaling factor of:

$$\times \frac{100}{25.5}$$

must first be applied to the measured ratio. For other values of R_N an appropriate scaling factor must be used.

4.3.2.3. Temperature Measurement using an External Reference Resistor

An alternative approach for resistance thermometers with a nominal resistance that is not 100 ohms is to use an external standard resistor R_S of similar resistance. If required, the bridge arrangement can be calibrated using the R_S Trim facility to give a direct readout of the R_t/R_O ratio with a corresponding increase in accuracy.

Connect the Model F700 Bridge as shown in Figure 4.11. The thermometer is connected to the R_t connectors and should be established in a test apparatus set up at a known temperature such as the triple point of water. Allow the system to stabilize.

The standard resistor R_S should be connected to the R_S connectors. Note: R_S should have the same nominal resistance, as that of the thermometer. Bridge performance will depend on the quality of the R_S resistor used. Only a high quality stable resistor with a low temperature coefficient should be used.

Select the external reference resistors R_S. Set the thumb-wheel switches to read the R_t/R_O ratio for the set temperature, as given in the calibration certificate. Select the appropriate thermometer current. Set the meter sensitivity x10 100 ohm R_S, (x100 1 ohm R_S). Select the R_S Trim push button switch to enable the R_S Trim facility. Adjust the R_S Trim potentiometer to balance the bridge. Lock the R_S Trim potentiometer taking care not to disturb the bridge balance.

The bridge and thermometer are now calibrated at the set temperature. The bridge can now be used to measure other temperatures as in section a) above, but the external reference resistor and the R_S Trim circuitry should remain selected.

The measured ratio can be used directly to obtain the temperature from the thermometer calibration data.

If the bridge is not first calibrated, temperature measurements can still be made using an external reference resistor. A scaling factor must first be applied to the measured ratio:

$$\text{True Ratio} = \text{Measured Ratio} \times \frac{R_S}{R_O}$$

where R_S is resistance of the external reference resistor and R_O is resistance of the thermometer at 0°C as given in the calibration data. The measurements are made in section a) above, but with the external resistor R_S selected. In this uncalibrated mode, the R_S Trim facility is not used and should be switched out of circuit.

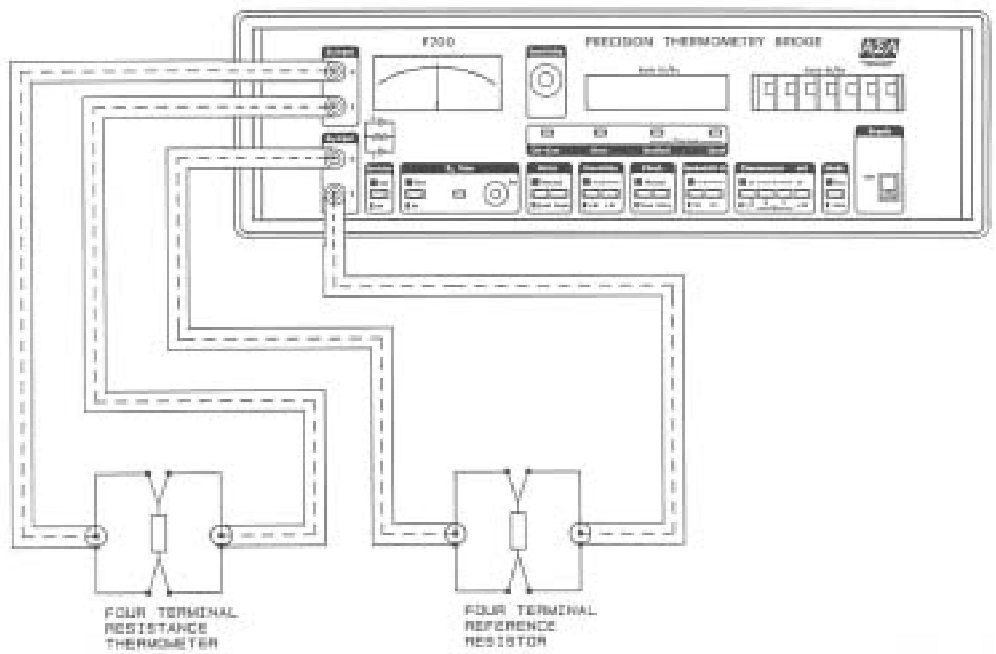


Figure 4.11. Temperature measurement with External Reference Resistor.

4.3.2.4. Checking Stability and Ageing of a Thermometer

Once the Model F700 Bridge has been calibrated for a given thermometer using the R_S Trim facility, the stability and ageing of the thermometer can be regularly checked. The thermometer should be set up in a test apparatus for measuring a known temperature such as the triple point of water, as in 4.3.2.2 or 4.3.2.3.

Select the R_S Trim potentiometer. Allow the system to stabilize. The bridge will balance if there has been no change in the thermometer's characteristics. Any imbalance indicates that the thermometer may need annealing and the thermometer/bridge system recalibrating, as above.

4.3.2.5. Differential Temperature Measurement

The Model F700 Bridge can be used for differential temperature experiments. Connect two thermometers, one to the R_t connectors and one to the R_S connectors, as shown in Figure 4.12. Following the procedure in a) above, the ratio R_t to R_S (internal) can be measured to give the ration N_1 which can be used to determine the temperature (R_t) thermometer. This is obtained when the INT/EXT push button switch is set to select the internal reference resistor. Selecting the external mode using the INT/EXT push button switch allows the resistance ratio of the two thermometers, N_2, to be determined. The following relationships can then be established:

$$N_1 = \frac{R_t}{R_O} \; \frac{R_O}{R_{SI}} \quad \text{(measured)}$$

where R_t is resistance of the first thermometer at the experimental temperature conditions.

R_O is the resistance of the first thermometer at 0°C.

R_{SI} is the actual resistance of the internal reference resistor.

$$N_2 = \frac{R_t}{R_S}$$

where R_S is the resistance of the second thermometer at the experimental temperature conditions.

if:

$$N_3 = \frac{R_S}{R_{ò}}$$

where $R_{ò}$ is the resistance of the second thermometer at 0°C.

then:

$$N_3 = \frac{N_1}{N_2} \; \frac{R_O}{R_{ò}} \; \frac{R_{SI}}{R_O} \quad \text{(derived)}$$

For differential temperature measurements we require to know:

$$\frac{R_O}{R_{SI}}$$

so that:

$$\frac{R_t}{R_O}$$ can be calculated.

From this, we can obtain the actual temperature of the first thermometer by referring to it's calibration data.

The R_S Trim circuitry can be used to set the ratio:

$$\frac{R_O}{R_{SI}}$$

equal to unity for nominal 100 ohm thermometers. This is done following procedure in 5.3.2.2. For thermometers of other nominal resistance scaling factors must be applied. Hence the actual temperatures for the two thermometers can then be calculated and the difference in temperature established. N_1 with INT/EXT push button switch set to internal, N_2 with INT/EXT push button switch set to external.
The derived ratio N_3 and the calibration data for the two thermometers gives sufficient information to establish the required data.

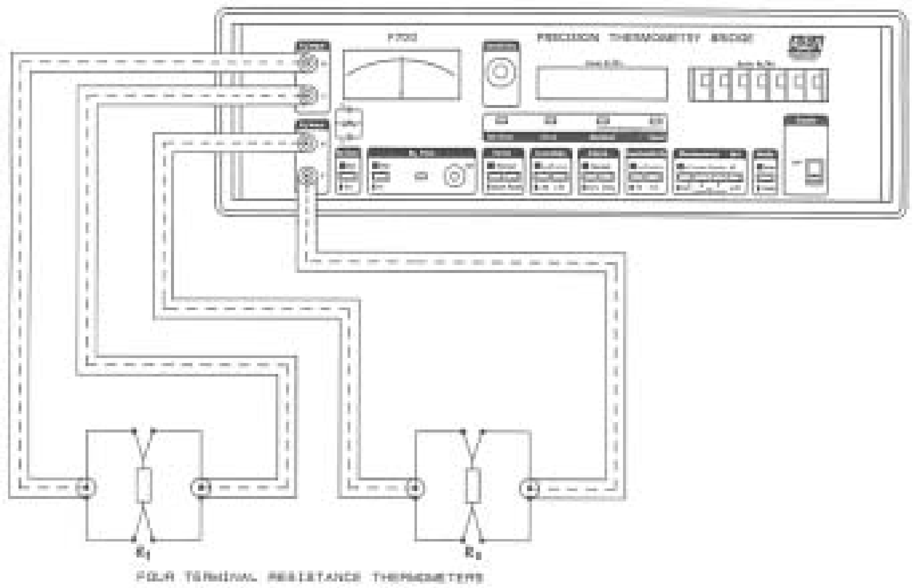


Figure 4.12. Differential Temperature Measurement.

4.3.3. Temperature Control

The bridge balance signal is available as an output on the rear panel of the Model F700. This DC signal can be used as an error reference input to a temperature control system. The measurement thermometer should be established in the apparatus to be controlled using one of the connection methods outlined in section 4.3.2, above. From the thermometer calibration data the required ratio of its resistance to the standard resistor for the required operating temperature can be established. This ratio (taking any scaling factors into account) should be set on the front panel thumb-wheel switches.

The output from SKT2 is proportional to the temperature error and can be used to drive the temperature control electronics. The Model F700 bridge output has a 1Hz bandwidth. The relative sensitivity can be set to x1, x10 or x100 by selecting the appropriate meter sensitivity push buttons.

Alternatively, the unfiltered output is available at SKT1, external filtering can then be used, but the internal gain settings are still active.

5. COMPUTER INTERFACING TO THE F700

5.1. RS232 Interface Option

Connection to this interface is via a 25-way D-type connector (male). The pins are configured as follows:

Pin no.

2	Tx	Data from F700
3	Rx	Data into F700
7	GND	GND reference
20	DTR	Wired true internally

5.1.1. Data Format

The interface is configured for 300 baud, 8 bits, no parity sent or checked and 2 stop bits. The F700 recognizes the following ASCII characters as valid commands. All commands may be sent in strings of up to 25 characters long. A line feed (ASCII 10) must be sent after each command or string of commands in order to terminate the data transfer.

5.1.2. F700 RS232 Commands

Bn - Bandwidth. Alters the bandwidth of the meter

BO	=	1Hz
B1	=	10Hz
B2	=	0.1Hz

Cnn - current. Alters the thermometer current

C00	=	0.1mA	C07	=	0.2 x √2mA
C02	=	0.5mA	C09	=	√2mA
C03	=	1mA	C10	=	2 x √2mA
C04	=	2mA	C11	=	5 x √2mA
C05	=	5mA	C12	=	10mA
C06	=	0.1 x √2mA	C13	=	10mA x √2

D — Outputs the ratio of the bridge along with status information. The ratio is only valid when the instrument is in the automatic mode.

The output string is of the form:

N.NNNNNNS Where S is the status

B = balanced

L = too low

H = too high

The output string is terminated by carriage return (ASCII 13) and line feed (ASCII 10) characters.

En	Sets internal or external standard resistor E0 = Internal Rs E1 = External Rs
Gn	Gain. Alters manual gain of bridge G0 = x1 G1 = x10 G2 = x100
L	Local lockout - disables front panel switches. Causes F700 to be controlled via the RS232 interface. Local lockout is set automatically with B, C, E or G commands. Sets the "on-line" LED.
O	Local lockout off - re-enables front panel operation of instrument. Switches off the "on-line" LED.
PN.NNNNNN	Preset. Sets the F700 to a ratio of N.NNNNNN The legal range is from 0.000000 to 3.999999.
Q or ?	Query. Sends the on-line settings of the F700 as a byte back to the computer. Decoding this byte (see Q or ? decoding table) provides the on-line settings of the F700 remote control functions.
S	Start. Starts the F700 rebalancing only.
K	Clear. Resets all commands and rebalances F700.
W	Wait. Holds F700 until re-start or cleared.

5.2. IEEE Interface Option

IEEE Interface can not be used with RS232 interface connected.

Important: Ensure that IEEE address code is set correctly on F700 Hex rotary switch. Factory default address is 9 (see IEEE address Hex rotary switch).

Each IEEE command or string of commands sent must be terminated with a carriage a line feed (ASCII 10).

Maximum of 30 characters can be sent to the instrument before termination. All commands will be carried out only after the termination sequence is found.

Figure 5.1. IEEE Address switch.

5.2.1. F700 IEEE Commands

Bn Bandwidth. Alters the bandwidth of the meter

BO	=	1Hz
B1	=	10Hz
B2	=	0.1Hz

Cnn - current. Alters the thermometer current

C00	=	0.1mA	C07	=	0.2 x √2mA
C02	=	0.5mA	C09	=	√2mA
C03	=	1mA	C10	=	2 x √2mA
C04	=	2mA	C11	=	5 x √2mA
C05	=	5mA	C12	=	10mA
C06	=	0.1 x √2mA	C13	=	10mA x √2

D Outputs the ratio of the bridge along with status information. The ratio is only valid when the instrument is in the automatic mode.

The output string is of the form:

N.NNNNNNS Where S is the status

B = balanced

L = too low

H = too high

The output string is terminated by carriage return (ASCII 13) and line feed (ASCII 10) characters.

En	Sets internal or external standard resistor E0 = Internal Rs E1 = External Rs
Gn	Gain. Alters manual gain of bridge G0 = x1 G1 = x10 G2 = x100
L	Local lockout - disables front panel switches. Causes F700 to be controlled via the IEEE interface. Local lockout is set automatically with B, C, E or G commands. Sets the "on-line" LED.
O	Local lockout off - re-enables front panel operation of instrument. Switches off the "on-line" LED.
PN.NNNNNN	Preset. Sets the F700 to a ratio of N.NNNNNN The legal range is from 0.000000 to 3.999999.
Q or ?	Query. Sends the on-line settings of the F700 as a byte back to the computer. Decoding this byte (see Q or ? decoding table) provides the on-line settings of the F700 remote control functions.
S	Start. Starts the F700 rebalancing only.
K	Clear. Resets all commands and rebalances F700.
W	Wait. Holds F700 until re-start or cleared.

5.3. Q or ? Command Decoding

To decode the data returned from the F700 temperature bridge when using the 'Q' or '?' status command.

The returned string is in the form of two hexidecimal numbers.

The left most number represents the current setting and the right most number represents the bandwidth and gain setting.

Current	C	C	C	C	Hex
0.1	1	1	1	1	F
0.2	1	1	1	0	E
0.5	1	0	1	1	B
1	1	1	0	1	D
2	1	1	0	0	C
5	1	0	0	1	9
10	1	0	0	0	8
0.1 x √2	0	1	1	1	7
0.2 x √2	0	1	1	0	6
0.5 x √2	0	0	1	1	3
1 x √2	0	1	0	1	5
2 x √2	0	1	0	0	4
5 x √2	0	0	0	1	1
10 x √2	0	0	0	0	0

Bandwidth & Gain	BW	BW	BW	BW	Hex
1 Hz & x100	1	1	0	0	C
1 Hz & x10	1	1	0	1	D
1 Hz & x1	1	1	1	1	F
10 Hz & x100	1	0	0	0	8
10 Hz & x10	1	0	0	1	9
10 Hz & x1	1	0	0	1	B
0.1 Hz & x100	0	1	0	0	4
0.1 Hz & x10	0	1	0	1	5
0.1 Hz & x1	0	1	1	1	7

6. Specification

6.1. Resistance Measurement Specification

The ASL Model F700 is a bridge instrument which measures the ratio of two, four terminal resistors, R_t and R_S. The following specification relates to the R_t/R_S ratio measurement.

6.2. Display Range

0.000000 to 3.999999

With a standard resistor of 100 ohms, the measured range of R_T is 0 to 399.9999 ohms in 0.0001 ohm steps selected by the front panel thumb-wheel switches. An estimate of the next decimal place can be made from the out of balance meter display.

6.3. Internal Reference Resistor

An internal reference resistor R_S mounted in a temperature controlled oven is provided.

Value:	100 ohms + 50ppm
	(settable via R_S Trim)
Temperature coefficient:	< 1ppm/°C
Long term stability:	better than 1ppm/month

6.4. External Reference Resistor

The external reference resistor may be any value in the range 1 to 1000 ohms.

6.5. Absolute Calibration

An R_S Trim control is fitted so that the bridge can be calibrated against an external standard or adjusted to compensate for variations from the nominal value of R_O when used with resistance thermometers.

Range of R_S Trim:	±100 ppm of R_S

6.6. Accuracy

Accuracy of Ratio R_t/R_S :	better than + 1ppm of FS or reference at ratio of 1.000000
	0.27mK (1ppm)

6.7. Resolution

Using a 100 ohm reference resistor, R_S, the least significant digit is equivalent to 10^{-4} ohms. Typically, a resistance change of 8 x 10^{-6} ohms can be read from the display meter when the bridge is operated with a 1mA drive current, sensitivity switches at 10 x 10, fine sensitivity at 7, BW 0.1Hz for a 100 ohm reference resistor. Under these conditions the smallest measurable change in resistance under an external monitor and a bandwidth of 0.1Hz is typically 8 x 10^{-6} ohms.

6.8. Lead Drive Impedance on the Bridge Resistors

Maximum series resistance	10 ohms per lead
Maximum shunt capacitance	10 nF across each lead

These are approximately equivalent to two 100 metre coaxial cables connected to each resistor, with a cable capacitance of 100pf per meter and a series resistance of 100m ohms per meter.

6.9. Current in Bridge Resistors

0.1, 0.2, 0.5,

1, 2, 5mA or 10mA

These are selected at the front panel with √2 and 0.1 multipliers.

6.10. Operating Frequency

The bridge operates at 1.5 times the local line frequency and is phase locked to it.

6.11. Bandwidth

10, 1 or 0.1Hz selected at the front panel.

6.12. Temperature Measurement Specification

The performance of the bridge as a temperature measurement device is also dependent on the quality and type of resistance thermometer used. The specification below is based on the bridge performance when operated with a high quality platinum resistance thermometer (100 ohm).

6.13. Temperature Range

4K to 962°C

Below 20K sensitivity for platinum resistance thermometers falls off and significantly limits instrument performance.

6.14. Accuracy

Better than 0.27mK at (0.00027°C)

6.15. Resolution

Least significant digit equivalent to 0.00027°C at 0°C

6.16. Typical Resistance Thermometer Performance

Typical Performance characteristics for platinum resistance thermometer (100 ohm) with a 100 ohm reference resistor and operated at 1mA sensor current are:

Temp	**R_t ohms**	**Sensitivity 1/R dR/dT**	**Mk/div.**	**Observable change. mK for detector bandwidth 1 Hz0**	**1 Hz**
600°C	318	1.03×10^{-3}	0.31	0.155	0.052
0°C	100	3.98×10^{-3}	0.25	0.044	0.015
-180°C	25.996	16.66×10^{-3}	0.23	0.023	0.008

6.17. Environment

Operating Temperature:	15°C to 25°C for full accuracy, 0°C to 50°C maximum.
Humidity:	Specified to 90% RH at 40°C non-condensing.
Power Requirements:	240VAC ±10%, 220VAC ±10%, 120VAC ±10%, 100VAC ±10%
	Supply Voltage range is user selectable on rear panel.
Frequency range:	47-63Hz.
Power consumption:	70 VA Max
Dimensions:	520mm wide, 155mm high, 466mm deep (20.47" wide, 6.1" high, 18.35" deep)
	NB: Additional clearance of about 50mm (2") is needed at the rear for cable entry.
Weight:	15 Kg (33 Ibs)

6.18. Communications

RS232C:	Factory set to 300 Baud, 8 bits, no parity and 2 stop bits
IEEE-488	factory set to address 9
Analogue:	SKT 1 Maximum output ±15 VppAC
	SKT 2 Maximum output ±10 Vdc

7. Cleaning and Maintenance

7.1. Cleaning

Make sure the F700 is turned off and unplug the mains supply cable.

Clean the outside of the instrument with a soft, clean cloth dampened with mild detergent. Do not allow water to enter the instrument.

WARNING Never use alcohol or thinners as these will damage the instrument.

Never use a hard or abrasive brush.

7.2. Preventive Maintenance

WARNING Regular inspection of the mains supply cable is required to ensure that the insulation is not damaged.

7.3. General safety Warning

WARNING If the F700 is used in a manner not specified by ASL, then the protection provided by the instrument may be impaired.

7.4. Routine Maintenance

The F700 is tested and calibrated before dispatch, using special procedures and reference standards. It is not normally practical for customers to effect repairs and calibrations themselves.

Maintenance tasks are therefore limited to keeping the instrument and its leads clean with occasional Cal checks. In particular the connectors for the resistors RT and RS should be kept clean to prevent leakage currents flowing. The outer of the BNC connectors and the cable braid are not at earth potential and should not be earthed. Damaged cable and connectors are a common cause of poor and intermittent operation.

If difficulties are experienced with the Model F700 Bridge the operator is advised to follow the procedures outlined on section 4.3 as an aid to 'trouble-shooting'. All serviceability and calibration problems should be referred to your supplier before returning an instrument for repair or recalibration.

8. Accessories and Options

The following accessories and options are available for the F700 Bridge:

FA-1	1 pair coaxial leads, BNC to BNC, 3 metres long
FA-2	1 pair coaxial leads BNC to open end, 3 metres long
FA-3	1 adaptor box (BNC to terminal and BNC)
FA-4	2 Terminal Binding Post to BNC - 2 OFF
T25-650-1	Standard reference PRT Ro = 25.5 ohms (nominal). 2 metre cable 4 wire plus screen with spade terminal connections. Stem length 450mm, quartz. R_{100}/Ro 1.3925 (min). Reproducibility 0.01K or better. Temperature range -189 to +650 °C.
T100-650-1	Physically similar to T25-650-1, but with Ro = 100 + 0.05 ohms. Suitable for use in laboratory environments, but not for general industrial applications. Temperature range -189 to +650 °C.
T25-660-1	Secondary transfer standard PRT 25.5 ohm 4 wire with 4 metres connecting cable to spade terminals. Temperature range 0 to +650 °C.
T100-450-2	Working reference PRT Ro = 100 ohms, 2 meter cable with spade terminals. Stem length 450mm stainless steel with quartz liner. Temperature range -100 to +450 °C. Alpha = 0.00385.
T100-450-3	As T100-450-2 except Alpha = 0.00392.
T100-600	Working reference PRT Ro = 100 ohms, 2 meter cable with spade terminals. Stem length 460mm quartz. Temperature range -50 to +600 °C. Alpha = 0.00385.
T0.25-962-1	High Temperature standards PRT. Ro=0.25 ohms. Temperature range up to 962 °C.
SB148/SB158	10 channel automatic/remote scanner. Expandable to 60 channels. IEEE-488 or RS232 compatible. Current source for unselected PRTs.
FR4	Four, oven controlled reference resistors for systems applications. 1, 10, 25 & 100 ohms.
RW	Oil filled Standards Resistors. 1, 10, 25, 100 & 1000 ohms.
RR	Laboratory Reference Resistors. 1, 10, 25, 100 & 1000 ohms.
RTE	Thermal enclosure for RW & RR resistors.
Soft700	PC compatible, graphical based Data Acquisition and Control Software.

9. Service and Warranty

F700 equipment and accessories, (unless stated otherwise), are covered by a 12 month warranty for parts and labor, but not including costs incurred in returning it to the factory for repair, from the date of dispatch from Automatic Systems Laboratories.

9.1. Technical Support

For all technical support, repair, warranty and service inquiries please contact:

Isotech North America
158 Brentwood Drive, Unit 4
Colchester, VT 05446
Phone: (802) 863-8050
Fax: (802)863-8125
Email: sales@ isotechna.com
Web: www.isotechna.com

9.2. Returned Instruments

All returned goods should be sent carriage paid, insured and packed well, to the above address.

9.3. Documentation

The shipment should include:

I. Your goods return note, a delivery note or an export invoice stating clearly GOODS RETURNED FOR REPAIR.

II. Your Company / Establishment order or contract reference number.

III. The name of your purchasing and technical contact.

IV. A brief fault report.

9.4. Repair Quotations

We shall be pleased to advise estimated repair costs upon receipt and initial inspection of returned goods.

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