Model TTI-7-R
Precision Digital Thermometer
Operators Handbook

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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 main 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

1.1 Overview

The TTI-7-R Precision Thermometer is a high accuracy instrument designed for laboratory and industrial temperature measurement and calibration applications.

Features include:

- unique dual capability for both thermocouple and resistance thermometer measurements;
- number of input channel can be expanded from two to ten channels;
- large graphic LCD display for temperature measurement values as well as configuration settings and statistical results;
- advanced functions include differential measurement, four programmable scanning routines, programmable timer, data logging to none volatile memory, statistical reporting;
- analogue output, IEEE 488 and RS232 communication interfaces available for automated monitoring and calibration applications;
- internal battery provides up to 20 hours mains free operation for remote measurement and data logging applications.

The TTI-7-R will operate with any Pt25 (25 Ohm) and all 2, 3 and 4-wire Pt100 (100 Ohm) platinum resistance thermometers as well as most standard international thermocouple types. Temperature measurement units are selectable by single front panel key operation; °C, °F,K Base measurement units mV, Ω are also displayed.

Resistance accuracy is better than ±4mΩ for Pt100 400 Ohm range and ±1.5mΩ for Pt25 100 Ohm range (over full range of –200 to 100°C at +20°C ±2°C). This is equivalent to temperature measurement precision of ±15mK for Pt25 thermometers and ±10mK for Pt100 thermometers. Total system measurement uncertainties as low as ±20mK are possible when the TTI-7-R is used with a calibrated reference thermometer.

Overall system accuracy depends on the PRT quality and calibration. See Section 9 for details of the system measurement accuracy specification.

Standard miniature and 4mm instrument sockets allow convenient connection for thermocouple inputs. Connection sockets incorporate integral temperature compensation sensors making high accuracy thermocouple measurement possible without the use of an external reference junction.

Standard features of the TTI-7-R Precision Thermometer include:

- direct temperature measurement display in °C, °F,K;
- 2 x Pt 25 or Pt100 channel inputs on front panel using 4mm gold plated spade lug connectors or wire/banana plugs;
- 2, 3 and 4 wire PRT probe measurement;
- Thermocouples B,C,D,E,J,K,N,R,S,T,U,W
- 1 to 20 probe coefficients for ITS90 or CVD entered and stored from programming PRT calibrations;
- High Accuracy to 0.01 deg.C over –200 to 660 deg.C
- High Resolution 0.001 deg.C for 25/100 Ohm PRT’s and 0.01 deg.C for TC’s;
- Measuring Range –200 to 1100 deg.C for PRT’s and 0 to 2315 deg.C TC’s;
- PRT self-heating and measurement current polarity selection;
- illuminated display;
- compact rugged case;
- 2 to 10 channel expansion with rear panel SPRT, RTD, and TC modules;
- Automatic Cold Junction compensation for TC’s;
- Switched DC (current reversal) option to eliminate thermal e.m.f.s on PRT’s;
- Internal data logging and storage of 4000 measurements;
- Statistical data internally (Min, Max, Peak/Peak, Average, Std. Deviation) ;
- Differential (Difference between any 2 channels connected) ;
- PC interface (RS232) included;
- Portable 20 hour use using internal battery + charger fitted or mains supply;

1.2 Definitions and Terminology

i. 0℃ = 273.15K

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

iii. 1 milli-degree C = 0.001 °*C* = 1m℃ = 1mK= 1.8m°F

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

v. Alpha, or Ω, is the temperature coefficient, or temperature sensitivity, of the platinum wire used in PRTs. In general, the greater the alpha value, the better the PRT thermometer measurement reproducibility, stability and performance.

vi. Abbreviations for platinum resistance thermometers include: PRT (Platinum Resistance Thermometer)

Pt100 (PRT with nominally 100Ω resistance at 0°C) RTD (Resistance Temperature Device) vii. Thermocouples are referred to as a TC element or TC sensor.

viii. The TTI-7-R 's thermocouple connection sockets are often referred to as a temperature compensated reference junction. See Section 1.3 for more details.

ix. System accuracy refers to the overall, combined accuracy of the TTI-7-R and thermometer.

Key functions and menu options are described as **[Function]** in the text or the actual keytop is shown.

General warning symbol. This indicates that a hazardous condition or general danger may exist. **You must read the relevant sections in the Operator's Handbook before operating the instrument.**

1.3 Principles of measurement

1.3.1 PRT measurement

The TTI-7-R measures the voltage (V_t) developed across the unknown sensor resistance (R_t) and the voltage (V_s) across a stable internal reference resistance (R_s) connected in series and passing the same current. The voltages are in proportion to the resistances so the thermometer resistance is derived from: $R_t = R_s \times V_t / V_s$
This technique achieves immunity from slow moving time and temperature drift in the electronics as it is not affected by voltage measurement gain variations or current source fluctuations.

In the same way that AC resistance measurement eliminates thermal EMFs, switched DC achieves a similar advantage. Switched DC works by reversing the current flow on alternate measurement cycles and taking the average value, thereby cancelling any thermal EMF offsets from the measurement.

For PRTs, the relationship between resistance and temperature varies slightly from one PRT to another. Therefore, no matter how accurately the TTI-7-R measures the PRT resistance, if the relationship between resistance and temperature for a particular PRT is not known, accurate temperature measurement is not possible.

The TTI-7-R uses PRT calibration data to overcome this problem and calculates temperature from temperature conversion functions stored in internal memory. This method enables the TTI-7-R accurately to convert resistance to temperature, uniquely for each PRT used. It is very important therefore that a PRT is used on the correct and properly configured input channel.

The system accuracy is a combination of the TTI-7-R accuracy in measuring PRT resistance and the calibration uncertainty placed on the PRTs by the calibrating laboratory. Using the TTI-7-R with PRT type 935-14-61, this is ±0.020°C for temperatures from -80°C to +350°C. See section 9.1 for PRT measurement performance details.

1.3.2 Thermocouple measurement

As well as the PRT resistance measurement facility the TTI-7-R also functions as a precision milli-voltmeter. Designed for high accuracy measurement over the EMF voltage range of all standard base and precious metal thermocouples, the TTI-7-R achieves a basic voltage accuracy of better than 3µV
(at +20 °C ±2 °C) over the full measurement range and significantly better over smaller ranges. See Section 9.2 for thermocouple measurement performance details. Thermocouple EMFs are converted to temperature using the NIST monograph 175 linearization functions. Special types C and D use the linearizations specified by ASTM E988.

The voltage input connection is specially designed to minimise the thermal gradient between the terminals. This is particularly important when the internal reference junction compensation is used, as any temperature difference at the connection junction will influence the measurement result. The connection junction is introduced in Section 1.3.3 below.

1.3.3 Thermocouple reference junction compensation

The electrical connection between the thermocouple element and the TTI-7-R input connector is often referred to as the internal reference junction. All standard thermocouple reference functions are defined relative to *0°C.* To eliminate the physical need to reproduce this temperature inside the TTI-7-R , the actual connection temperature is accurately measured with an internal PRT. This temperature is converted to an equivalent EMF and added to the actual thermocouple voltage measurement, thereby correcting for the connection temperature.

For high precision thermocouple measurement applications, i.e. calibration, an external reference junction may be used. Using an external reference junction eliminates the uncertainties associated with reference junction compensation.

2. Setting up the TTI-7-R

2.1 Safety information

Please read and follow these important safety instructions:

- Read the safety information sheet at the beginning of this handbook before operating the TTI-7-R ;
- Make the necessary electrical safety and connection checks. In particular, select the correct line voltage and make sure that the correct AC power fuse is installed. Incorrect voltage or fuse selection present both an electrical safety and a fire hazard.

2.2 Unpacking the instrument

When you unpack the TTI-7-R thermometer, check that the following items are present before starting to use the unit:

- 1x TTI-7-R thermometer
- 1x AC power cord
- 1x Operator's handbook
- 1x Calibration certificate

Please contact the ISOTECH NA Technical Services Group immediately if any of these items are missing or damaged.

2.3 Voltage selection and fuse rating

The AC Power Input Unit incorporates a voltage selector and fuse holder, to enable the TTI-7-R operating voltage and fuse rating to be selected for the local AC electricity supply. The table below describes the correct voltage selection range and fuse to use.

Voltage Selection	Voltage Range	Fuse Type
100V	90-110V	T630mA (250V AC)
120V	108- 132V	T630mA (250V AC)
220V	198-244V	T315mA (250V AC)
240V	216-264V	T315mA (250V AC)

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

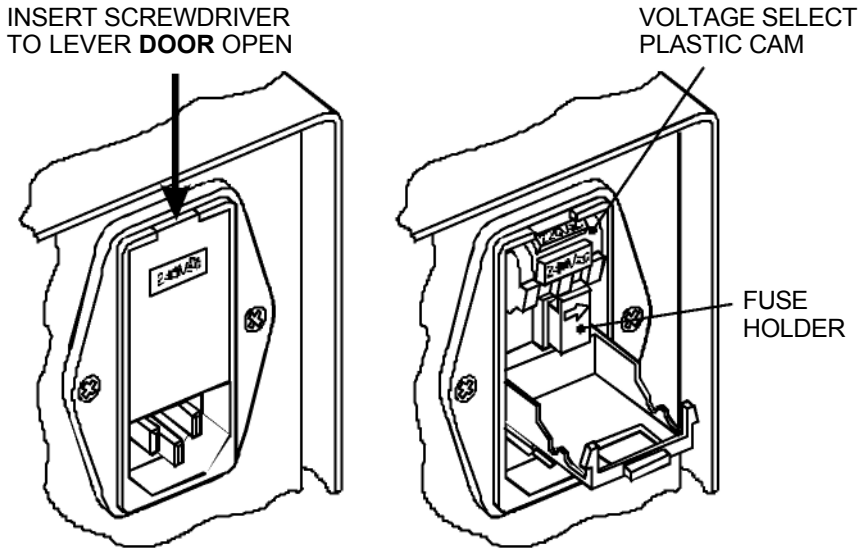
2.3.1 Setting the Voltage and Fuse Rating

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 as detailed in Figure 2.1.

Where fused plugs are connected to the AC power cord, the correct fuse rating is 3 Amps. The AC power cord provided with the TTI-7-R is colour coded in accordance with national standards to match the plug type fitted, as follows:

			
	Earth (protective conductor)	Green	Green/Yellow
	Live	Black	Brown
	Neutral	White	Blue

Figure 2.1 - Fused Power Input Unit and Voltage Selector



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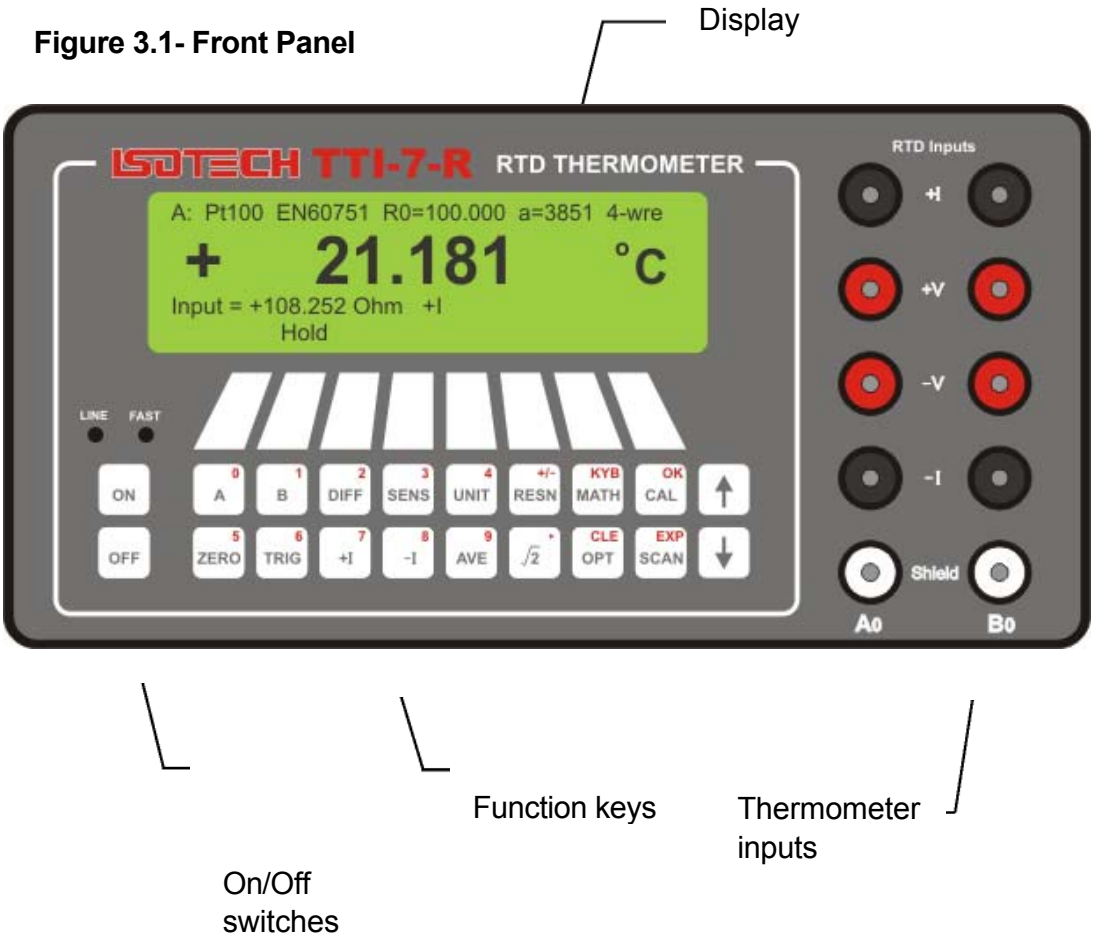
3. About the TTI-7-R

This section introduces you to the features and functions of the TTI-7-R Precision Thermometer.

3.1 The Front Panel

Figure 3.1- Front Panel



3.2 On/Off switch and internal battery

The ON / OFF keys switch the TTI-7-R on and off. During power on all TTI-7-R measurement functions are reset to their default state.

It is important to note that **THE POWER OFF FUNCTION DOES NOT DISCONNECT THE TTI-7-R FROM THE ELECTRICITY SUPPLY.** The power supply remains connected to the mains supply.

Battery charging operation is unaffected by the ON / OFF key operation.

The TTI-7-R 0 may be operated from the AC electricity supply or the internal battery. Fully charged batteries provide approximately 8 hours continuous operation. The internal battery charger operates whenever the electricity supply is connected. Front panel LEDs indicate connection to the AC electricity supply and when the battery is charging.

The batteries are a sealed lead acid type and require no routine maintenance. Continuous charging causes no harm to the batteries. Operate the TTI-7-R from the mains when possible to ensure the batteries are always fully charged.

<LOW BATTERY> indication is displayed when the batteries have approximately 10% charge or 50 minutes operating time remaining. To extend the battery operation time, switch the display backlight off. See Section 5.6.1.

If the batteries are left discharged for a long time, they become difficult to charge on the first re-charging cycle. During this first re-charge, it may not be possible to turn on the TTI-7-R . Leave the TTI-7-R connected to the AC electricity supply for at least 12 hours to allow the batteries to fully re-charge before using the TTI-7-R again.

3.3 The Function Keypad

All TTI-7-R measurement and programming facilities are accessed through the function keypad. A brief description of key functions is given in the table below. For a detailed description of how to use the keys to configure and operate the TTI-7-R , refer to Section 5.

Table 3.1 Summary of basic key functions

Key symbol	Description	Function	Direct function or Menu
Setting up Input Channels			
A	Select input channel A0 to A4	Selects and displays measurement channel A0 to A4	Direct from keypad
B	Select input channel BO to B4	Selects and displays measurement channel BO to B4	Direct from keypad
Diff	Select differential measurement Ch1 - Ch2	Relative measurement function which displays the difference between the Ch1 and Ch2 inputs	Direct from keypad
Setting up Measurement Options			
SENS	Temperature sensor type	Selects sensor type and measurement configuration for the selected channel	Menu
UNIT	Measurement units	Selects measurement display units: °C, °F, K	Direct from keypad
RES	Measurement display resolution	Selects measurement display resolution: Thermocouple: 0.1, 0.01 PRT:0.01, 0.001	Direct from keypad
ZERO	Measurement display zero function	Nulls the display at the current reading and displays measured values relative to the nulled value.	Direct from keypad
TRIG	Measurement run/ hold/single step	Display hold function, triggers single or continuous measurement.	Direct from keypad
Logging Data and Statistical Displays			
MATH	Math display functions	Selects the math menu statistical display and function	Menu
CAL	Calibration menu functions	Selects the instrument calibration menu functions	Menu
Options and configuration			
OPT	Setup options and functions	Selects the instrument configuration options menu and communication interface functions	Menu

(Table 3.1 continued:)

SCAN	Scanner, timer and data logger functions	Scanner, timer and data logger menu.	Menu
PRT measurement current			
+ I	PRT measurement positive current mode	Positive PRT measurement current polarity selection	Direct from keypad
-I	PRT measurement negative current mode	Negative PRT measurement current polarity selection	Direct from keypad
AVE	PRT measurement current reversal mode	Measures average sensor resistance with successive positive and negative current polarity Default PRT measurement state	Direct from keypad
□2	PRT measurement 2 current selection	2 measurement current division, reduces measurement current to allow PRT self heating effect to be calculated	Direct from keypad
Scroll and contrast control			
▲	Up command key; Display contrast, page scroll	Controls the display contrast and page scroll functions	Direct from keypad
▼	Down command key; Display contrast, page scroll	Controls the display contrast and page scroll functions	Direct from keypad

3.4 About the TTI-7-R Display

The liquid crystal graphic display clearly indicates the measured temperature and measurement status as well as displaying available menu options and measurement analysis when selected. Whilst in Temperature Mode (see Section 5.1), there are three possible display layouts:

Figure 3.2 - Main display layout (PRT measurement)

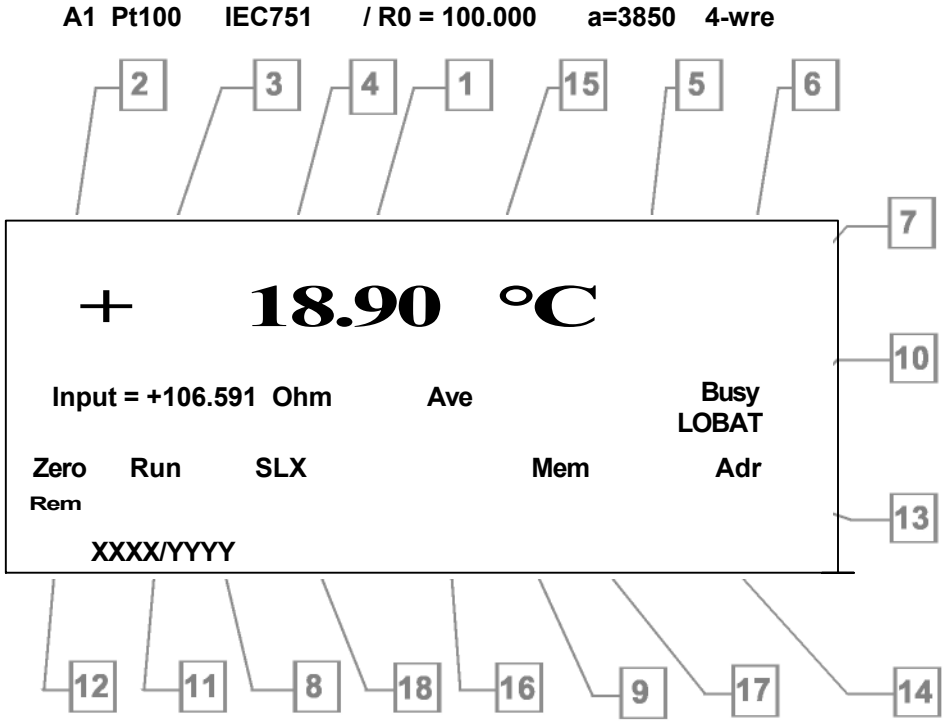


Figure 3.3 - Main display layout (Thermocouple measurement)

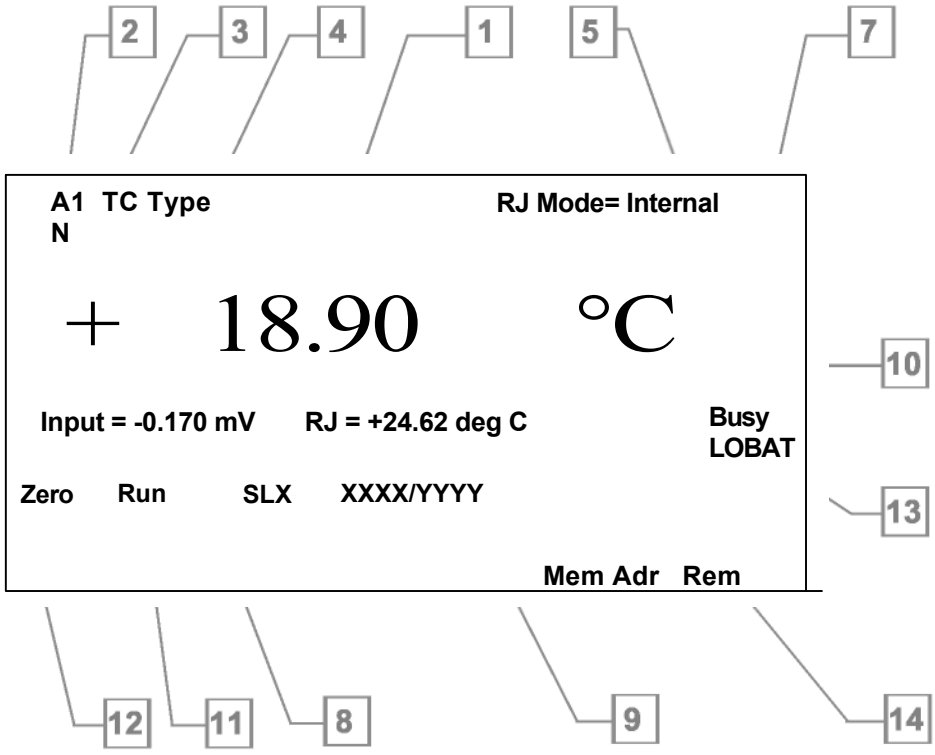
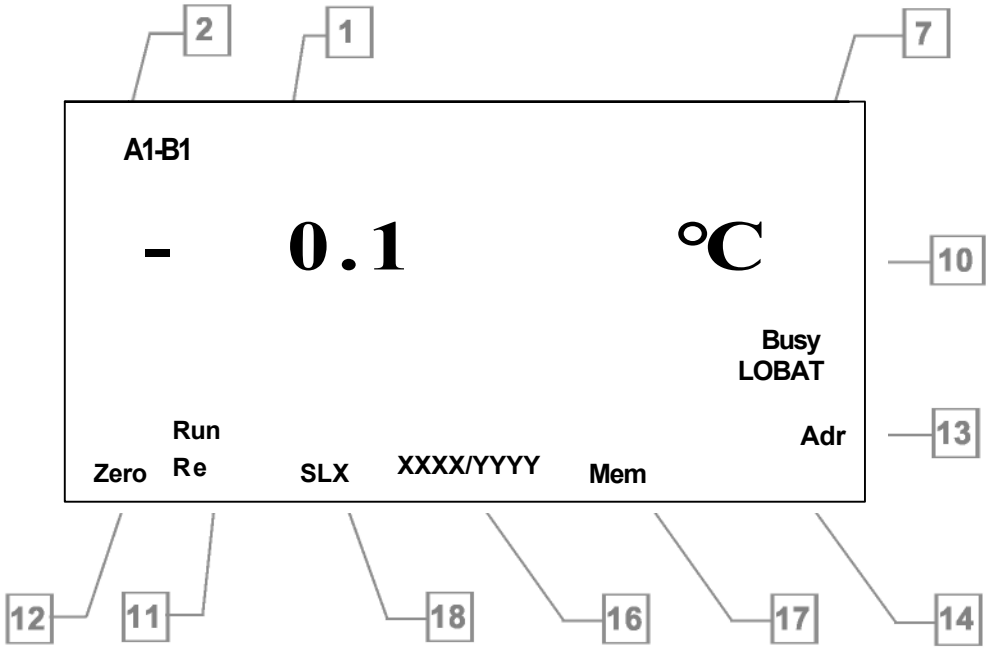


Figure 3.4 -Main display layout (Relative A1-B1 measurement)



The table below describes the location of information as it appears in the various display layouts:

Table 3.2 - Measurement mode display features

	PRT measurement	Thermocouple	Relative Ch1 - Ch2
1	Selected channel temperature	Selected channel temperature	Temperature difference between CM and Ch2
2	Input channel selected	Input channel selected	CM - Ch2
3	Pt100	TC	Not used
4	PRT linearization standard	Thermocouple type selected, letter designation	Not used
5	PRT alpha value	Reference junction mode	Not used
6	3, 4 wire measurement configuration	Not used	Not used
7	Temperature display units	Temperature display units	Temperature display units
8	Measured input value in Ohms	Measured input value in mV	Not used
9	Measurement current polarity	Reference Junction temperature if selected	Not used
10	Measurement status	Measurement status	Measurement status
11	Trigger run/ hold, single condition	Trigger run/ hold, single condition	Trigger run/ hold, single condition
12	Measurement zeroed indication	Measurement zeroed indication	Measurement zeroed indication
13	Low Battery indication	Low Battery indication	Low Battery indication
14	Re mote/Addressed remote operation	Remote/Addressed remote operation	Re mote/Addressed remote operation
15	R0 value in ohms	Not used	Not used
16	X samples taken of Y number of samples	X samples taken of Y number of samples	X samples taken of Y number of samples
17	Logging data to none volatile memory	Logging data to none volatile memory	Logging data to none volatile memory
18	Scanning mode ON SLx scan list	Scanning mode ON SLx scan list	Scanning mode ON SLx scan list

3.5 Thermometer inputs

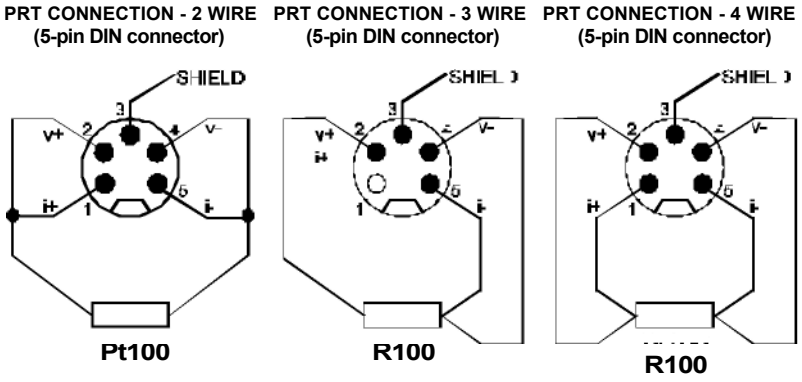
The TTI-7-R has two main thermometer input channels, the input sockets are located on the instruments front panel.

The two input channels can be independently configured for measurement of PRT sensors or thermocouples.

Separate connection is provided for PRTs and thermocouples, enabling easy direct connection of most thermometer types.

PRTs are connected via the 5 pin DIN sockets. You may connect 2, 3, or 4 wire PRTs as shown in Figure 3.5. See Section 5.3.3 on PRT selection. Un-terminated platinum resistance thermometers may be connected through an optional adapter box which is available as an accessory, (Part Number FA-ADAP-250). Refer to the Accessory section at the end of this handbook.

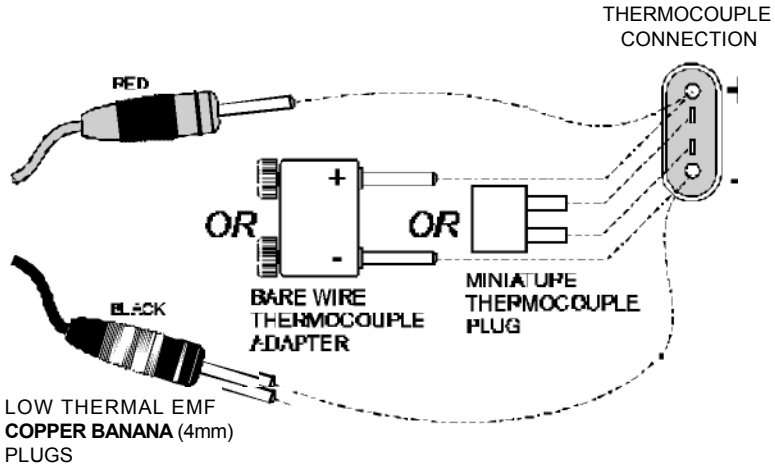
Figure 3.5 - PRT input connection configuration



View towards front panel connector

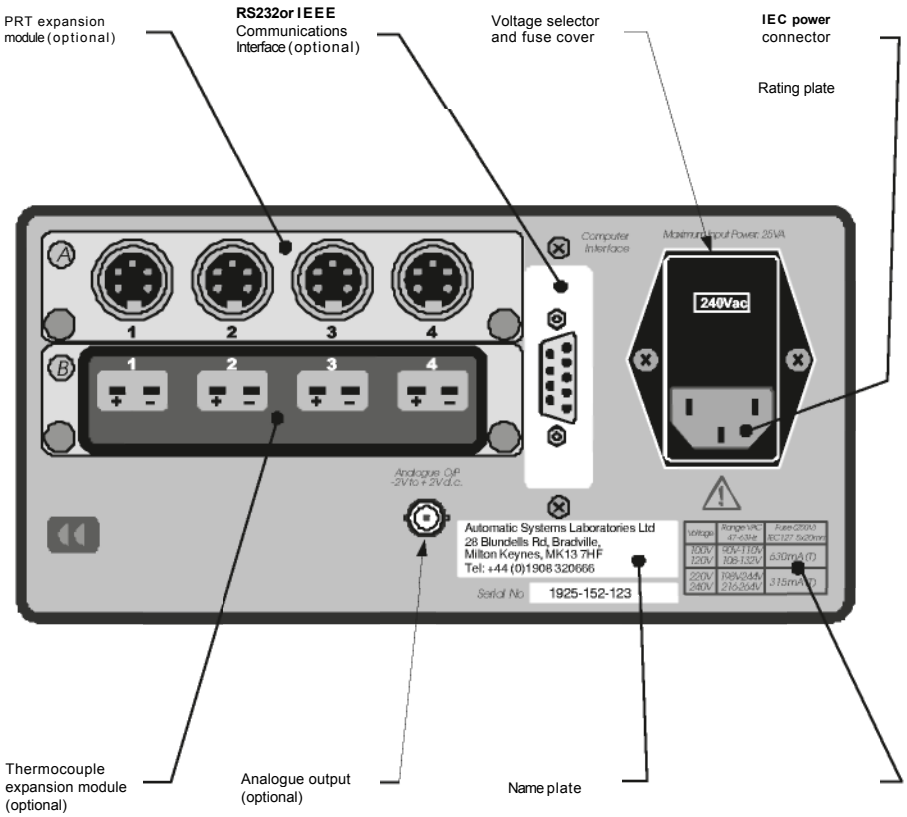
Thermocouples may be directly connected to the TTI-7-R either at the standard miniature sockets or the two 4mm instrument sockets as shown in Figure 3.6. Special adapter connectors are available for connecting bare wire thermocouples to the TTI-7-R . These sockets are within a temperature compensated isothermal block which eliminates the need for an external ice point reference junction. However, the TTI-7-R may also be used with an external ice point reference for high precision measurement and calibration work.

Figure 3.6 - Thermocouple input connection



3.6 Rear panel

Figure 3.7 - Rear Panel layout, showing all options



3.6.1 AC Power Input Socket

Accepts an IEC type power connector.

The AC power input unit incorporates a voltage selection tumbler, to enable the user to match the TTI-7-R to the local AC voltage supply, and a power line fuse holder.

3.6.2 Rating plate

Instrument rating plate, contains the AC voltage selection and line fuse rating, operating supply frequency range, the instrument maximum power consumption and instrument serial number.

3.6.3 Input channel expansion card

Optional input channel expansion card slots. Blanking plates are fitted if there is no input channel expansion cards.

3.6.4 RS232/IEEE 488.2 Communication interface card

Optional RS232/IEEE 488.2 communication interface card slot. A blanking plate is fitted if there is no communication interface card.

3.6.5 Analogue output

Optional analogue output BNC socket. A blanking plug is fitted if there is no analogue output.

3.6.6 Name plate

Instrument name plate, contains the manufacture name and address details.

4. Measuring Temperature

4.1 Measurement uncertainty and traceability

Measurement is usually made on the assumption that there is a true value. Whenever a measurement is performed it is unlikely that the measured value will equal the true value. The difference between the two values is the measurement error which will lie within the specified limits of uncertainty. Uncertainty is defined as an estimate characterising the range of values within which the true value lies.

By taking a statistically significant number of measurement samples, a distribution of results will emerge. Confidence in the distribution increases as more measurements are made. Using statistical methods, the distribution may be described in terms of mean, variance and standard deviation. The uncertainty or precision limit of a particular measurement is characterised by this distribution.

Traceability is defined as the property of a measurement that may be related to appropriate reference standards through an unbroken chain of comparisons. Through traceability it is possible to demonstrate the accuracy of a measurement in terms of SI units.

4.2 International temperature scale

The purpose of the International Temperature Scale is to define procedures by which certain specified practical thermometers including PRTs and thermocouples of the required quality can be calibrated. The values of temperature obtained from them can be precise and reproducible, matching at the same time the corresponding thermodynamic values as closely as current technology permits.

Since 1968 when the International Practical Temperature Scale of 1968 (IPTS68) was adopted, there have been significant advances in the techniques employed in establishing temperature standards and in the measurement of thermodynamic temperature. The International Temperature Scale of 1990 (ITS-90) gives practical effect to these improvements. Particular features are:

- ITS-90 specifies the use of the PRT up to the freezing point of silver, 961.*78 °C.* The platinum 10% rhodium/platinum thermocouple is no longer specified for use in the scale, though it and other noble metal thermocouples will continue to be used as secondary standards.
- New, more precise, fixed points have been introduced and mathematical procedures for calculating resistance temperature equivalents have been revised so as to reduce the 'non-uniqueness' of the scale: that is, to reduce the differences which occur between different, identically calibrated PRTs. In particular, the calibration of a PRT can no longer be extrapolated beyond the freezing point of zinc, 419.527 ℃, but requires a measurement at the freezing point of aluminium, 660.*323 °C.*
- Alternative definitions are permitted in certain sub-ranges, the calibration of a PRT can be terminated at almost any fixed point. This allows primary calibrations to be carried out with suitable PRTs over reduced ranges, and will be of special importance to metrology standards departments which need to make precise measurements at ambient temperatures.
- The part of the ITS-90 scale which may be measured by PRTs extends from 83.8058 K (-189.3442 °C) to 961.78 ℃. The TTI-7-R
  is specified to measure temperature over the range -200 °C to +962 *°C.* The actual range of temperatures which may be measured depends on the type and range of the PRT.

The ITS-90 scale has much improved continuity, precision and reproducibility compared with IPTS68. The implementation of the ITS-90 scale according to its definition calls for changes in equipment and procedure compared with IPTS68, but lower uncertainties of calibration are achievable in all parts of the range. However, the instruments and equipment needed to implement the ITS-90 scale in calibration laboratories will be substantially the same.

4.3 Thermocouple measurement introduction

Very broadly the thermoelectric effect occurs when an electrical circuit consisting of dissimilar metal conductors is subjected to a temperature gradient. An electric potential or voltage is developed along the conductors. This voltage potential varies proportionally with temperature and provides a means by which to measure temperature.

There are two categories of thermocouple:

- Rare metal, Platinum based types
- Base metal, Nickel based

Rare metal, platinum types are mostly used for high temperature precision thermometry. Maximum temperatures of 1700 °C and measurement uncertainties of up to 0.3 °*C* are possible. The sensitivity of platinum based thermocouples is usually in the region of 10µV/ °*C,* which means that high accuracy, high resolution measurements require sensitive instruments such as the TTI-7-R .

Base metal thermocouples easily account for the bulk of temperature sensors used today, and offer the advantages of being easy to package into a variety of sensor configurations and relatively low cost. Base metal thermocouples operate over a wide temperature range with high temperature types designed for use up to 1600 °C. Temperatures above 2300°*C* are possible with new high temperature tungsten rhenium types. Typical sensitivity figures of

>30µV/ °*C* characterise most of the base metal thermocouple family.

Base metal thermocouples are easily affected by contamination effects which results in decalibration and drift. This is especially pronounced at high temperatures where drift figures of the order of 10 °*C* are possible. It is important to be aware of the particular contamination effects and to select the correct thermocouple for the measurement environment. The N type thermocouple offers the best performance in terms of reproducibility and measurement uncertainty, operating up to 1250 °*C*. It is the best choice for most general measurement applications, calling for accuracy with low time and temperature drift.

4.3.1 Connecting thermocouples

Thermocouples measure temperature difference. As all practical thermocouples consist of at least 2 junctions, it is important when performing absolute temperature measurement that one of the junctions is referenced to a known temperature.

The reference junction and voltage measurement precision significantly influence the overall temperature measurement accuracy. Intermediate connection junctions such as connectors and extension cables between the measurement thermocouple and the TTI-7-R also influence the measurement result.

4.4 PRT measurement

The TTI-7-R will operate with either 25 Ohm SPRT's/PRT's or a range of 2, 3 and 4-wire 100 Ohm PRTs. The best performance will be achieved only where good quality PRTs are used from reputable, proven sources. As with any measured parameter, the performance of a measurement system depends upon its stability and repeatability. Low quality PRTs are likely to reduce system performance.

The relationship between temperature and resistance depends on several factors, including the alpha value and the PRT calibration.

Consequently more than one equation is required for resistance to temperature conversion. Calibration data for the PRTs takes the form of Callendar van Dusen coefficients.

ISOTECH NA Inc. provides a range of proven PRTs especially for use with the TTI-7-R , as well as offering a service to provide customised PRTs to meet individual customers' requirements.

High "alpha" PRTs: The best possible system accuracy is achieved using high "alpha" *(Ω)* PRTs, or more correctly, PRTs using high Ω (high purity) platinum wire.

Low "alpha" PRTs: Low Ω PRTs contain a higher level of impurities in the platinum resistance wire used. This affects the resistance value at a given temperature (the temperature coefficient). As impurities already exist in the platinum resistance wire, additional contamination has a reduced effect and hence low Ω PRTs are more immune to contamination and are therefore better for industrial applications. To ensure a robust PRT, the detector within the PRT is contained within materials, which can themselves be the source of contamination at elevated temperatures. The PRTs supplied by ISOTECH NA Inc. have been optimized for the temperature ranges for which they are specified and, when calibrated, are temperature cycled to enhance stability in use.

PRTs which are used outside their design and/or calibration temperature range, especially at higher temperatures, risk irreversible alteration to their calibration either by induced thermal stresses or by contamination.

4.4.1 PRT linearization functions

The TTI-7-R provides 3 standard and 20 user definable algorithms for converting resistance to temperature. The choice will depend on the type of PRT and its calibration. See also Section 9, which gives PRT sensor information.

IEC751 (1983):- used for un-calibrated industrial PRTs with 0.003850 "alpha" value, to provide a conversion of resistance to temperature in accordance with the IEC751 (IPTS 68) standard.

- EN60751 (1992):- used for un-calibrated industrial PRTs with 0.003851 "alpha" value, to provide a conversion of resistance to temperature in accordance with the BS EN60751 (ITS 90) standard.

- US/JIS:- used for un-calibrated industrial PRTs with 0.003916 "alpha" value, to provide a conversion of resistance to temperature in accordance with the JEMIMA standard.

Un-calibrated PRTs conforming to IEC751/DIN43760/BS1904 have traditionally used the IEC751 pre-programmed standard, which provides a conversion in accordance with published DIN43760 or BS1904 tables. These tables were created using temperatures defined by the superseded International Practical Temperature Scale of 1968 (IPTS68) and have inaccuracies compared with the International Temperature Scale of 1990 (ITS-90). ISOTECH NA Inc. has included the values for standard coefficients from IEC751 and the more recent EN60751 standards. The use of EN60751 is now recommended for use with uncalibrated industrial PRTs.

IEC751

Selecting IEC751 from the standard menu selects the standard coefficients from IEC751 (DIN43760/ BS1904 -based on IPTS68). The coefficients for IEC751 are as follows:

	Ro	A	B	C
IEC751	100 Ohms	3.90802×10^{-3}	-5.802×10^{-7}	-4.2735×10^{-12}

EN751

Selecting EN751 from the standard menu selects the standard coefficients from BS EN60751 based on ITS90. The advantage of this is that it removes the temperature conversion errors associated with the old IEC751 standard which is based on the earlier and superseded IPTS68. The coefficients for EN60751 are as follows:

	Ro	A	B	C
EN60751	100 Ohms	3.9083×10^{-3}	-5.775×10^{-7}	-4.183×10^{-12}

US/JIS

Selecting US/JIS from the standard menu selects the standard coefficients from JEMIMA for high alpha PRT reference thermometers. The coefficients for US/JIS are as follows:

	Ro	A	B	C
JIS/US	100 Ohms	3.97478×10^{-3}	-5.8775×10^{-7}	-3.4813×10^{-12}

Usr

Selecting Usr from the standard menu allows the coefficients provided with calibrated PRTs to be used in converting resistance to temperature.

Either 25 or 100 Ohm SPRT's/RTD's may be used and coefficients for ITS90 or Callendar Van Dusen entered. The instrument recognises from data entered under Ro if a 25 or 100 Ohm probe is being used and automatically adjusts the measuring range and measuring current.

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5. Operating the TTI-7-R

5.1 About the display screen

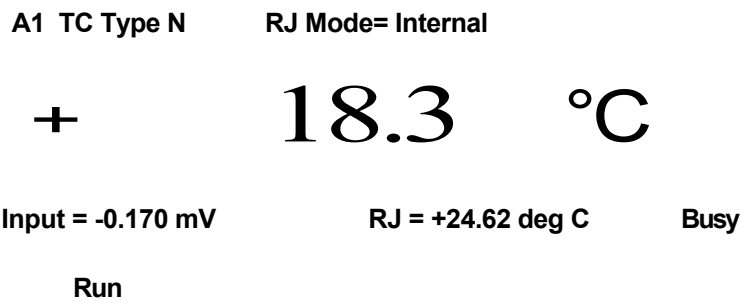
The TTI-7-R display screen is your direct link to the instrument, presenting you with information or menus that prompt you on what to do next.

It has two modes:

- **the Temperature Measurement Mode** which displays status information and a sequence of temperature readings;
- **the Configuration Mode** which lets you set up and configure the equipment.

Figure 5.1 shows an example of the **Temperature Measurement Mode** display. The top line of the screen gives status information: in this example, an N type thermocouple is connected to input socket A1 and the internal reference junction method has been selected. The temperature reading is displayed in degrees Celsius.

Figure 5.1 - Example of Temperature Measurement Mode

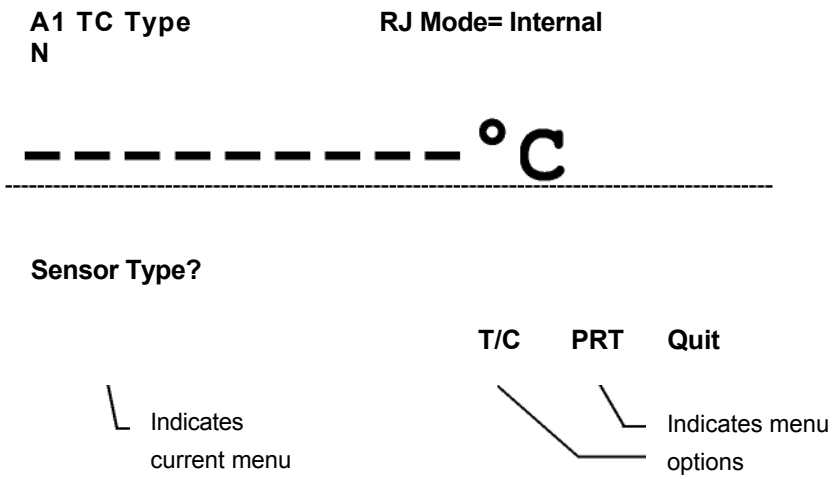


The keypad below the display screen controls the -R . Some keys perform a function directly. For example, pressing changes the temperature units. Other keys switch the display to configuration mode which allows you to select options through a series of menus.

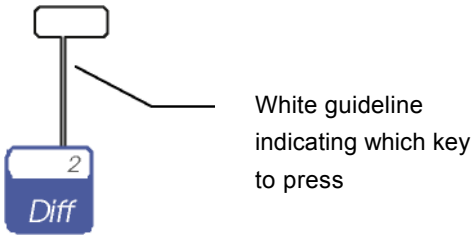
The option menus all follow the same format. The configuration mode is indicated on the screen by a dashed line displayed directly

below the main reading. An instruction prompt under the dashed line indicates the current menu. The available menu options are displayed on the bottom row of the display as shown in Figure 5.2. Press the corresponding function key to select an option.

Figure 5.2 - Example of Configuration Mode screen



A white guideline printed on the front panel helps you to link the menu option printed on the screen with the correct key on the keypad.



5.2 About function keys

You only use the top row of function keys to select menu options. The lower row of function keys are enabled only when entering numerical data; these instances are covered later in this section. Both rows of function keys are shown in Figure 5.3.

Figure 5.3 - Function keys

The [Quit] and [OK] menu options consistently use the QUIT/MATH and OK/MEM keys. Use the **[Quit]** key to leave a menu or return to the Temperature Measurement Mode screen. Use the **[OK]** key to confirm a particular choice and continue to the next set of menu options.

Not all function keys are used to access the Configuration Mode. Some just invoke the function which is printed on the key. For example, pressing 4/UNIT cycles you through a sequence of Celsius, Fahrenheit and Kelvin temperature units. If you miss the option you want, just continue until it is displayed again.

The rest of this section describes how to set up the equipment, log data and review the results. It also describes how to modify some of the settings, such as date and time. Some of these are reset to default values every time the machine is switched on.

5.3 Power-up sequence

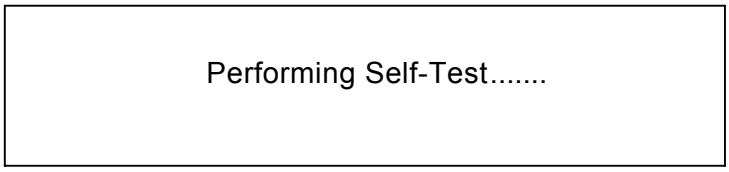
The instruments power on/off is controlled from the ON / OFF keys located on the TTI-7-R front panel.

On power-up, the TTI-7-R performs a memory self-test routine followed by a system configuration check.

5.3.1 Self-Test

On power-up the TTI-7-R performs a memory self-test routine

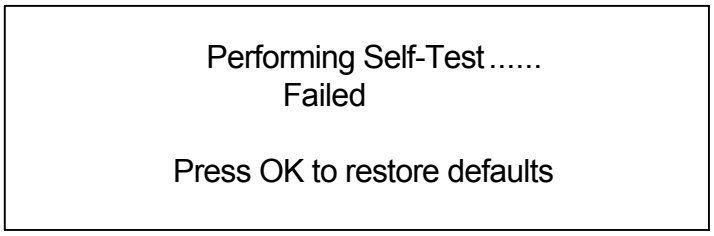
Figure 5.4 - Memory Self-Test Display



On successfully completing the memory self-test the TTI-7-R will report PASSED and proceed with a system configuration check.

If the memory self-test fails the TTI-7-R reports the message FAILED Press OK to restore defaults.

Figure 5.5 - Memory Self-Test Fail Display



Press the **[OK]** key to restore the instrument variables to the factory default values.

5.3.2 System Configuration

On power-up the TTI-7-R performs a system configuration check searching for input channel expansion cards or communication card. The screen displays:

Checking system configuration

The following information is read from each card on detection and displayed by the system configuration display for 2 seconds.

Communication card

RS-232, Baud rate, Character bits, Parity, Start bit, Stop bit.

IEEE488.2, Address.

Input channel expansion card

Card ID, Serial Number, Card type, Channel numbers.

Figure 5.6 - Example System Configuration Display

System configuration

RS-232 9600,8,0,1,2

Card A1	Sn12345	4Ch TC	Ch A1 to A4
Card B1	Sn30123	4Ch PRT	Ch B1 to B4

The system configuration can also be reviewed from the options menu.

After the power-up sequence, the instrument begins its normal operation.

5.4 Setting up Measurement Options

This section describes how to set up the TTI-7-R for your specific measurement requirements.

You need to select an input channel before configuring a probe.

5.4.1 Selecting thermometer input channel

To select an input channel with no input channel expansion cards fitted, press ′/A to select input channel **AD** or 1/B to select input channel BO.

To select an input channel with an input channel expansion card fitted, press ′/A to select channels **[A0 to** A4], press 1/B to select channel [B0 **to** B4]. The screen displays:

Enter channel number: (A or B)
Quit

Enter the channel number from the TTI-7-R function keypad at the A or B prompt. Select **[Quit]** to return to the main display.

The selected channel number is displayed in the top left hand corner of the display screen.

If a channel is selected that is not available the TTI-7-R will display an error message **channel not available** and prompt for a new channel number.

5.4.2 Selecting differential input measurement

Press 2/DIFF 1 to select differential measurement with no input channel expansion cards fitted.

To select differential measurement with an input channel expansion card fitted press 2/DIFF. The screen displays:

Enter channel number: (Ch1-Ch2):
Quit

Enter the channel numbers from the TTI-7-R function keypad, each channel number consists of a letter A or B followed by a single digit number, A and B are entered from the  and  function

keys. A differential measurement can be taken from any two available channels. Select **[Quit]** to return to the main display.

If a channel is selected that is not available the TTI-7-R will display an error message **channel not available** and prompt for new channel numbers.

The selected channels are displayed in the top left-hand corner of the display screen.

The TTI-7-R will displays the difference between the input channels **[Ch1-Ch2].**

5.4.3 Setting up a PRT measurement

Three standard PRT linearization functions are available. In addition, 20 user-definable memories are available for coefficients provided with calibrated probes. These memories allow calibration coefficients to be stored in the Callendar van Dusen form for high precision temperature measurement.

1.To configure a selected channel press 3/SENS .

2. For input channels **[A0] and [B0], the Sensor type?** menu will be displayed. Select **[PRT]** option, the **standard?** menu will be displayed.

Sensor type?T/C PRT
Quit

For PRT input channel expansion cards the **Standard?** menu will be displayed:

Standard?							
	Rev	IEC 751	US/ Jis	EN-751	Usr	Quit	OK

3. Next select a linearization standard from the list displayed on the screen. Note that you cannot start measuring temperature until you have made this selection.

The TTI-7-R is pre-programmed with three standard linearization standards (see Section 4.4.1) as follows:

i. **[IEC751]** IEC751 (1983)

ii. **[EN751]** BS EN60751 (1992)

iII. [US/JIS] JEMIMA

To choose one of these linearization standards, press the appropriate function key and then **[OK]** if you want to go on to configure 3 wire or 4 wire measurement or configure another channel. Otherwise press **[Quit].** The previous 3 wire or 4 wire settings will remain unchanged.

4. If you press **[OK],** the screen displays:

Connection?3W 4W
Quit OK

5. Select the connection option you want, select 4 wire measurement when using 2 wire PRTs.

6. Select **[Quit]** to return to Temperature Measurement Mode.

7. To configure all the channels of an expansion card to the same set up, select one of the channels on the card and follow steps 1 to 5 above. At the **Connection?** menu select **[OK],** the screen displays:

Select channel?
Ch- Ch+ All Quit OK

8. Select **[All]** to configure all the channels of the expansion card to the same set-up.

9. **[Ch-] and [Ch+]** can be used to select a channel without returning to the Temperature Measurement Mode.

10. On completion of configuring all the input channels select **[Quit]** to return to Temperature Measurement Mode.

5.4.4 Setting up a PRT measurement with user defined probe memories

1. Press 3/SENS and then the [PRT] function key. The screen displays:

```
Standard?
                IEC    US/    EN-
      Rev       751    JIS    751    Usr          Quit   OK
```

2. Select the **[Usr]** option. The screen displays:

```
Enter Probe #(1-20):

                                                  Quit   OK
```

3. Enter a number between 1 and 20 using the numbers on the keypad and then **[OK].** The number you have entered is shown on the top line on the display. If you make an error, press USER/OPTN and re-enter number. The TTI-7-R will only accept values in the range 1-20 and will signal an error if your entry is outside this range.

5.4.5 Setting up a PRT measurement: checking/editing probe memory co-eff. values

This allows you to assign coefficient values to probe memories or check the values already assigned.

1. Press 3/SENS and if PRT and TC inputs used, the screen requests [PRT] or [TC]. When only a PRT channel is available (NO channel expansion modules fitted) the screen shows:

Standard?						
	IEC	**US/**	**EN-**			
Rev	**751**	**JIS**	**751**	**Usr**	**Quit**	**OK**

2. Select the [Rev] option. If you have already selected one of the three standard linearizations, the four pre-programmed standard coefficients are displayed at the top of the screen. These cannot be altered.

3. If you want to enter a new set of coefficients, press User in 'Standard' screen above. The screen requests a probe coefficient set 1 to 20. Enter an empty memory box number, e.g. 11. The screen displays:

User 11 empty		
	Enter	**Quit**

4. Select enter. The screen shows:

IPRT	***SPRTCVD***	***ITS90***

5. Select required probe coefficient type, e.g. SPRT, ITS90 and the screen shows:

Ro Ap Bp Cp >>	**Quit**	**Ok**

.

6. Select and enter each coefficient in turn. (If no coefficient exists, do not enter any value). To enter the coefficient, e.g. –3.98e-2. first put in a – sign, then the number 3.98 from the front panel keys. For the exponential form, press the exponential key on the front panel (on the lower right

side) and then the number 2.

7. Go to the next page >> to enter the other coefficients. Dp, An, Bn, and Wt as in 6, above. Note: The coefficients entered can be viewed at the top of the screen.

8. Select Ok:

Save new coefficients	***Yes***	***No***

Select Yes.

9. If you are entering CVD coefficients, select CVD in item 4 above. Then proceed as in items 5, 6 and 7 to enter the Ro, A, B and C terms.

Note: The 20 probe memories are already calibrated with the BS EN60751 standard when the unit is shipped. This lets you obtain sensible results from the onset; you can go back and edit the probe coefficients at a later date, not necessarily at the time you select them.

5.4.6 Selecting thermocouple type

1. Press 

and then the [TC] menu key. The screen displays:

Thermocouple type?							
B	**C**	**D**	**E**	**J**	**»**	**Quit**	**OK**

2. Select one of the ten thermocouple standards supported; B, C, D, E, J are displayed on the first screen: K, N, R, S, T on the second. Switch between the screens with the [»] key. Type the appropriate key and then **[Quit].** Measurement will start as soon as you have selected the standard you want. The thermocouple type is displayed in the top left-hand corner of the screen.

5.4.7 Selecting the reference junction compensation method

1. You can select the reference junction compensation method after selecting the thermocouple type by pressing **[OK]** instead of **[Quit].** The screen displays:

RJ mode?

Off Int Ext Quit OK

The menu options list the three reference junction methods supported:

Menu option	Description	When used
[Int]	Internal reference junction compensation using the TTI-7-R 's internal temperature compensated copper isothermal junction. This is the default mode.	For direct temperature connection with no external reference junction. High accuracy measurement, requiring no additional connection reference junctions.
[Ext]	External reference junction compensation using PRT measurement of reference junction. No measurement channels are lost as the reference channel PRT uses the corresponding input channel.	For temperature controlled or ovenised reference junctions.
[Off]	No reference junction compensation applied to the measurement. All measurements are made with respect to 0 °C.	Used with an external ice point reference junction. Suitable for highest precision measurement.

Select the reference junction method with the appropriate function key.

If you have selected **[Off] or [Int],** you can now press **[Quit]** to start measurement.

5.4.8 Selecting ext. ref. junction PRT linearization whose temperature is measured by a PRT connected to the same channel.

1. **The [Ext]** menu option allows you to set up an external reference junction whose temperature is measured by a PRT connected to the same channel. When you select **[Ext]** you are prompted to choose the PRT linearization for this PRT, the screen displays:

Standard?

IEC 751 **US/ JIS** **EN-751** **Usr** **Quit** **OK**

2. This lets you choose one of three standard linearizations which can be used with uncalibrated probes. A fourth option, **[Usr],** gives you access to the 20 probe memories for Callendar van Dusen coefficients provided with calibrated probes.

3. If you want to select one of the standard linearization options, **[IEC751], [US/JIS] or [EN751]**, press the appropriate function key and then **[Quit].** Reference junction information is displayed at the top right hand corner of the screen, e.g.

RJ Mode= Ext US/JIS

4. If you want to access one of the probe calibrations already in memory, press **[Usr].** The screen displays:

Enter Probe #(1-20):

Quit **OK**

Use the keypad to enter the probe number and then press **[Quit].** **Section 5.3.5** describes how to enter user coefficients.

5.5 Selecting Screen Display Options

This section describes how to modify information displayed by the TTI-7-R . It covers:

5.5.1 Selecting measurement units

Press 4/UNIT to sequence between the three measurement units available. These are Celsius *(°C),* Fahrenheit (°F) and Kelvin (K). The measurement unit selected is applied to all temperature displays, including logged data.

5.5.2 Selecting display resolution modes

Press +-/RES to toggle between the two display resolution modes available. The table below gives the display resolutions for thermocouple and PRT inputs. The TTI-7-R defaults to low resolution mode when first switched on.

	High	Low
Thermocouple	0.01	0.1
PRT	0.001	0.01

5.5.3 Selecting relative temperature measurement

In Zero mode, the TTI-7-R displays temperature relative to a fixed reference point. Press 5/ZERO to store the current display value; this will be subtracted from all subsequent readings. To cancel Zero mode, either press 5/ZERO again, change the input channel, change the sensor type or turn off the power.

When Zero mode is enabled, a **Zero** message is displayed in the bottom left hand corner of the screen.

5.5.4 Using the measurement trigger function [Run/Hold]

The TTI-7-R default trigger mode is Run/Hold. It can also be configured

to operate in single shot mode. Press the 

key to alternate between continuous measurement (Run), and measurement hold (Hold). Measurement hold mode stops all measurement operations, freezing the current display value. It also halts all scanning and data logging operations. When measurement hold is enabled, a **Hold** message is displayed on the bottom line.

Press 3/TRIG again to resume measurement, scanning or data logging operations. A Run message is displayed on the bottom line and the message Busy flashes on every time a new temperature measurement is taken.

Setting the trigger mode to single shot mode is described in Section 5.6.3. In single shot mode, the TTI-7-R remains in the hold state until

you press the 3/TRIG key; it then captures a single measurement reading.

If you have scanning enabled this allows you to single step through the scanning routine.

If the data logger is enabled all the spot readings will be stored in the data log memory.

5.5.5 Selecting PRT measurement sense current

PRT measurement uncertainty can be affected by external EMFs and PRT self heating. The TTI-7-R allows you to select the measurement sense current magnitude and polarity so that you can evaluate the magnitude of such external factors.

a) Selecting positive measuring current polarity (+I)

Press /+1 for positive measuring current polarity. The measurement time is approximately 1.8 seconds per reading for channels A and B, and 3.6 seconds for Ch1-Ch2 relative measurement.

b) Selecting negative measuring current polarity (-I)

Press 

for reversed or negative measuring current polarity. The measurement time is approximately 1.8 seconds per reading for channels A and B, and 3.6 seconds for Ch1-Ch2 relative measurement.

c) Selecting average current

Press 9/AVE to select automatically alternated dc measuring current polarity switching at a rate of approximately O.SHz. Thermal EMF measurement errors are eliminated by taking the average value of the forward and reverse polarity readings. The measurement time is approximately 3.6 seconds per reading for channels A and B, and 7.2 seconds for Ch1-Ch2 relative measurement. The Average current mode is the power up default condition.

d) Selecting √2 current multiplier

This option reduces current through the probes by √2 (half-power), to determine any probe self heating. The best method of using this option is first to let the sensor reach a steady temperature and note the value. It may take some time to stabilise.

Press 

and immediately select 

the reduced current through the probe will reduce the heating effect on the probe, and the value displayed will represent the temperature change due to the reduced current.

When the reading has stabilised, note the temperature change. Add twice the temperature change to the original temperature (observing the sign; the final temperature should be lower than the original value). The result is the actual temperature with the effect of probe self heating eliminated.

5.6 Data Logger

The TTI-7-R is fitted with a very powerful easy to use data logger.

The data logger consists of three functions, each function can be used independently, or all three functions can be combined to provide the powerful data logger.

5.6.1 Data logger functions

Scan: The scanner function lets you switch between a number of input channels. Up to four independent scanning lists can be configured and stored in non-volatile memory. A scanning list consists of a list of channels, the timer cycle delay, sample rate and cycle count. Each scanning list can be quickly set-up, reviewed and edited.

Timer: The built in timer can be programmed to control the cycle delay, sample rate and the cycle count.

Mem: Up to 4000 readings can be stored to none-volatile memory with a time and date stamp for review later.

5.6.2 Setting up the data logger

Press the SCAN key to bring up the data logger menu. The screen displays:

Scanner is: Off		**Memory is: Off**			
Scan		**Timer**	**Mem**	**Quit**	**OK**

The first line of the menu shows the current configured state of the data logger modules.

Scanner is: Indicates the scanner is OFF or the selected scan list when the scanner is ON.

Memory is: Indicates the data logging to memory ON/OFF state.

5.6.3 Configuring the Scanner

To access the scanning list menu, select **[Scan]** from the data logger menu. The screen displays:

Scanning list is: Off							
SL1	**SL2**	**SL3**	**SL4**	**Edt**	**Off**	**Quit**	**OK**

Switching scanner on/off: Scanner OFF is the default state when the instrument is powered up. To switch the scanner ON select one of the scanning lists **[SL1] to [SL4].** To switch the scanner OFF select **[Off]** from the menu. The first line of the menu shows the current state of the scanner.

Edit a scanning list: To edit a scanning list, first select the scanning list to be edited, then select **[Edt]** from the scanning list menu. The screen displays:

Scanning list edit: SL1								
AD	**BO**	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	
<	**>**	**Add**	**Del**				**Quit**	**OK**

The scanning list edit menu can display up to eight channels on each page at a time, only available channels in the system will be shown.

To add or remove a channel from a scanning list, position the flashing cursor over the appropriate channel using the [<] or [>] options.

Use the **[Add] or [Del]** options to add or delete a channel to the scanning list.

Active channels in the scanning list are shown in reverse text (white on black), none active channels are shown in normal text (black on white).

Figure 5.7- Example of a scanning list

Scanning list edit: SL1							
A0	BO	A1	A2	A3	A4	B1	B2
<	**>**	**Add**	**Del**		**Quit**	**OK**	

Channels A0, A1, A2, A3 and B1 are active channels that will be scanned, the remaining channels will not be scanned.

5.6.4 Configuring the Timer

The instrument timer function can be programmed to control the measurement sample rate, cycle delay and cycle loop count. Figure 5.8 details the timer flow diagram for single channel data logging, figure 5.9 details the flow diagram for multiple channel data logging.

To access the timer edit menu, select [Timer] from the data logger menu. For single channel data logging (scanner off), the screen displays:

```
Cyc=Cont        Delay=00:00:00

<      >      Clear      Edit    Quit   OK
```

For multiple channel data logging (scanner on), the screen displays:

```
Cyc=Cont        Delay=00:00:00        Rate=00:00:00

<      >      Clear                  Edit      Quit   OK
```

To set-up the timer, use the [<] and [>] options to position the flashing cursor over the appropriate parameter to edit.

To set a parameter to its default value select **[Clear].**

To edit the parameter value select **[Edit],** the screen display:

```
Cyc=Cont        Delay=00:00:00        Rate=00:00:00
                                                  OK
```

Enter the required parameter value directly from the TTI-7-R numerical key-pad and select [OK] to return to the timer edit menu. Errors can

be cleared using the front panel 

key. Repeat the process for each of the timer parameters.

Timer Parameters

Cyc= Sets the number of scanning cycles required (1 to 9999 or continues), default value is continues.

Delay= Sets the required delay hh:mm:ss between scanning cycles (00:00:00 to 99:59:59 seconds), default is 00:00:00.

Rate= Sets the required delay hh:mm:ss between samples (00:00:00 to 99:59:59 seconds), default is 00:00:00.

Figure 5.8 - Single channel timer flow diagram

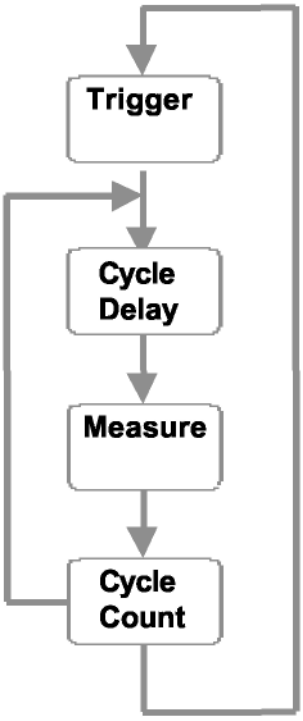
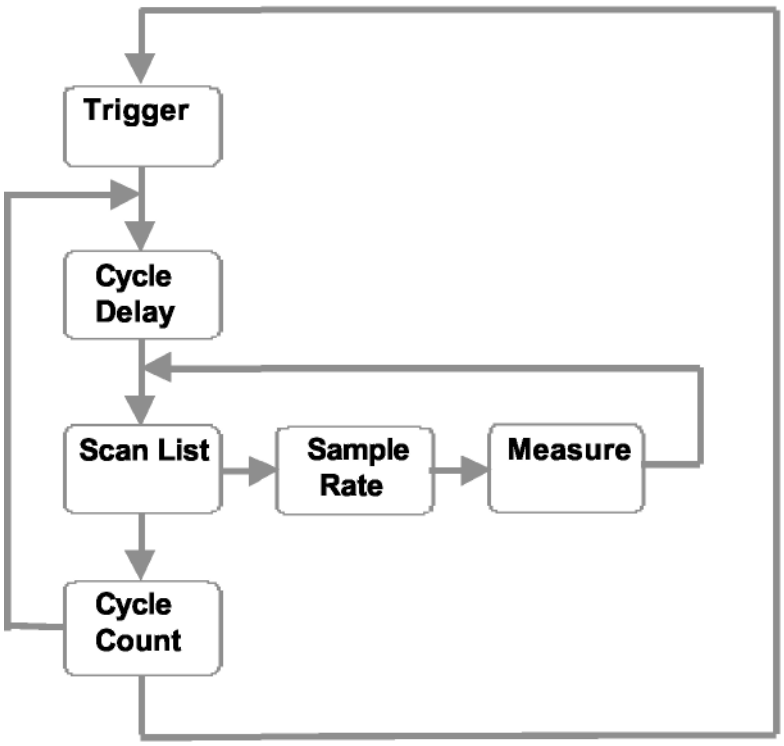


Figure 5.9 - Multiple channel timer flow diagram



5.6.5 Configuring the data log memory

The TTI-7-R can record up to 4000 readings in none-volatile data log memory. You can analyse this data either while it is being logged, or later, even when the TTI-7-R has been disconnected from the mains. Reviewing statistics or logged data will temporarily suspend recording of data.

To access the data logger memory menu, select **[Mem]** from the data logger menu. The screen displays:

Memory is: Off						
Rev	**New**	**On**	**Off**		**Quit**	**OK**

Switching data log to memory on/off: Data logging OFF is the default condition when the equipment is powered up. To switch on data logging, select **[On].** Select **[Off]** to switch off data logging. The screen message reflects the current data logging status e.g. **Memory is: OFF/Memory is: ON.**

Clearing previously stored results: Select the **[New]** option to delete all previously recorded data log results. The screen displays :

Clear the current log?			
	Yes	**No**	**Quit**

Press **[Yes]** to clear the log. As deleted data cannot be retrieved, you are asked to confirm that this is what you want to do by pressing **[Yes]** again. This takes you back to the previous screen. **[Quit]** takes you to the Temperature Measurement screen.

You need to record some actual data before using the **[Rev]** option on this menu as described in Section 5.5.3.

5.6.6 Starting the data log

Once you have set up the scanner, timer and data log memory you can start to log data.

The bottom line of the Running Mode screen now displays:

Hold	**SLx**	**x/yyyy**	**Mem**

Where **SLx** indicates the scanning list the scanner will use, Mem indicates that data logging to memory is On, x is the number of samples recorded and yyyy is the number of samples required.

1. To start logging data, press the 3/TRIG key. The bottom line of the display now shows the Run message, and the sample number starts to increase with each sample taken.

2. At any point, you can halt data logging by pressing 3/TRIG again, and the **Hold** message is shown. Logging will also switch to **Hold** automatically once the TTI-7-R has logged the required number of samples.

3. If the data log is complete i.e. the number of samples taken equals the number of samples specified, logging stops and **Hold** is displayed. You can restart data logging only after the existing log has been deleted or the number of samples required has been increased. The screen displays:

Clear the current log?
Yes **No**

4. Press **[Yes]** if you wish to delete the current log. Press **[Yes]** again, to confirm that this is what you want to do.

5. Once the log memory has been cleared, press 3/TRIG to start the data logger.

5.6.7 Reviewing log results

You can review logged data at any time, both during the actual logging and after data recording is complete.

To review the data logger memory, select **[Mem]** from the data logger menu. The screen displays:

Memory is: Off
Rev New On Off Quit OK

1. Select **[Rev]** to examine the data log. This is displayed six records at a time, arranged in five columns.

Log #	Indicates the log sample number from the logging sequence
Ch #	Indicates the measurement channel
Temp (cleg)	Stored temperature value
Date	Date temperature reading stored (dd/mm/yy) format
Time	Time temperature reading stored (mm:hh:ss) format

2. An example 'page' of a data review screen is shown below:

	Ch#	Temp(degC)	Date	Time
1	AO	17.897	20/04/98	14:38:40
2	A1	17.897	20/04/98	14:38:41
3	A2	17.896	20/04/98	14:38:43
4	A3	17.897	20/04/98	14:38:44
5	A4	17.895	20/04/98	14:38:59
6	BO	17.895	20/04/98	14:39:01

3. Use the up/down control keys to scroll through the data.

4. Press ⇑ to scroll table up;

5. Press ⇓ to scroll table down.

6. Press **[OK]** to go back to the Data Logging menu.

5.6.8 Reviewing log statistics

You can examine a statistical log analysis at any time, both during the actual logging and after data recording is complete. Reviewing statistical analysis will temporarily suspend logging of data. If the input channel is changed during data logging, no statistical analysis report will be displayed.

1. Press OUT/METH to bring up the Statistics screen. The screen

Statistics/Filtering ?		
	Stats	**Quit**

2. Select **[Stats]** to examine the analysis report. The statistical analysis displays values in the selected measurement units and reports the following statistical information:

Number of samples	Indicates the number of log samples analysed
Min	Minimum temperature value of the logged data records
Max	Maximum temperature value of the logged data records
Mean	Arithmetic Mean temperature of the logged data records
Ptp *(peak to peak value)*	Range of logged data records (Min-Max)
SD	Standard deviation value

3. An example 'page' of a statistical screen is shown below:

Analysis of current log (A: deg C)				
Number of samples: 50				
Min	: 17.893	Max	:	18.275
Mean	: 18.068	Ptp	:	0.281
SD	: 0.0850			
		Quit		OK

5.7 Setting up the basic controls

You can configure certain settings on the TTI-7-R by pressing This takes you to the options menu. The screen displays:

Options?

Sys Conf **Set Up** **Rem I/F** **Trg** **Ver** **Quit**

The table below gives a summary of all the available options.

Sys Conf	Review system configuration
Set Up	Display backlight on/off Keyboard beeper on/off Set TTI-7-R clock time Set TTI-7-R clock date format dd/mm/yy, mm/dd/yy Set TTI-7-R clock date
Rem I/F	*(If RS232 remote interface card fitted)* Set remote interface Baud rate Set remote interface to Talk only mode *(If IEEE488.2 remote interface card fitted)* Set IEEE address
Trg	Select Trigger mode to Run/Hold or single shot
Ver	Review Model number, Firmware version number

5.7.1 Review system configuration

On power-up the TTI-7-R performs a system configuration check searching for input channel expansion cards or communication card.

The following information is read from each card on detection and displayed by the system configuration display.

Communication card

RS-232, Baud rate, Character bits, Parity, Start bit, Stop bit.

IEEE488.2, Address.

Input channel expansion card

Card ID, Serial Number, Card type, Channel numbers.

To review the system configuration select Sys Conf from the options? menu. The screen displays the system configuration.

Figure 5.4 - Example System Configuration Display

System configuration

RS-232 9600,8,0,1,2

Card A1 Sn 12345 4Ch TC Ch A1 to A4
Card B1 Sn30123 4Ch PRT Ch B1 to B4

Quit

5.7.2 Setting up the TTI-7-R

1. Press **[Set Up]** in the menu. This allows you to:

   - Switch the display backlight on/off;
   - Set the keyboard beeper on/off;
   - Set the TTI-7-R clock time;
   - Set the TTI-7-R clock data format;
   - Set the TTI-7-R clock date.

   You access each of the options in turn, pressing **[OK]** to move on to the next option or **[Quit]** to save the selection and return to the Temperature Measurement screen,

1. **Backlight:** At power up, the LCD backlight default is **[On].** To switch it off, select the **[Off]** option. This is useful when using the internal batteries, and either operating the data logger or remotely monitoring temperature for extended periods. Switching off the backlight will extend the life of a fully charged battery from approximately eight to 14 hours.

2. **Beeper:** At power up the audible beeper key is **[On].** To disable it, select the **[Off]** option.

3. **Time setting:** The TTI-7-R clock time function is used to identify data in logged records. The screen displays the current time. If you want to change it, select **[Chg].**

Time is 07:00:32			
	Chg	**Quit**	**OK**

Enter the new time as a sequence of six digits in the format [Hour Minute Seconds] using the 24-hour time format. Then select **[OK].** The new time is displayed on the screen; you can correct it if necessary by pressing **[Chg]** again and repeating the process. *USER/OPTN* deletes the entire data entry.

4. **Date format:** The TTI-7-R calendar date format can be configured for dd/mm/yy or mm/dd/yy. The screen displays the current format. If you want to change it, select **[Chg].**

Date format is dd/mm/yy			
	Chg	**Quit**	**OK**

5. **Date setting:** The TTI-7-R calendar date function is used to identify data in logged records. The screen displays the current date. If you want to change it, select **[Chg].**

Date is 06/04/98			
	Chg	**Quit**	**OK**

Enter the new date as a sequence of six digits in the selected date format. For example, to set the date to April 6th 1998 in the format dd/mm/yy, enter **[0] [6] [0] [4] [9] [8]** and then press **[OK].** The new date is displayed on the screen; you can correct it if necessary by pressing **[Chg]** again and repeating the process. USER/OPTN deletes the entire data entry.

5.7.3 Configuring the communications interface

The TTI-7-R can be fitted with one of the following types of communications interface card:

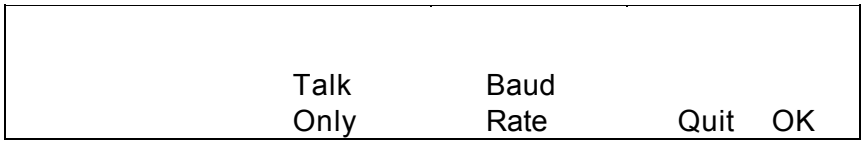
1. RS-232 serial communications interface
2. IEEE-488.2 parallel communications interface.

The optional communications interface lets you assign remote control of the TTI-7-R to an external computer.

5.7.3.1 Configuring the RS232 communications interface

If an RS232 serial communications interface card is fitted, select the **[Rem I/F]** option in the main configuration menu. If there is no interface fitted, the TTI-7-R displays the message **Option not available.**

The screen displays:



Switching on Talk Only Mode: You use the Talk only Mode to send results directly to a serial printer, without the need for a PC. In this mode, the TTI-7-R continuously outputs temperature data and measurement results to the RS232 serial port. Output data format is covered in Section 7.

When you select the **[Talk Only]** option, the screen displays:

Talk only mode is OFF?

Chg **Quit** **OK**

Select **[Chg]** to enable Talk Only mode. At power up, Talk Only Mode is disabled i.e. the interface is in full talk/listen mode. The TTI-7-R will remain in Talk Only Mode until it is switched off or until you select the **[Chg]** option again from this menu. All incoming serial interface commands are ignored when Talk Only Mode is operating.

2. **Setting baud rate**: To change the RS232 serial data transfer rate, select **[Baud Rate]** from the **[Rem I/F]** menu. The screen displays the current setting. Press the **[Chg]** option to alter this setting.

Enter new Baud rate
Quit OK

The RS232 communications interface serial rate data transfer options are: 75; 110; 150; 300; 600; 1200; 2400; 4800; 9600; 19200 baud. The factory default value is 9600 baud.

Enter the new baud rate using the numeric keys on the keypad and then select **[OK]** to save this setting and return to the previous menu. For example, to enter 19200, you press [1] **[9] [2] [0] [0].** If you enter a baud rate which is not recognised by the TTI-7-R , it displays an error message and you need to repeat the

procedure. 

deletes the entire data entry.

Serial transfer data format is fixed at:

Start bit	1
Data word length	8 bits
Parity checking	None
Stop bit	1
XON/XOFF	Not implemented

5.7.3.2 Configuring the IEEE 488.2 communications interface

If an IEEE-488.2 parallel communications interface card is fitted, select the **[Rem I/F]** option in the main configuration menu.

The screen displays:

Talk			
Only	**Addr**	**Quit**	**OK**

Select the **[Addr]** option, the screen displays the current selected IEEE address.

Instrument address is 7			
	Chg	**Quit**	**OK**

To change the address select [Chg] and enter the new address from the function key pad.
Addresses in the range 0 to 30 are valid addresses.
The default factory set address is 7.

5.7.4 Setting up Trigger Mode

There are two trigger modes available to control measurement and data logging operations:

[Run] Run/Hold mode, continuous measurement option.

Pressing 3/TRIG in this mode alternates between continuous measurement and measurement hold. The power up default state is continuous measurement operation.

[Sng] Single shot mode. Single measurement mode collects a single measurement each time you press the 3/TRIG key and pauses between key presses.

1. From the configuration menu, press USER/OPTN. The screen displays:

Trigger mode is RUN/HOLD?
Sng Run Quit OK

2. Select **[Run]** for Run/Hold measuring or **[Sng]** for single shot triggering. Select **[OK]** to save the trigger mode setting and return to the configuration menu. **[Quit]** saves the trigger selection and returns you directly to Temperature Measurement Mode.

5.7.5 Displaying the firmware version

Select **[Ver]** from the configuration menu to display details about the TTI-7-R . The screen displays:

Model TTI-7-R Version 4.0 16/12/97
Quit OK

Instrument Model number

Firmware version reference

Firmware issue date

5.7.6 Adjusting the display contrast

You can change the display contrast while in Temperature Measurement Mode. Press and hold down the ▲ key or the ▼ key until the display is adjusted correctly. Note that display contrast is not reset when the TTI-7-R is switched off.

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6. Calibrating the TTI-7-R

6.1 TTI-7-R Instrument calibration

The dc bridge measurement technique used in the TTI-7-R is inherently very stable and linear, better than ± 6 mΩ over the full range at +20 °C ±2 °C (equivalent to ± 15 mK with a Pt100 PRT). However drift of reference components will occur with time making periodic re-calibration necessary.

We recommend you return your TTI-7-R to an ISOTECH NA service centre for recalibration at least every 12 months. Please contact the ISOTECH NA Technical Services Group for recalibration advice and a quotation.

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7. Communications Interface

7.1 Introduction

The TTI-7-R can be fitted with one of the following types of communications interface card:

RS-232 serial communications interface

or

IEEE-488 parallel communications interface

The optional communications interface lets you assign remote control of the TTI-7-R to an external computer. The computer can also read the measured value and instrument status.

Alternatively you can use the communications interface to log data directly to a serial printer. See Section 5.5.2 for further details.

The cards plug directly into the instrument's main PCB assembly, with the interface connector accessible on the rear panel. Interface cards may be retro-fitted at any time. The TTI-7-R 's software automatically detects the type of interface card fitted at power-up. The control parameters for the communications interface can be set from the front panel.

The interface instruction set is common to both interfaces and generally follows the IEEE488.2/SCPI protocol.

7.2 Fitting the Interface

WARNING: Switch off the instrument and remove the AC power cord before removing the instrument case. ANTI-STATIC PRECAUTIONS MUST BE TAKEN WHILE INSTALLING THE INTERFACE CARD.

1. Remove the six screws holding the top half of the instrument case (see figure 7.1) and lift off vertically, taking care not to stretch or break the ground connection to the case cover (green/yellow wire).
2. Remove the two screws holding the communications interface blanking plate located on the rear panel.
3. *(IEEE only)* Remove the four screws holding the rear panel to allow the interface output connector to fit.
4. Fit the interface card in socket J18 on the instrument's main PCB, ensure the connector is firmly located.
5. *(IEEE only)* Replace the instrument rear panel and secure the four mounting screws.
6. Secure the interface to the rear panel with the two screws from the blanking plate.
7. Refit the instrument top case and replace the six securing screws.

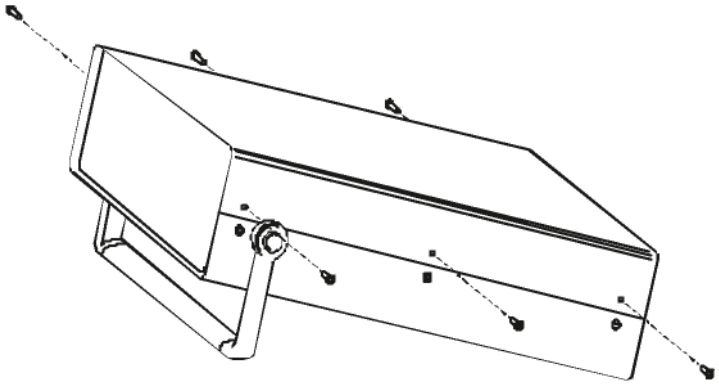


Figure 7.1 - Fitting an interface PCB

7.3 Overview of the RS-232 Serial Interface

This conforms to specification ANSI/EIA/TIA-232-E-1991 Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) employing serial binary data interchange.

Signal levels; MARK (logical "1"); -3V to -15V

SPACE (logical "0"); +3V to +15V

Data is transferred using the TXD (transmit data) and RXD (receive data) lines.

Hardware handshaking for each character transfer uses the RTS (request to send) and CTS (clear to send) lines. RTS is an output from the instrument that indicates its receiver status. When asserted (low), it indicates that it is ready to receive another character. When negated (high), the instrument receiver buffer is full and cannot receive another character until the buffer is processed (if the PC sends one, it may be lost). As soon as space becomes available in the receiver buffer, RTS is re-asserted to allow the PC to send the next character.

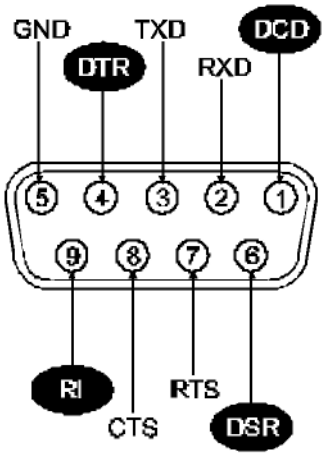
When the instrument detects receipt of a command terminator character, RTS is negated whilst the command line buffer is read and validated. This is to prevent the PC sending further characters whilst a command is being validated. Following validation, RTS is re-asserted to permit the next command to be transmitted by the PC.

CTS is an input to the instrument and controls the transmission of characters. If the PC asserts CTS (low), then the instrument will transmit the next character from the output buffer (if one is waiting). If the PC negates CTS (high), then the instrument will not transmit the character, but will wait until CTS is re-asserted. TXD will remain in the mark (low) condition whilst CTS is negated. Note that changing CTS during transmission of a character will not disrupt the transmission of that character.

7.3.1 The RS-232 Connector

RS-232 connection is via a 9-way (socket) D-type connector on the back panel as shown in Figure 7.2.

Figure 7.2 - RS-232 Connector



View towards rear panel RS232 connector

=Not connected on TTI-7-R

7.3.2 Pin Connections

Computer			TTI-7-R	
25-Pin Connector	9-Pin Connector	Function	9-Pin Connector	Function
3	2	Rx	3	Tx
2	3	Tx	2	Rx
7	5	GND	5	GND
6*	6*	DSR		
4*	7*	RTS	8	CTS
5	8	CTS	7	RTS

* Pins must be linked

To make an RS232 connection, use fully screened cable assemblies to maintain EMC integrity. A 5-wire (TXD, RXD, GND, RTS, CTS) cross over cable is recommended.

Three wire connection (TXD, RXD, GND) is not recommended, but may be implemented by connecting RTS and CTS together at the TTI-7-R end. In this case, the DTE must not send characters too

quickly as this will cause the TTI-7-R receive buffer (4 characters) to overflow, leading to lost data.

7.3.3 RS-232 Settings

The RS-232 interface factory settings are:

9600 baud 8
character bits
No Parity 1 Start
Bit 1 Stop Bit

The serial communications data rate can be set from the instrument's front panel. Refer to Section 5.6.2 for configuration details. The data format cannot be changed.

7.3.4 RS-232 Operating Modes

The instrument can be set from the front panel to operate in either Talk Only Mode or Talk/Listen Mode. At power-up the instrument defaults to Talk/Listen Mode.

Talk Only Mode

In Talk Only Mode, the interface ignores all incoming interface commands and the instrument remains in Local control mode. The result of each temperature measurement is sent to the interface output with the resolution and units as per the main display.

This mode is useful for sending results directly to a serial printer without the need for a PC.

Talk/Listen Mode

In Talk/Listen Mode, the communications interface permits remote control of the instrument by an external computer. The measured value and instrument status can also be read by the computer.

To enable communication in Talk/Listen Mode the instrument must first be set for Remote Mode Operation.

7.3.5 RS-232 Interface Commands

SYSTem:REMote

Place the TTI-7-R in the remote mode for RS-232 operation. The REM legend on the display indicates that the instrument is under control of the remote interface. The front panel keys will be locked out.

SYSTem:LOCal

Return the instrument to the Local mode from RS-232 operation. All keys on the front panel are fully functional. This is the default at power-up.

7.4 Programming the Interface

7.4.1 Introduction

All interfaces are programmed in a common language which is based on SCPI (Standard Commands for Programmable Instruments). Although similar in style, full conformance to the SCPI and IEEE488.2 standards is not guarantied. The following sections provide a guide to the structure and syntax of the programming language.

7.4.2 Command Tree

Commands are arranged as a hierarchical "tree", similar to the filing system trees found in personal computers. Commands start at the root level and progress down each level in more detail. The complete path must be specified to access the lower level commands. Only one command path per line is accepted.

7.4.3 Command Directives

Colon (:)

The colon is used to separate command keywords and automatically move the path down to the next level. All new command lines automatically start at the root-level. A colon must not be sent as the first character. This is treated as a non-recognised character and the "command error" bit (5) of the Standard Event Register is set.

Whitespace (TAB or SPACE)

A whitespace character must be used to separate the first parameter from a command keyword. If omitted, the "command error" bit (5) of the Standard Event Register is set.

Comma (,)

If a command requires multiple parameters, a comma must be used to separate parameters from one another in the parameter list.

Query (?)

Commands ending in a query (?) indicate that a response is expected from the instrument. This is usually a request for a measured value or status. Commands sent without a query request the instrument to perform a function but not to send a response. The instrument will not output a response without a query command (except in Talk Only Mode).

Common Commands (*)

Commands beginning with an asterisk (*) are called common commands and have a precise function as defined by the IEEE-488.2 standard. All instruments behave in an identical way. These commands are primarily concerned with control, reset, self-test and status.

Command Terminators (CR) or (LF)

All messages sent to the instrument must be terminated with either a carriage return (CR) character or a line feed (LF) character. It is permitted to send (CR)(LF) to terminate a message; the (LF) is ignored.

For IEEE-488, asserting EOI (end or identify) with the last character sent is also treated as a message terminator. Message termination always forces the command path back to the root-level ready for the next command message.

7.4.4 Command Syntax

Most command keywords have both a long and short form. The bus controller can send commands in either form and also in any combination of upper and lower case characters. Instrument responses, however, are always in short form, upper case.

Data Types

The bus controller can also send data in a range of formats, but the instrument always responds in a precise format. There are four principal data types:

Numeric Parameters are decimal numbers which include an optional sign, mantissa, decimal point and exponent. Engineering suffix units are not accepted. Ver 4.0 does not accept numeric parameters.

Discrete Parameters have limited values e.g. SINGle, INFinite. Like command keywords they can have long and short forms, upper and lower case.

Boolean Parameters have a single binary value. The controller can send OFF or 0, ON or 1, but the instrument response is always 0 or 1.

String Parameters contain ASCII characters which are placed between a pair of double quotation marks, i.e." ".

Input Buffer

The instrument receives messages into an input buffer and only starts executing commands after receipt of a command terminator. The buffer can store up to 100 characters including command directives and terminator.

Sending a new command before the existing command is executed may cause unreliable operation. It is advisable to query the Status Byte (*STB) to check on the current status of the instrument before sending a new command. Sending a command whilst the instrument is transmitting (following a ? command) may result in the transmitted response being corrupted. It is advisable to wait for the expected response to be transmitted before sending a new command.

Output Data Format

Non-reading queries		<80 ASCII character string
Single-reading	IEEE	SDDDD.DDD(LF)
	RS-232	SDDDD.DDD (CR) (LF)
Multiple readings	IEEE	SDDDD.DDD, ... , .. ,(LF)
	RS-232	SDDDD.DDD, ... , .. ,(CR)(LF)
Talk Only format		ChA: SDDDD.DDD degC (or F, K)
	where	S= sign (+/-) D = decimal Digit (0-9) <CR> = carriage return character <LF> = linefeed character

The resolution and units will be as set by the last manual or bus commands.

7.5 IEEE-488.2 Common Command Group

Common commands are device commands that are common to all devices on the bus. These commands are designated and defined by IEEE-488.2 standard.

7.5.1 IEEE-488.2 Common Command Summary

Mnemonic	Description
*CLS	Clears all event registers and error queue.
*ESE <NRf>	Program the Standard Event Enable Register.
*ESE?	Read the Standard Event Enable Register.
*ESR?	Read the Standard Event Register and clear it.
*IDN?	Returns the manufacturer, model number, serial number, Firmware issue.
*OPC	Sets the Operation Complete bit in the Standard Event Status Register after all pending commands have been executed.
*OPC?	Places an ASCII "1 " into the output queue when all Pending selected device operations have been complete.
*RST	Return the instrument to the *RST default conditions.
*SRE<NRF>	Programs the Service Request Enable Register.
*SRE?	Reads the Service Request Enable Register.
*STB?	Reads the Status Byte Register (bit 6 is MSS not RQS).
*TRG	Sends a bus trigger to the instrument.
*TST?	Performs a checksum test on ROM and returns the result.
*WAI	Wait until all previous commands are executed.

7.5.2 IEEE-488.2 Common Commands

***CLS**

Clears the Status Byte Summary Register and all event registers.

***ESE {<enable value>}**

Enable bits in the Standard Event Enable Register. The selected bits are then reported to the Status Byte.

***ESE?**

Query the Standard Event Enable Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

***ESR?**

Query the Standard Event Register. The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register.

***IDN?**

Read the instrument's identification string. This is of the form;
"{manufacturer},{model no.},{serial no.},{software version}"
Note: The serial number field is not used.

*OPC

This command sets the instrument's Operation Complete Command State active. When any in-progress command is complete, the state returns to idle and the Operation Complete bit (0) is set. The command should only be used in conjunction with non-query commands and is only available for IEEE.

Example

Data logging can take an appreciable time to execute, so it is useful to program the instrument to generate a service request on completion of the logging function.

The following command sequence can be used:

*ESR 1 Enables Operation Complete to set the Standard Event bit.
*SRE 32 Enables Standard Event to trigger service request.
*CLS Clears the Operation Complete bit. INITiate
Initiates data logging. *OPC Sets RQS on completion of the log

Alternatively, the application program may continuously poll the Operation Complete bit using *ESR?

***OPC?**

This command sets the instrument's Operation Complete Query State active. When any in-progress command is complete, the state returns to idle, a '1' is placed in the output queue and therefore the Message Available bit (4) is set.. The command should only be used in conjunction with non-query commands and is only available for IEEE.

Example

Data logging can take an appreciable time to execute, so it is useful to program the instrument to generate a service request on completion of the logging function.

The following command sequence can be used:

*SRE 16 Enables Message Available bit to trigger a service request.
*CLS Clears the Message Available bit.
INITiate Initiates data logging. *OPC Sets RQS on completion of the log

Alternatively, the application programme may continuously poll the Message Available bit using *STB?

***RST**

Clears all pending operations, resets the Operation Complete Command State and Operation Complete Query State.

***SRE <NRf>**

Enable bits in the Service Request Enable Register. The selected bits are then reported to the Status Byte.

***SRE?**

Query the Service Request Enable Register. The instrument returns a decimal value that corresponds to the binary-weight sum of all bits set in the register.

***STB?**

Query the Status Byte Summary Register. The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register.

***TRG**

Identical to the INITiate command. A

single measurement is made.

***TST?**

Always returns '0' to indicate self-test OK.

***WAI**

This command is accepted but ignored as all commands are executed sequentially. It is provided only for compatibility with IEEE-488.2.

7.6 Measurement Command Group

The measurement command group is used to select channels, configure channel parameters and acquire readings.

7.6.1 Measurement command summary

Command	Description
CONFigure:CHANnel:	Select the specified channel.
CONFigure?	Query the channel configuration.
CONFigure:TEMPerature:TC	Configure a channel for TC measurement.
CONFigure:TEMPerature:RTD	Configure a channel for RTD measurement.
FETCh?	Fetch a single reading.
READ?	Initiate a measurement and fetch a reading.
MEASure:CHANnel?	Select the specified channel. Initiate a measurement and fetch a reading.
MEASure:TEMPerature:TC?	Configure a channel for TC measurement. Initiate a measurement and fetch a reading.
MEASure:TEMPerature:RTD?	Configure a channel for RTD measurement. Initiate a measurement and fetch a reading.

7.6.2 CONFigure Commands

Configure commands are used to select and configure channel parameters without triggering a measurement.

CONFigure:CHANnel {channel}

Selects the specified channel to be measured (use CONF :TEMP to configure the measurement parameters).

Only channels that are available can be selected or the command will be ignored.

{channel} A0, A1, A2, A3, A4
B0, B1, B2, B3, B4
Ch1 - Ch2

Terminates the current measurement cycle and scanning routine. Sets the trigger mode to single shot. Selects the channel as specified by the command. Sets the scanner mode to Off. Sets the logging to memory mode to Off.

CONFigure?

Used to query the current configuration. The response is an ASCII string of either of the following forms:

"{channel},TC,{type},{rj mode},{ext rj mode}"

{channel}	A0, A1 , A2, A3, A4 B0, B1 , B2, B3, B4 Ch1-Ch2	
{type}	B,C,D,E,J,K,N,R,S,T	
{rj mode}	Off, Int, Ext	
For rj mode set to Off or Int		
{ext rj standard}	()	
For rj mode set to Ext		
{ext rj standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)

" {channel},RTD,{type},{standard},{con},{current mode},{root 2}"

{channel}	A0, A1 , A2, A3, A4 B0, B1 , B2, B3, B4 Ch1-Ch2	
{type}	Pt100	
{standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)
{con}	3, 4	(3 or 4 wire)
{current mode}	I, -I, AVE	
{root 2}	0, 1	0 = off, 1 = on

CONFigure:TEMPerature:TC {type},{rj mode},{ext rj standard}

Sets the selected channel for a thermocouple measurement according to the following parameters.

{type}	B,C,D,E,J,K,N,R,S, T	
{rj mode}	Off, Int, Ext	
For rj mode set to Off or	Nt	
{ext rj standard}	0	
For rj mode set to Ext		
{ext rj standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)

Note: For {rj mode} set to Off or Int, the {ext rj standard} parameter must be set to 0 otherwise the command is not recognised.

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to single shot.
Selects the channel as specified by the command.
Sets the scanner mode to Off.
Sets the logging to memory mode to Off.

CONFigure:TEMPerature:RTD{type},{standard},{con},{current mode},{root 2}

Sets the selected channel for an RTD measurement according to the following parameters.

{type}	Pt100	
{standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)
{con}	3, 4	(3 or 4 wire connectivity)
{current mode}	I, -I, AVE	
{root 2}	0, 1	0 = off, 1 = on

Terminates the current measurement cycle and scanning routine.

Sets the trigger mode to single shot.
Selects the channel as specified by the command.
Sets the scanner mode to Off.
Sets the logging to memory mode to Off.

FETCH?

Transfer the last reading stored in the instrument's internal memory by the INITiate command to the instrument's output buffer. After reading, the memory is cleared and further FETCh? commands do not return anything until a fresh INITiate command is sent.

READ?

A measurement is made and the result is sent directly to the output buffer. The trigger mode is as set using TRIG:MODE command. If in SINGle mode, only one reading is taken. If in INFinite mode, readings continue, with all values sent to the output buffer.

7.6.3 MEASure Command

These work similar to the CON Figure commands, except that an immediate measurement is performed with the result being sent to the output buffer.

MEASure:CHANnel? {channel}

Selects the channel to be measured (use CONF:TEMP to configure the measurement parameters).

{channel} A0, A1, A2, A3, A4
B0, B1, B2, B3, B4
Ch1 -Ch2

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to single shot.
Selects the channel as specified by the command.
Sets the scanner mode to Off.
Sets the logging to memory mode to Off.
Initiates a single measurement and fetches a single reading.

MEASure:TEMPerature:TC? {type},{rj mode},{ext rj standard}

Sets the selected channel for a thermocouple measurement according to the following parameters.

{type}	B,C,D,E,J,K,N,R,S, T	
{rj mode}	Off, Int, Ext	
For rj mode set to Off or Int		
{ext rj standard}	0	
For rj mode set to Ext		
{ext rj standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)

Note: For {rj mode} set to Off or Int, the {ext rj standard} parameter must be set to 0 otherwise the command is not recognised.

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to single shot.
Selects the channel as specified by the command.
Sets the scanner mode to Off.
Sets the logging to memory mode to Off.
Initiates a measurement and fetches a single reading.

MEASure:TEMPerature:RTD?{type},{standard},{con},{current mode},{root 2}

Sets the selected channel for an RTD measurement according to the following parameters.

{type}	Pt100	
{standard}	1	(IEC751)
	2	(US/JIS)
	3	(EN60751)
	4-23	(User Probe 1-20)
{con}	3, 4	(3 or 4 wire connectivity)
{current mode}	I, -I, AVE	
{root 2}	0, 1	0 = off, 1 = on

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to single shot.
Selects the channel as specified by the command.
Sets the scanner mode to Off.
Sets the logging to memory mode to Off.
Initiates a single measurement and fetches a single reading.

7.7 SENSe Command Group

The SENSe command group is used to control the instrument measurement parameters.

7.7.1 Sense command summary

Command	Description
SENSe:TEMPerature:UNIT	Sets the temperature units to be used.
SENSe:TEMPerature:UNIT?	Queries the temperature units.
SENSe:TEMPerature:RESolution	Sets the temperature resolution.
SENSe:TEMPerature:RESolution?	Queries the temperature resolution.
SENSe:ZERO:AUTO	Sets the auto-zero measurement mode.
SENSeZERO:AUTO?	Queries the auto-zero measurement mode.

7.7.2 Sense Commands

SENSe:TEMPerature:UNIT {parameter}

Sets the temperature units to be used in all responses.

{parameter}	C	Degrees Celsius
	F	Degrees Fahrenheit
	K	Degrees Kelvin

SENSe:TEMPerature:UNIT?

Queries the temperature units selection in force.

Returns	"C"	Degrees Celsius
	"F"	Degrees Fahrenheit
	"K"	Degrees Kelvin

SENSe:TEMPerature:RESolution {<resolution>}

Sets the temperature resolution to be used in all responses. The default resolution at power-up is 0.01.

{resolution}	1, 0.1, 0.01, 0.001

SENSe:TEMPerature:RESolution?

Queries the temperature resolution.

Returns	1, 0.1, 0.01 or 0.001	

SENSe:ZERO:AUTO {mode}

Turns the auto-zero mode on or off. Default at power-up is auto-zero mode off.

{mode}	1, on	Auto-zero on
	0, off	Auto-zero off

Auto-zero is only available for single channel measurements. The 'on' mode is automatically reset to 'off if any of the following commands are sent:

CONFigure:TEMPerature:TC {type},{rj mode},{ext rj standard}
CONFigure:TEMPerature:RTD {type},{standard},{con},{current mode},{root 2}
CONFigure:CHANnel {channel}
MEASure:TEMPerature:TC? {type},{rj mode},{ext rj standard}
MEASure:TEMPerature:RTD? {type},{standard},{con},{current mode},{root 2}
MEASure:CHANnel? {channel}
ROUTe:SCAN:LSELect {slx}

SENSe:ZERO:AUTO?

Queries the auto-zero mode status.

Returns	1	Auto-zero on
	0	Auto-zero off

7.8 Mathematical Operation Commands

The CALCulate:AVERage group of commands performs statistical calculations on the current contents of the data logger memory.

A minimum of two readings must be stored otherwise an "execution error" is generated i.e. bit (4) of the Standard Event Register is set. This error is also generated if the log contains inconsistent entries i.e. readings taken on different channels.

7.8.1 CALCulate:AVERage command summary

Command	Description
CALCulate:AVERage:MINimum?	Queries the minimum stored temperature.
CALCulate:AVERage:MAXimum?	Queries the maximum stored temperature
CALCulate :AVERage:AVERage?	Queries the average stored temperature.
CALCulate :AVERage:COUNt?	Queries the number of stored readings.
CALCulate :AVERage:PEAK?	Queries the peak to peak value.
CALCulate :AVERage:SDEV?	Queries the standard deviation value.

7.8.2 CALCulate:AVERage commands

CALCulate :AVERage:MINimum?

Return the minimum temperature value stored in the data log.

CALCulate :AVERage:MAXimum?

Return the maximum temperature value stored in the data log.

CALCulate :AVERage:AVERage?

Return the average of all temperature values stored in the data log.

CALCulate :AVERage:COUNt?

Return the number of readings stored in the data log.

CALCulate :AVERage:PEAK?

Return the peak-to-peak value of the temperature values stored in the data log i.e. max - min.

CALCulate :AVERage:SDEV?

Return the standard deviation of the temperature values stored in the data log. This is effectively a measure of RMS noise.

7.9 Route Command Group

The ROUTe:SCAN commands are used to control the instruments scanner operation and configure the scanning lists.

The instrument can save up to four independent scanning lists in none-volatile memory, each scanning list also retains its individually programmed cycle count, trigger delay time and sample rate.

7.9.1 Route command summary

Command	Description
ROUTe:SCAN:LSELect	Sets the scanner mode and selects a scan list.
ROUTe:SCAN:LSELect?	Queries the scanner mode and scan list.
ROUTe:SCAN:INTernal	Configure the specified internal scan list.
ROUTe:SCAN:INTernal?	Queries the specified internal scan list.

7.9.2 Route commands

ROUTe:SCAN:LSELect <slx>

This command is used to set the scanner mode and select the scan list, the scanner is enabled by selecting a scanning list.

An empty scanning list can not be selected, the ROUTe:SCAN:INTernal command should be used to configure the scanning list.

<slx>	SL1, SL2, SL3, SL4	Enable scanner Select slx scanning list
	OFF	Disable scanner

Terminates the current measurement cycle and scanning routine. Sets the Run/Hold trigger mode to Hold when enabling the scanner. Sets the scanner operation and selects the scanning list as specified by the command.

ROUTe:SCAN:LSELect?

Queries the state of the scanner and returns the selected scanning list if enabled.

Returns	"SL1", "SL2", "SL3", "SL4"	Selected scanning list
	"OFF"	Scanner disabled

ROUTe:SCAN:INTernal <slx>, <scanlist>

This command is used to configure the specified scanning lists for the internal scanner cards.

<slx>	SL1, SL2, SL3, SL4	Select scanning list
<scanlist>	A0, A1, A2, A3, A4, B0, B1, B2, B3, B4	Set channel active

To configure a scanning list specify the scanning list number followed by a list of channels that are required to be active in the list. Only channels that are available should be specified or the command will be ignored.
To query a scanning list use the ROUTe:SCAN:INT? <slx> command.

Configuring a scanning list that is in use will result in the instrument terminating the current measurement cycle and scanning routine. Sets the Run/Hold trigger mode to Hold. Sets the scanning list as specified by the command.

ROUTe:SCAN:INTernal? <slx>

Query the configuration of a scanning list.

The instrument will return a list of selected channels in the specified scanning list or NONE for an empty scanning list.

<slx>	SL1, SL2, SL3, SL4	Select scanning list
Returns	"A0, B0, A1, A2, A3, A4, B1, B2, B3, B4"	List of active channels
	"NONE"	Empty scanning list

7.10 Trigger Command Group

The TRIGger and SAMPle commands are used to control the instruments scanner operation and configure the scanning lists.

7.10.1 Trigger command summary

Command	Description
INITiate	Initiate a single measurement.
ABORt	Abort the current measurement.
TRIGger:MODE	Sets the trigger mode.
TRIGger:MODE?	Queries the trigger mode.
TRIGger:COUNt	Sets the specified timer cycle count value.
TRIGger:COUNt?	Queries specified the timer cycle count value.
TRIGger:DELay	Sets the specified timer cycle delay value.
TRIGger:DELay?	Queries the specified timer cycle delay value.
SAMPle:COUNt?	Queries the specified sample count.
SAMPle:DELay	Sets the specified timer sample delay.
SAMPle:DELay?	Queries the specified timer sample delay.

7.10.2 Trigger commands

INITiate

This command is used to Initiate a single measurement without returning a reading.
The reading is stored internally and is not sent to the output buffer.
The Measurement Available bit (8) of the Operation Condition Register is set on completion.
Use the FETCh? command to transfer the reading to the output buffer and clear the Measurement Available bit.

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to Single shot.
Initiates a single measurement without returning a reading.
Sets the Measurement Available bit (8) of the Operation Condition Register on completion.

ABORt

This command is used to stop the current measurement and clear the input and output buffers.

Terminates the current measurement cycle and scanning routine.
Sets the Run/Hold trigger mode to Hold.

TRIGgen:MODE <mode>

This command is used to set the trigger mode to single or infinite. Setting the trigger mode to single results in a single measurement being taken when triggered.
Setting the trigger mode to infinite will result in continuous measurement being taken when triggered.

For IEEE the trigger mode is always forced to single.
If the TRIGger:MODE INF command is sent it will generate a Command Error and the command will be ignored.

<mode>	SINGle	Single shot trigger mode
	INFinite	Infinite trigger mode (Run/Hold)

Terminates the current measurement cycle and scanning routine.
Sets the trigger mode to the state as defined by the command, when set to infinite mode the instrument will default to Hold.

TRIGger:MODE?

Query the trigger mode setting.

Returns	SING	Single shot trigger mode
	INF	Infinite trigger mode (Run/Hold)

TRIGgen:COUNt <n>
TRIGgen:COUNt <slx>, <n>

The TRIGger:COUNt <n> command is used to set the timer general cycle count value.

The TRIGger:COUNt <slx>,<n> command is used to set the individual scanning list timer cycle count values.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
<n>	1 to 9999	Specify cycle count value
	CONTinuos	Cycle count value to continuos
	DEFault	Cycle count value to continuos

Changing a timer cycle count value that is currently in use will result in the instrument terminating the current measurement cycle and scanning routine.
Sets the Run/Hold trigger mode to Hold.
Sets the timer cycle count to the value as specified by the command.

TRIGger:COUNt?
TRIGgen:COUNt? <slx>

TRIGger:COUNt? queries the timer general cycle count value.
TRIGger:COUNt? <slx> queries the specified scanning list timer cycle count value.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
Returns	"1" to "9999"	Cycle count value
	"CONT"	Cycle count continuos

TRIGger:DELay <hh:mm:ss>
TRIGgen:DELay <slx>, <hh:mm:ss>

The TRIGger:DELay <hh:mm:ss> command is used to set the required general timer cycle delay time.
The TRIGger:COUNt <slx>,<hh:mm:ss> command is used to set the required individual scanning list timer cycle delay time.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
<hh:mm :ss>	00:00:00 to 99:59:59	Specify timer delay

Terminates the current measurement cycle and scanning routine.
Sets the Run/Hold trigger mode to Hold.
Sets the required timer delay to the value as specified by the command.

TRIGger:DELay?
TRIGger:DELay? <slx>

TRIGger:DELay? queries the general timer cycle delay time.
TRIGger:DELay? <slx> queries the specified scanning list timer cycle delay time.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
Returns	"00:00:00" to "99:59:59"	Timer delay hh:mm:ss.

SAMPle:COUNt?
SAMPle:COUNt? <slx>

SAMPle:COUNt? queries the general timer sample count.
The sample count is the same as the general timer sample count.
SAMPle:COUNt? <slx> queries the specified scanning list sample count.
The sample count is the product of the timer cycle count and the number of active channels in the specified scanning list.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
Returns	1 to "CONT"	Sample count

Note:
If the DATAlogger:MODE is set to On the sample count will be limited to a maximum of 4000 samples or the amount of available data logging memory.

SAMPle:DELay <slx>, <hh:mm:ss>

This command is used to set the specified scanning list timer sample delay.

<slx>	SL1, SL2, SL3, SL4	Specify scan list
<hh:mm:ss>	00:00:00 to 99:59:59	Specify trigger delay
	DEFault	Trigger delay 00:00:00

Changing a timer sample delay value that is currently in use will result in the instrument terminating the current measurement cycle and scanning routine.
Sets the Run/Hold trigger mode to Hold.
Sets the timer sample delay to the value as specified by the command.

SAMPle:DELay? <slx>

Query the specified scanning list timer sample delay.

<slx>	SL1, SL2, SL3, SL4	Specify scan list	Returns
00:00:00 to 99:59:59	Sample delay hh:mm:ss		

7.11 System Related Commands

The SYSTem commands are used to control the instrument none-measurement global parameters.

7.11.1 System command summary

Command	Description
DISPlay:BACKlight	Sets the display back light mode.
DISPlay:BACKlight?	Queries the display back light mode.
SYSTem:BEEPer	Sounds a single beep immediately.
SYSTem:BEEPer:STATe	Sets the front panel beeper mode.
SYSTem :BEEPer:STATe?	Queries the front panel beeper mode.
SYSTem:TIME	Sets the internal clock time.
SYSTem :TIME?	Queries the internal clock time.
SYSTem:DATE	Sets the internal clock date.
SYSTem :DATE?	Queries the internal clock date.
SYSTem:DATE:FORMat	Sets the internal clock date format.
SYSTem :DATE:FORMat?	Queries the internal clock date format.

7.11.2 System commands

DISPlay:BACKlight {mode}

Turns the front-panel display backlight on or off.
Default at power-up is display backlight on.

{mode}	1, on	Display backlight on
	0, off	Display backlight off

DISPlay:BACKlight?

Query the front-panel display backlight mode setting.

Returns	1	Display backlight on
	0	Display backlight off

SYSTem:BEEPer

Issue a single beep immediately.

SYSTem:BEEPer:STATe {mode}

Turns the front-panel beeper on or off. Default at power-up is front-panel beeper on.

{mode}	1, on	Front-panel beeper on
	0, off	Front-panel beeper off

SYSTem:BEEPer:STATe?

Query the front-panel beeper mode setting.

Returns	1	Front-panel beeper on
	0	Front-panel beeper off

SYSTem:TIME {hh},{mm},{ss}

Set the system calendar/clock time value. The instrument uses the 24 hour clock format.

{hh},{mm},{ss} 24 hour clock format

SYSTem:TIME?

Query the system calendar/clock time value.

Returns "hh,mm,ss" 24 hour clock format.

SYSTem:DATE:FORMat {format}

Set the system calendar/clock date format for use in date and time stamping of data logging.

{format}	dd:mm:yy
	mm:dd:yy

SYSTem:DATE:FORMat?

Query the system calendar/clock date format.

Returns "DD:MM:YY" or "MM:DD:YY'

SYSTem:DATE {format}

Set the system calendar/clock date value.

{format} {dd},{mm},{yy} or [mm],[dd],[yy]

SYSTem:DATE?

Query the system calendar/clock date value.

Returns "dd,mm,yy" or "mm,dd,yy"

7.12 DATAlogger Command Group

This group of commands stores and retrieves measurement values using the data logging memory. This memory is non-volatile and can store up to 4000 readings.

7.12.1 Datalogger command summary

Command	Description
DATAlogger:MODE	Sets the data logger mode.
DATAlogger:MODE?	Queries the data logger mode.
DATAlogger:CLEAr	Clears the data logger memory.
DATAlogger:STARt	Start logging readings to data log memory.
DATAlogger:STOP	Stop logging readings to data log memory.
DATAlogger:STEP	Single step logging readings to data log memory.
DATAlogger:VALUe?	Request a specified number of readings from data log memory.
DATAlogger:POINts?	Queries the number of readings stored in the data log memory.

7.12.2 Datalogger commands

DATAlogger:MODE {mode}

Turns data logging to memory on or off.

{mode}	1, on	Data logger on
	0, off	Data logger off

Terminates the current measurement cycle.
Sets the Run/Hold trigger mode to Hold.
Sets the logging to memory mode as specified by the command.
Re-sets the scanner routine if the scanner mode is On.

DATAlogger:MODE?

Query the state of the data logger mode setting.

Returns	"ON"	Data logger on
	"OFF"	Data logger off

DATAlogger:CLEAr

Clears the data logger memory.

CAUTION: All the current stored data will be lost!

Terminates the current measurement cycle.
Clears the data logger memory.
Re-sets the sample and data logger counter.
Re-sets the scanner routine if the scanner mode is On.

DATAlogger:STARt

The DATAlogger:STARt command like the READ? command is used to Initiate single or multiple readings the readings are sent to the data logger memory but not to the output buffer.

DATAlogger:STARt command is only active when DATAlogger:MODE is ON.

If the data logger memory is full, any further DATAlogger:STARt commands will generate an "execution error" the command will be ignored.

Terminates the current measurement cycle.
Initiates a single or multiple measurement and stores the result in the data logger memory.
Re-sets the scanner routine to the beginning and starts the next cycle if the scanner mode is On.

DATAlogger:STOP

The DATAlogger:STOP command performs the same function as the ABORt command, terminating the current measurement cycle and clearing the input and output buffers.

DATAlogger:STOP command is only active when DATAlogger:MODE is ON.

DATAlogger:STARt or DATAlogger:STEP commands can be used to continue the logger from this point.

Terminates the current measurement cycle.
Sets the Run/Hold trigger mode to Hold.

DATAlogger:STEP

The DATAlogger:STEP command is used to Initiate a single measurement and stores the result in the next location of the data logger memory.

DATAlogger:STEP command is only active when DATAlogger:MODE is ON.

The command can be used to single step through a scanner routine saving the results in the data logger memory.

On completion of the scanner routine the next DATAlogger:STEP command will re-set the scanner routine to the beginning and start the next cycle.

If the data logger memory is full, any further DATAlogger:STEP commands will generate an "execution error" the command will be ignored.

Terminates the current measurement cycle.
Sets the trigger mode to Single shot.
Initiates a single measurement and stores the result in the next location of the data logger memory.

DATAlogger:VALue? {<value>}

Transfers a specified number of data logger reading from the memory to the output buffer.

Sending ABORt will terminate the operation.

{value}	1 to 4000	Request a specific number of readings
	all	Request all data logger readings

The output format is:

{<recordno.>},"{channel}",{<temperature>},"{unit}","{date}", "{time}"

DATAlogger:POINts?

Query the number of readings actually stored in the data log memory.

Returns	0	No readings stored
	4000	Maximum readings stored

7.13 Status Reporting Structure AND Commands

There are five groups of registers involved. The Questionable Data and Operation groups each consist of three registers:

Codition Registers

The Condition Register contains the current status of the instrument and is continuously updated. The register value can be read at any time using the appropriate query (?) command.

Event Registers

The Event Register detects '0' to '1' transitions in the Condition Register and the appropriate bit is set. The register value can be read at any time using the appropriate query (?) command. Reading an Event Register results in all the bits of that register being cleared, and the corresponding bit of the Status Summary Byte is also cleared.

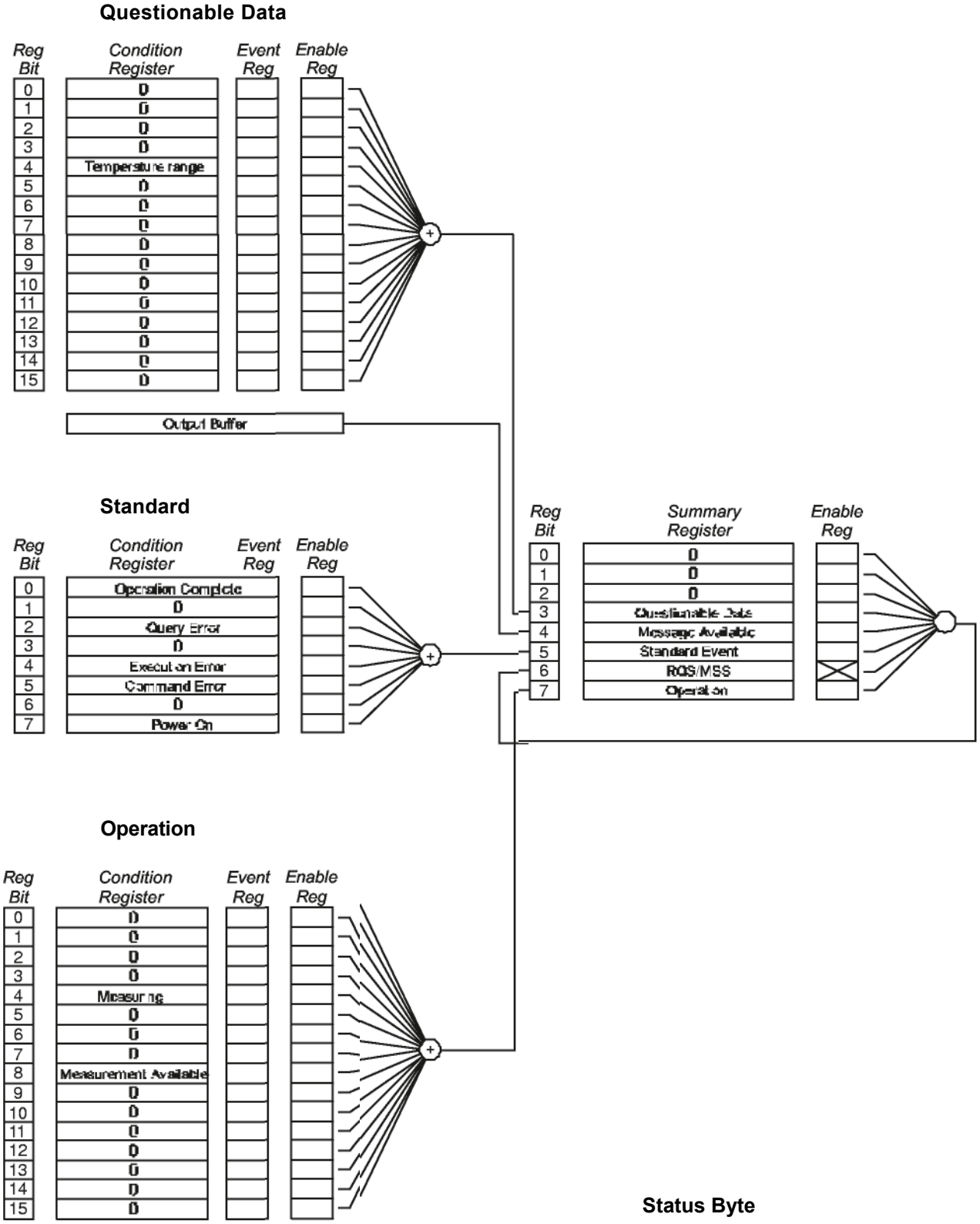
Enable Registers

The Enable Register is a mask which allows any of the bits from the Event Register to set the appropriate bit in the Status Byte. Setting an enable bit to '1' enables the event bit; clearing the enable bit inhibits the corresponding event bit. The register value can be read at any time using the appropriate query (?) command.

The Standard Event group is similar, but consists only of the Event and Enable Registers. There is no Condition Register. The Output Buffer stores a single line message to be transmitted to the bus. This can be up to 80 characters long. The message is normally the result of a query (?) command. The Status Byte is a single register which can be quickly read to get a summary of the other registers.

Only a few status bits are used in the instrument, and this reporting system may look a little unwieldy at first. However, it follows the style of SCPI and the unused bits are allocated to other functions which allow for expansion and compatibility with other SCPI compliant devices. Note that all Event Registers are cleared after reading, but the Condition Registers, Enable Registers, and Status Byte are left unchanged after reading.

7.13.1 The Status Reporting System is summarised in the following diagram.



The status bits have the following meanings:

Temperature Range

This bit is set when the last measurement resulted in a computed temperature that was outside the measuring range of the instrument. It is also set when the "crossed wires" condition is detected.

Execution Error

This bit is set when a valid command has been received and recognised, but could not be executed at the time for some reason e.g. sending DATAlogger:STARt when the data logger mode is turned off. The command is ignored.

Command Error

This bit is set when the command line is not recognised. This could be an invalid command, parameter or syntax. The command is ignored.

Measuring

This bit is set when a new measurement starts and is cleared when complete. It corresponds to the BUSY legend on the front panel display.

Measurement Available

This bit is set when a new measurement started by the INITiate command has completed. The bit is cleared when the FETCh? command is used to transfer the value to the output buffer.

Message Available

This bit is set when the output buffer contains a message. It is cleared when the buffer is empty.

STATus:QUEStionable:CONDition?

Query the Questionable Data Condition Register. The instrument returns a binary-weighted decimal value representing the bits set in the condition register.

STATus:QUEStionable:EVENt?

Query the Questionable Data Event Register. The instrument returns a binary-weighted decimal value representing the bits set in the event register.

STATus:QUEStionable:ENABle {<enable value>}

Enable bits in the Questionable Data Enable Register. The selected bits are then reported to the Status Byte.

STATus:QUEStionable:ENABle?

Query the Questionable Data Enable Register. The instrument returns a binary-weighted decimal value representing the bits set in the enable register.

STATus:OPERation:CONDition?

Query the Operation Condition Register. The instrument returns a binary-weighted decimal value representing the bits set in the condition register.

STATus:OPERation:EVENt?

Query the Operation Event Register. The instrument returns a binary-weighted decimal value representing the bits set in the event register.

STATus:OPERation:ENABle {<enable value>}

Enable bits in the Operation Enable Register. The selected bits are then reported to the Status Byte.

STATus:OPERation:ENABle?

Query the Operation Enable Register. The instrument returns a binary-weighted decimal value representing the bits set in the enable register.

***ESR?**

Query the Standard Event Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

***ESE {<enable value>}**

Enable bits in the Standard Event Enable Register. The selected bits are then reported to the Status Byte.

***ESE?**

Query the Standard Event Enable Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

***STB?**

Query the Status Byte Summary Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

***CLS**

Clears the Status Byte Summary Register and all event registers.

7.14 Command Summary

IEEE-488.2 Common Commands

*CLS
*ESE<NRf>
*ESE?
*ESR?
*IDN?
*OPC
*OPC?
*RST
*SRE <NRf>
*SRE?
*STB?
*TRG
*TST?
*WAI

Signal Oriented Measurement Commands

CONFigure :CHANnel {channel}
CONFigure?
CONFigure:TEMPerature:TC {type},{rj mode},{ext rj standard}
CONFigure:TEMPerature:RTD {type},{standard},{con},{current mode},{root 2}
FETCh?
READ?
MEASure:CHANnel? {channel}
MEASure:TEMPerature:TC? {type},{rj mode},{ext rj standard}
MEASure:TEMPerature:RTD? {type},{standard},{con},{current mode},{root 2}

SENSe

SENSe:TEMPerature:UNIT {parameter}
SENSe:TEMPerature:UNIT?
SENSe:TEMPerature:RESolution{<resolution>}
SENSe:TEMPerature:RESolution?
SENSe:ZERO:AUTO {off/on}
SENSe:ZERO:AUTO?

Mathematical Operation Commands

CALCulate
CALCulate:AVERage:MINimum?
CALCulate:AVERage:MAXimum?
CALCulate:AVERage:AVERage?
CALCulate :AVERage :COU Nt?
CALCulate:AVERage:PEAK?
CALCulate:AVERage:SDEV?
CALCulate:LIMit:LOWer {parameter}
CALCulate:LIMit:UPPer {parameter}
CALCulate:LIMit:LOWer?
CALCulate:LIMit:UPPer?

Route command summary

ROUTe:SCAN:LSELect
ROUTe:SCAN:LSELect?
ROUTe:SCAN:INTernal
ROUTe:SCAN:INTernal?

Triggering Commands

INITiate
ABORT
TRIGger:MODE
TRIGger:MODE?
TRIGger:COUNt
TRIGger:COUNt?
TRIGger:DELay
TRIGger:DELay?
SAMPle:COUNt?
SAMPle:DELay
SAMPle:DELay?

System Related Commands

DISPlay:BACKlight {off/on}
DISPlay:BACKlight? SYSTem
:BEEPer
SYSTem:BEEPer:STATe {off/on}
SYSTem:BEEPer:STATe?
SYSTem:TIME {hh},{mm},{ss}

SYSTem:TIME?
SYSTem:DATE {dd},{mm},{yy}
SYSTem:DATE?
SYSTem:DATE:FORMat
SYSTem:DATE:FORMat?

DATAlogger

DATAlogger:MODE {off/on}
DATAlogger:MODE?
DATAlogger:CLEAr
DATAlogger:STARt
DATAlogger:STOP
DATAlogger:STEP
DATAlogger:VALue? {<value>/all}
DATAlogger:POINts?

Status Reporting Commands

STATus

STATus:QUEStionable:CONDition?
STATus:QUEStionable:EVENt?
STATus:QUEStionable:ENABle {<enable value>}
STATus:QUEStionable:ENABle?
STATus :PRESet
STATus:OPERation:CONDition?
STATus:OPERation:EVENt?
STATus:OPERation:ENABle {<enable value>}
STATus:OPERation:ENABle?

RS-232 Interface Commands

SYSTem:LOCal
SYSTem:REMote

7.15 Analogue Output

The TTI-7-R analogue output provides an output voltage in the range of ±2 Volts that is directly proportional to the displayed reading and selected scaling factor. The analogue output is updated on completion of every measurement cycle and is obtained from the digital measurement by digital to analogue conversion.

7.15.1 Specification

Resolution 1°C
Sensitivity 1 mV/ °C
Analogue Output range ±2V F.S.

7.15.2 Default Settings

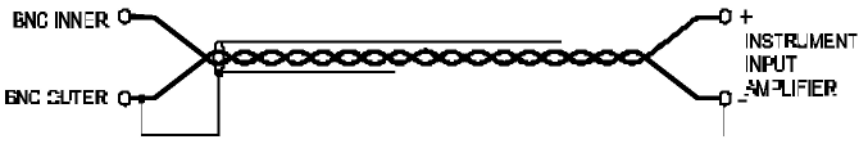
On power up, the TTI-7-R will initialise with the following settings:

Measurement units	deg C
Measurement PRT Input	PRT Input A
Resolution	Low resolution

7.15.3 Analogue Output Connection

Connection to the analogue output is via an insulated BNC output socket on the rear panel of the TTI-7-R . Connection to peripheral equipment should be made via a suitable twin core, twisted pair screened cable to the instrumentation input amplifier of the peripheral equipment, (see Figure 7.1).

Figure 7.1 - Twin Core, Twisted Pair, Screened Cable



8. Options and Accessories

8.1 Accessories

The following interfaces may be retro-fitted to the TTI-7-R

Order Suffix	Description
TTI-7-R -INT-D	RS232C Communications interface
TTI-7-R -INT-L	IEEE 488 Communications interface

The analogue output option must be specified at the time the instrument is ordered from the factory. It is not possible to retro-fit the analogue output option.

Other options available for the TTI-7-R include:

Part Number	Description
TTI-7-R-DP	DIN plug to 5-pin screw terminal plug converter
TTI-7-R-SC	Soft carry case

8.2 High Temperature PRTs

	WSP 660
R_O	100 Ω
Alpha	0.00392
Range	-189°C to +650 °C
Sheath	Inconnel
Sheath size	16" x 0.25
Cable Length	2 metres

8.3 Low Temperature PRTs

	T100-600-1 D	T100-250-1 D	T100-450-1 D	T100-200-1 D	T100-450-2 D
R_0	100 Ω	100 Ω	100 Ω	100 Ω	100 Ω
Alpha	<0.00390, typically 0.00385	<0.00390, typically 0.00385	<0.00390, typically 0.00385	<0.00390, typically 0.00385	0.00385
Range	-50 °C to +600 °C	-50 °C to +250 °C	-70 °C to +450 °C	-50 °C to +200 °C	-100 °C to +450 °C
Sheath	Fused Silica	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel
Sheath size	460mm x 6mm	350mm x 6mm	350mm x 6mm	30mm x 3mm	450mm x 6.35mm
Cable Length	2 metres	2 metres	2 metres	3 metres	2 metres

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9.Specifications

9.1A Pt100 resistance thermometer measurement

Pt100 calibration Characterisation	BS EN60 751, IEC751, US/JIS(JEMIMA)
Resistance measurement range	10 to 460 Ω
Pt100 display resolution	0.001°C
Resistance measurement uncertainty	± 2.5mΩ @ +20 °C ±2°C)
Temperature coefficient (resistance measurement)	± (3ppm of reading/ °C + 0.5mΩ / °C)
Long term stability (resistance measurement)	± 10ppm of reading / year
Temperature measurement uncertainty Pt100	Over - 190 to + 660°C ±0.01°C
Measurement configuration	3 and 4 wire selectable
Pt100 sense current	0.5 mA (DC) polarity switchable
User selectable measurement display units	°C/ °F/ K
Front panel connection	2 sets, 5 terminals
Input impedance	>10MΩ
Max common and differential mode input voltage	±40VDC, 28Vrms

9.1B Pt25 resistance thermometer measurement

Resistance range	0 to 110 Ω
Temperature measurement uncertainty Pt25	Over - 190 to + 660°C ±0.01°C
Pt25 sense current	1 mA (DC) polarity switchable

9.2 Thermocouple measurement

Thermocouple types supported	J, K, N, E, C, D, T, B, R, S
Thermocouple display resolution	0.01°C
Voltage measurement uncertainty	< ± (15ppm of reading + 1 µV)
Temperature coefficient	< ± (5ppm of reading/ °C + 0.01 µV/ °C)
Long term stability (voltage measurement)	± 240ppm of reading/ year

Thermocouple measurement uncertainty summarized for thermocouple material type

Thermocouple type	Range (°C)	Voltage range, (mV)	Measurement uncertainty (°C) (+20°C±5°C 1 year)
B	+250 to +1820	0.291 to 13.820	± (0.025% rdg +0.006% scale)
C	0 to +2315	0 to 37.066	± (0.057% rdg +0.025% scale)
D	0 to +2315	0 to 39.506	± (0.059% rdg +0.026% scale)
E	-200 to +1000	-8.825 to 76.373	± (0.031% rdg +0.004% scale)
J	-210 to +1200	-8.095 to 69.553	± (0.03% rdg +0.005% scale)
K	-200 to +1372	-5.891 to 54.886	± (0.035% rdg + 0.006% scale)
N	-200 to +1300	-3.990 to 47.513	± (0.035% rdg +0.005% scale)
R	-50 to +1768	-0.226 to 21.103	± (0.02% rdg + 0.015% scale)
S	-50 to +1768	-0.235 to 18.693	± (0.02% rdg + 0.015% scale)
T	-200 to +400	-5.603 to 20.872	± (0.025% rgd + 0.015% scale)

Primary measurement display units	mV
Connection	4mm gold plated shade lug, wine or banana plug.
Isothermal thermocouple connection temperature error	< ±0.1°C (@ +20°C) plus ±0.01°C per °C ambient deviation from +20°C (over specified operating temperature range)
Input impedance	>10MΩ
Max common and differential mode input voltage	±40VDC, 28Vrms

9.3 Internal battery operation

Operating time from fully charged	>20 hours (no backlight), 80 hours (backlight on)
Battery recharge time	<4hours

9.4 Supply

Mains supply voltage range selection

1	(90 - 110V)	100Vac
2	(108 - 132V)	120Vac
3	(198 - 244V)	220Vac
4	(216 - 264V)	240Vac
Power consumption:		30VA max
Supply frequency range		47 - 63Hz

9.5 Environmental

Storage temperature range	-20°C to +50°C
Service temperature range	0°C to +40°C
Specified operating temperature range	+15°C to +25°C
Operating relative humidity conditions	<80% RH, non-condensing

9.6 Data communication interface options

Control and data interface options	IEEE 488 or RS232

9.7 Analogue output option

Analogue output port	-2V to +2V range, 1 mV/°C scaling, 1°C resolution

9.8 Display

User interface, display	40x 8 character, (240x 64 pixel) NTN LCD green/ yellow back lit display

9.9 Physical

Dimensions:	Metal case with adjustable rest/handle, 240mm deep (front to back) x 260mm wide x 80mm high (9.45" deep x 10.24" wide x 3.15" high)
Weight:	5.5kg (12.1 lbs)

9.10 Pt25 and 100 System accuracy

System accuracy is the combined accuracy of the TTI-7-R plus the calibration uncertainty of the PRT. Accurate figures for the instrument and system with the range of calibrated PRTs available for the TTI-7-R are shown below.

TTI-7-R + WSP660 (-190 °C to + 660°C)

-180°C	-50 °C	0°C	+100°C	+250 °C	+660°C
±30mK	±20mK	±20mK	±20mK	±20mK	±25mK

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10. Cleaning and Maintenance

10.1 Cleaning

Make sure the TTI-7-R is disconnected from the mains supply before cleaning.

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.

10.2 Preventive Maintenance

WARNING: Inspect the mains supply cable regularly to ensure that insulation is not damaged.

10.3 General Safety Warning

WARNING: If the TTI-7-R is used in a manner not specified by ISOTECH NA, then the protection provided by the instrument may be impaired.

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11. Service and Warranty

TTI-7-R equipment and accessories, (unless stated otherwise), are covered by a 24 month warranty for parts and labour from the date of dispatch from ISOTECH NA. This warranty does not include costs incurred in returning the equipment to the factory for repair.

11.1 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

www.isotechna.com
sales@isotechna.com

11.2 Returned Instruments

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

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