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SI1287 Electrochemical Interface

USER GUIDE

SI1287
Electrochemical Interface

USER GUIDE

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For details of our agents in other countries, please contact our Farnborough, UK, office.

Solartron pursues a policy of continuous development and product improvement.
The specification in this document may therefore be changed without notice.

GENERAL SAFETY PRECAUTIONS

The equipment described in this manual has been designed in accordance with IEC publication 1010 Safety Requirements for Electronic Measuring Apparatus, and has been supplied in a safe condition. To avoid injury to an operator or service technician the safety precautions given below, and throughout the manual, must be strictly adhered to, whenever the equipment is operated, serviced or repaired. For specific safety details, please refer to the relevant sections within the manual.

The equipment is designed solely for electronic measurement and should be used for no other purpose. Solartron accept no responsibility for accidents or damage resulting from any failure to comply with these precautions.

GROUNDING
To minimize the hazard of electrical shock it is essential that the equipment is connected to a protective ground whenever the power supply, measurement or control circuits are connected, even if the equipment is switched off.

PROTECTIVE GROUND is connected via the ac supply cord. The cord must be plugged into an ac line outlet with a protective ground contact. When an extension lead is used, this must also contain a ground conductor. Always connect the ac supply cord to the supply outlet before connecting the control and signal cables; and, conversely, always disconnect control and signal cables before disconnecting the ac supply cord. The ac ground connection must have a continuous current rating of 25A.

AC SUPPLY VOLTAGE
Never operate the equipment from a line voltage or frequency in excess of that specified. Otherwise, the insulation of internal components may break down and cause excessive leakage currents.

FUSES
Before switching on the equipment check that the fuses accessible from the exterior of the equipment are of the correct rating. The rating of the ac line fuse must be in accordance with the voltage of the ac supply.

Should any fuse continually blow, do not insert a fuse of a higher rating. Switch the equipment off, clearly label it "unserviceable" and inform a service technician.

EXPLOSIVE ATMOSPHERES
NEVER OPERATE the equipment, or any sensors connected to the equipment, in a potentially explosive atmosphere. It is NOT intrinsically safe and could possibly cause an explosion.

NOTES, CAUTIONS AND WARNINGS
For the guidance and protection of the user, Notes, Cautions and Warnings appear throughout the manual. The significance of these is as follows:

NOTES	highlight important information for the reader's special attention.
CAUTIONS	guide the reader in avoiding damage to the equipment.
WARNINGS	guide the reader in avoiding a hazard that could cause injury or death.

Continued overleaf.

SAFETY PRECAUTIONS (continued from previous page)

SAFETY SYMBOLS

For the guidance and protection of the user, the following safety symbols appear on the equipment:

SYMBOL	MEANING
	Refer to operating manual for detailed instructions of use.
	Hazardous voltages.
	Protective conductor terminal. This must be connected to ground before operating the equipment.

AVOID UNSAFE EQUIPMENT

The equipment may be unsafe if any of the following statements apply:

- Equipment shows visible damage.
- Equipment has failed to perform an intended operation.
- Equipment has been subjected to prolonged storage under unfavorable conditions.
- Equipment has been subjected to severe physical stress.

If in any doubt as to the serviceability of the equipment, don't use it. Get it properly checked out by a qualified service technician.

LIVE CONDUCTORS

When the equipment is connected to its measurement inputs or supply, the opening of covers or removal of parts could expose live conductors. The equipment must be disconnected from all power and signal sources before it is opened for any adjustment, replacement, maintenance or repair. Adjustments, maintenance or repair, must be done only by qualified personnel, who should refer to the Servicing Manual.

EQUIPMENT MODIFICATION

To avoid introducing safety hazards, never install non-standard parts in the equipment, or make any unauthorized modification. To maintain safety, always return the equipment to Solartron for service and repair.

SI1287 Electrochemical Interface Contents

CHAPTER

1 Introduction

Introduces the facilities of the SI1287 Electrochemical Interface, gives a comparison to the 1286, and summarizes the content of the manual.

2 Using the SI1287

Guides you through some simple uses of the SI1287 and signposts the way to more advanced uses.

3 SI1287 Parameters and Commands

Provides a logical breakdown of the facilities and the commands that are used to drive them.

4 Remote Control

Describes the RS232 and GPIB facilities of the SI1287.

5 Using the SI1287 with an FRA

Guides you through connection and setup of the SI1287 when used with an FRA.

APPENDIX

A Installation Procedure

B Error Codes

C SI1287 Specification

INDEX

Chapter 1
Introduction

Section *Page*

1 **Electrochemistry and SI1287** 1.3
2 **Features of the SI1287** 1.3
3 **The Structure of the SI1287** 1.3
4 **SI1287 Improvements over 1286** 1.6
5 **Application Software** 1.7
6 **Further Reading** 1.7
7 **Using the SI1287 User Guide** 1.8

Figure

1.1 *SI1287 Block Schematic* 1.4

1 ELECTROCHEMISTRY AND SI1287

Electrochemical measurements rely on the electrical aspect of chemical processes to provide readable data. This is based on Faraday's law which relates the change in mass per unit area of a substance, to the magnitude of the current flowing through it. Measurements are made of the voltage and current acting in an electrochemical "cell", whose basic form is a pair of metal electrodes immersed in an electrolyte.

The wide range of studies to which electrochemical measurements can be usefully applied includes: corrosion, effectiveness of protective coatings, batteries, and biological processes.

For these measurements the SI1287 Electrochemical Interface can provide accurate d.c. polarization to establish the rate of ionization in the cell and frequency response analysis to study the cell impedance characteristics. The full spectrum of electrochemical measurement techniques can thus be employed to establish or study the mechanisms of various electrochemical phenomena.

2 FEATURES OF THE SI1287

The SI1287 Advanced Electrochemical Interface is an exceptional adaptable instrument. It can stand alone, or form the center of a powerful measurement system.

The SI1287 can be used either as a potentiostat or galvanostat, with selectable control loop bandwidth to ensure stable operation for various types of cell. Full compensation and correction facilities are provided to enable you to extract the most useful information from your experimental data, with the utmost precision.

Control of the SI1287 is managed manually from the front panel keyboard, or by simple commands that are applied from a controller, such as a personal computer, via the GPIB. Data from the SI1287 may be output in the form most suitable for your analysis requirements. ASCII and binary coded data is available, as well as ASCII coded status messages.

3 THE STRUCTURE OF THE SI1287

Figure 1.1 is a block diagram of the SI1287. The structure can be considered in three parts:

- Polarization control
- Voltage (Reference electrode) measurement
- Current measurement.

In addition to the blocks shown in Figure 1.1, the SI1287 also includes:

- two independent DVMs,
- results store,
- front panel display and keyboard,
- battery for retaining the set up and results store when power is removed,

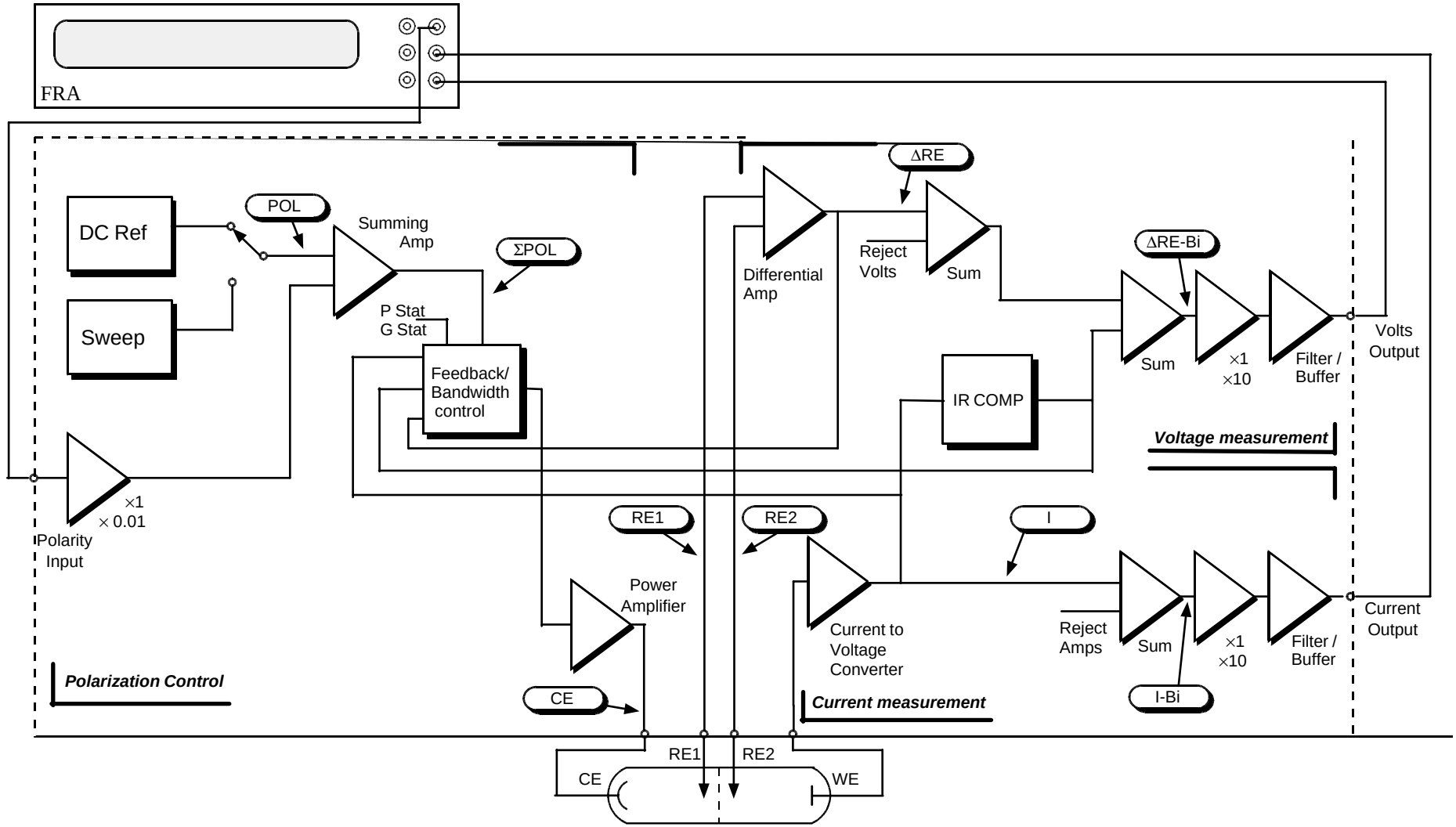


Fig 1.1 *SI1287 Block Schematic*

- GPIB and Serial input/output ports
- control circuitry to integrate all these facilities.

Although FRA connections are shown in the diagram for completeness, the SI1287 does not need one to make dc measurements.

DVM

SI1287 has two independent DVMs which have a '5 x 9s' output. The DVMs can be switched to measure a variety of different parameters independently, and these are indicated in Figure 1.1, thus: 

POLARIZATION CONTROL

Polarization of the cell is a combination of dc, swept dc and an external voltage, which normally comes from a Frequency Response Analyzer (FRA). Internal generators within the SI1287 generate an accurate and stable dc voltage (POL) which is added to the external (ac) signal from the FRA, to give ΣPOL. This signal is used to control the current through the cell, or the voltage across the reference electrodes, depending on whether the ECI is in galvanostat (i.e., current controlled) or potentiostat (voltage controlled) mode.

Feedback from the relevant cell parameter is used to control the polarization. In addition, the bandwidth of the feedback mechanism can be selected by the user to prevent unwanted oscillations from occurring. The polarization signal is also modified when IR compensation is used, either by adding a compensation voltage, or by interrupting the polarization to the cell.

VOLTAGE MEASUREMENT

The voltage across the reference electrodes (ΔRE) is measured by a differential amplifier, and this voltage is used to control the polarization when the SI1287 is in potentiostat mode.

In order to reject any unwanted steady dc level on the cell, a stable programmable voltage, generated within SI1287, can be subtracted from the measured voltage. If sampled IR compensation is being used, the resultant voltage is passed through a sample-and-hold circuit. The signal (ΔRE-Bi) is then buffered, optionally filtered, and output to one channel of the FRA.

CURRENT MEASUREMENT

The current from the working electrode is measured by passing it through a user-selectable resistor; this generates a voltage proportional to the current which is then measured by a differential amplifier. This allows the working electrode to be floating, and not connected to the instrument ground. If sampled IR compensation is invoked, the output of the differential amplifier is passed through a sample-and-hold circuit, to yield I. A programmable rejection voltage, representing a steady current through the cell which is to be offset, can be subtracted from the measured voltage to give (I-Bi) before it is buffered, optionally filtered and output as a voltage (proportional to the current in the cell) to the FRA.

RESULTS STORE

The History file is capable of storing up to 450 results, depending on the number of instrument set-ups stored in memory (each stored set-up reduces this number by 16).

4 SI1287 IMPROVEMENTS OVER 1286

The SI1286A ECI has been established for a number of years as one of the most advanced instruments of its type, and has an impressive specification. The SI1287A has an enhanced specification that enables even more sensitive measurements to be made, and opens up new areas of application.

A summary of the improvements is given below:

- Extra current range, giving increased current sensitivity: 1pA compared to 10pA on 1286;
- Floating Working Electrode;
- Reduced measurement noise;
- Improved DC sweep rate: 6mV/min up to 6000V/min with a resolution of 150µV/min, compared to 1286's 6mV/min resolution;
- Increased maximum DC polarization: ±14.5V, compared to ±12.8V for 1286;
- Sweep freeze capability;
- Conformance to EMC standards.

Some of the benefits of these improved specifications are listed below.

The 1287 has an additional current measurement resistor which adds a 200nA range with a resolution of 1pA. Together with the 1µV voltage sensitivity, and the improved measurement noise, the 1287 can measure effects which were previously hidden to the researcher. This improvement also adds another decade of impedance range, allowing measurements in excess of 1GΩ to be made accurately.

The extra current range and lower measurement noise also means that frequency sweep measurements can be made more quickly, since the integration time on the FRA can be reduced.

A further benefit of this extra sensitivity and lower noise is that Electrochemical Noise measurements - which require the accurate *simultaneous* measurement of very low voltages and currents - can now be made to yield useful results.

The ability to float the working electrode is of great benefit in many industrial applications where the working electrode has to be grounded - for tests on oil pipelines, for example. Even in the laboratory, equipment may need to be grounded for safety reasons, and this can now be handled by 1287.

The increased maximum polarization voltage enables experiments to be conducted on 12volt accumulators, which typically have a rest potential of >13V.

The 1287 can be programmed to freeze the polarization after a DC sweep, rather than return it to zero. This allows any number of sweeps to be performed in sequence without the need to turn the polarization off, to minimize disturbances to the cell.

5 APPLICATION SOFTWARE

SI1287 works equally well as a stand-alone instrument, or as part of a computer controlled system. The advantages of using a PC for control and data storage are:

- Complex set-ups can be stored and downloaded rapidly, avoiding the need for time consuming (and error prone) manual set-ups
- Easy-to-use mouse-driven menu selections to set up and display data
- Wide variety of display formats available
- Results can be stored on disk for later analysis and trending
- Polarization sweeps, impedance tests, harmonic analysis and EC noise tests can be run with ease
- Equivalent circuit simulation and curve fitting facilities give greater insight into reactions mechanisms

Other facilities include direct readout of corrosion rate and polarization resistance, 3-dimensional plotting routines, Tafel fitting software, and batch tests (including automatic test sequencing and full multiplexer support).

Our application software portfolio is constantly being updated. Please contact Solartron for more information and a free copy of the latest demonstration software.

6 FURTHER READING

Understanding Electrochemical Cells, by A.M. Kauffman. (Technical Report 017/85) This book gives a simple non-mathematical treatment of what happens in an electrochemical cell during a corrosion process. It is intended for technicians who wish to obtain an intuitive grasp of the phenomena involved.

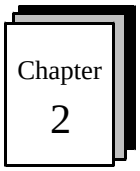
Identification of Electrochemical Processes by Frequency Response Analysis, by Claude Gabrielli. (Technical Report 004/83) This book gives a broad introduction to the many different techniques that can be used in electrochemistry. Although written by an electrochemist for electrochemists the book does not aim to be a deep study, but it does contain an extensive bibliography. You are thus directed to a number of classical treatises and scientific papers on many subjects of interest.

Use and Applications of Electrochemical Impedance Techniques, by Claude Gabrielli. (Technical Report No. 24) This book complements the author's other book (above), but is more application oriented. Again, reference is made to many scientific papers.

Use and Analysis of EIS Data for Metals and Alloys, by Florian Mansfeld. (Technical Report No. 26) This is a collection of reports, previously published by Schlumberger Technologies, which describes in some detail the different analytical processes required for data acquired by electrochemical impedance spectroscopy. The models proposed for the simulation and fitting of EIS data are discussed and each is illustrated by the interpretation of actual experimental data.

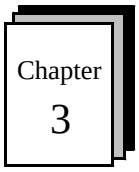
7 USING THE SI1287 USER GUIDE

The aim of the SI1287 User Guide is to provide useful information on how best to employ your Advanced Electrochemical Interface. To guide you in reading the manual a synopsis of Chapters 2 through 6 is given below:



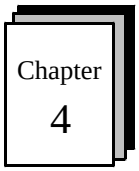
Using the SI1287

Guides you through some simple uses of the SI1287 and signposts the way to more advanced uses.



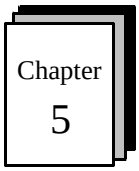
SI1287 Parameters and Commands

Provides a logical breakdown of the SI1287 facilities and lists the commands that are used to drive them.



Remote Control

Describes the RS423 and GPIB facilities of the SI1287 and gives details of the remote commands available.



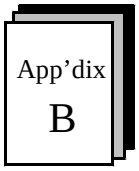
Using the SI1287 with an FRA

Guides you through the connection and setup of the instrument when used with an FRA.



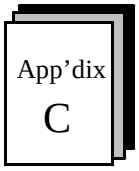
Installation

Gives full details of how to install the SI1287.



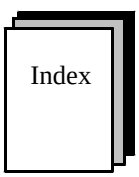
Error Codes

Lists the error codes and explains the meaning of each one.



SI1287 Specification

Contains the full specification of the SI1287.



Index

Cross references major topics within the manual.

Chapter 2
Using the SI1287

Section *Page*

1 **Introduction** 2.3

2 **Front Panel Key Operation** 2.3
2.1 Key Operation 2.3
2.2 Modes of Operation 2.4
2.3 Power Up 2.4

3 **Connecting to the SI1287** 2.5
3.1 Measurement of Grounded Electrodes 2.5

4 **Setting Parameters for a Potentiodynamic Polarization Curve** 2.7
4.1 External Connections 2.7
4.2 Initializing SI1287 ..... 2.8
4.3 Setting up Parameters 2.8

5 **Using the Display** 2.14

Figure

2.1 *SI1287 Front Panel : Keys and display section* 2.3
2.2 *Cell Connections* 2.4
2.3 *12861 Test Module Circuit* 2.7
2.4 *Plot of the Sweep* 2.13
2.5 *Plot of the Potentiodynamic Polarisation Curve* 2.13

1 INTRODUCTION

This chapter demonstrates how to set up and use the SI1287, using the front panel menus. The SI1287 can also be controlled remotely via RS423 and GPIB, refer to Chapter 4 for Remote Control details. Connections to a test cell module are also detailed, followed by the initial set up and relevant steps to produce results on the display.

The chapter aims to make you aware of the set-up and control facilities of the SI1287 and help build your confidence in the use of the instrument.

It should be noted that before attempting to use the SI1287, the installation and safety instructions should be followed; refer to the Safety notes at the start of the manual and the Installation procedure, Appendix A.

2 FRONT PANEL KEY OPERATION

There are three principal groups of keys on the SI1287 front panel; shift keys, main keys and stepping keys, see Fig 2.1.

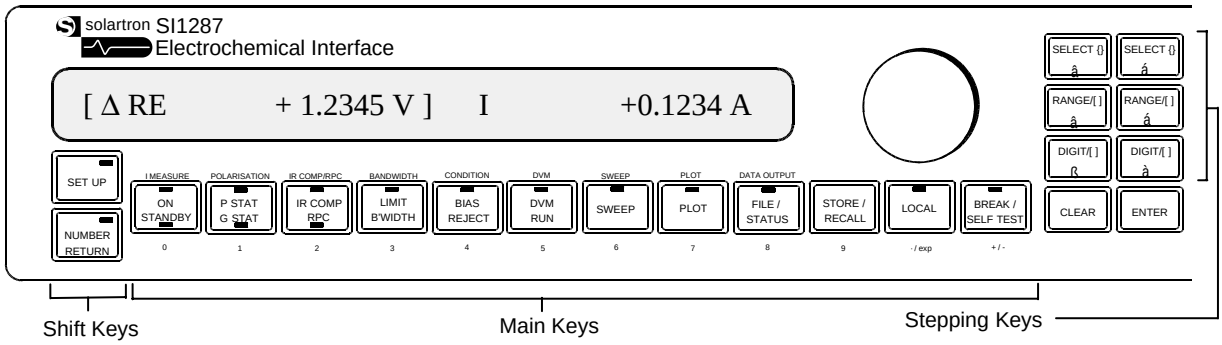


Fig 2.1 *SI1287 Front Panel : Keys and display section*

2.1 KEY OPERATION

LEDs (light emitting diodes) on the keys indicate if they are active. On keys with more than one active state (e.g. '*P STAT/G STAT*') the appropriate LED on the key face lights to show which state is 'on'.

Shift Keys
The Shift keys have a push-for-on (LED flashing), push-for-off (LED off) action. Both shift keys cannot be 'on' together, except during some parts of the self test routine.

Main Keys
The main keys when used in 'normal mode' are operated by repeated pushing to reach the required state, e.g. the '*IR COMP/RPC*' key selects '*IR COMP*' (top LED lit) at the first push, '*RPC*' (lower LED lit) at the second push and neither (both LEDs off) at the third push.

Stepping Keys
The stepping keys are used to step through lists of menu selections (etc.) in either direction. They step once per press, but auto-repeat when held down.

2.2 MODES OF OPERATION

Normal Mode
When both shift keys are off, the main keys act according to the label on each key face. This is called "normal" mode, and in this mode the keys are referred to as "action keys".

Parameter Set-up Mode
When the "SET UP" shift key is "on", the main keys act according to the label above each key. This is "parameter set-up" mode.

Number Entry Mode
When the "NUMBER RETURN" shift key is "on", the main keys act as a number keypad, according to the label below each key. This is "number entry" mode.

2.3 POWER UP

At power up, one of three messages is displayed:

"**Power Restored**"
This means that, after an interruption in the mains supply (whether deliberate or accidental), the SI1287 remembers all the existing menu settings, history file, and stored menu set-ups, using its internal battery.

"**Reset**"
This means that the SI1287 has returned all the menu settings to the default state, but left the history file and stored set-ups as they were.

This happens if the SI1287 detects a fault in its data base (existing menu settings). It may occur, for example, if the SI1287 has been without power for more than the 100 hours, which the internal battery is guaranteed to maintain the memory (but not long enough to corrupt the history file and stored menu set-ups).

"**Initialised**"
This means that all menu settings have been returned to the default state, and the history file and stored menu set-ups have been erased. This appears at power up when the SI1287 has been switched off for more than 100 hours.

3 CONNECTING TO THE SI1287

The following diagrams show how to connect a four-, three-, or two-terminal electrochemical cell to the terminals on the front panel of the SI1287.

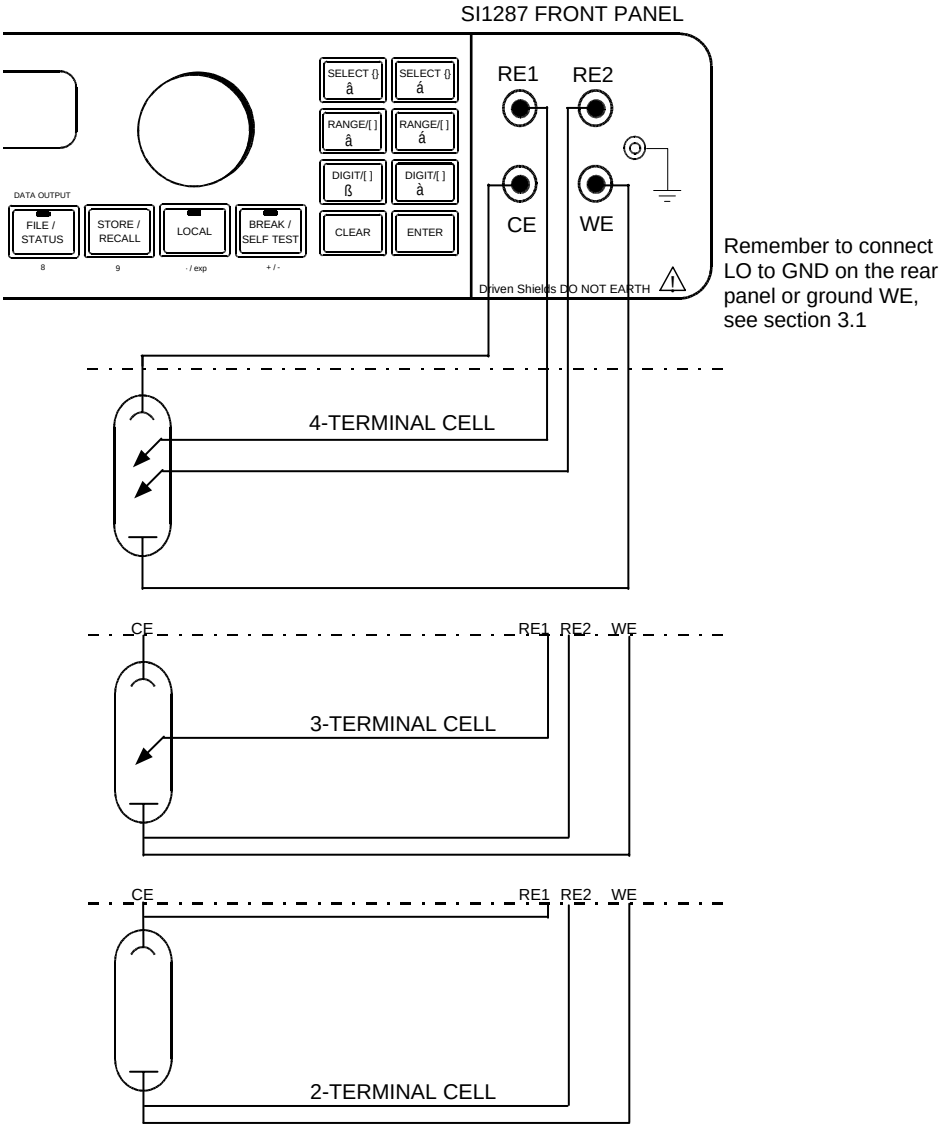


Fig 2.2 *Cell Connections*

The outer screen connections on the bnc connectors are connected internally to screen driver amplifiers, and must be left to float; they must **not** be connected to ground, each other, or any other voltage.

3.1 MEASUREMENT OF GROUNDED ELECTRODES

The polarization and measurement circuits share a common reference, which is connected to the LO terminal. Under most circumstances, where none of the cell terminals are grounded, the LO terminal should be connected to chassis ground by a link across the GROUND (green) and LO (black) binding posts at the rear of the SI1287, see figure 2.2. This will give the best accuracy in Impedance measurement.

However, in many field applications the WE electrode may be grounded, either deliberately or inherently (e.g., a steel joist or pipe buried in the ground). In this case, leave the LO terminal unconnected, to avoid having two grounded points in the circuit (which can cause polarization instability).

It is permissible to ground the WE, either at the instrument or at a point of the users choice (provided that the GROUND-LO link is disconnected). It is not advisable to ground the WE with the 20µA, 2µA and 200µA ranges selected. For grounded WE the impedance measurement errors will vary smoothly from zero at dc to ±10% at 10kHz.

If the cell container is metal and grounded, it is usually best to ground the CE electrode. However, this reduces the frequency response of the polarization loop.

4 SETTING PARAMETERS FOR A POTENTIODYNAMIC POLARIZATION CURVE

The purpose of this section is to give you a brief introduction to the front panel operation; how to set up parameters, read measurements and plot results. Once you have achieved this, you will be sufficiently familiar with the SI1287 to set up your own experiments. The 12861 Test Module is used to simulate the cell.

This exercise will plot current as a function of swept potential. This sort of plot provides a general overview of corrosion reactions in a wide potential range and is useful for applications where screening tests of inhibitors, alloying elements, passivity and electrode kinetics are required.

Section 4.1 details the connections to be made from the 12861 Test Cell Module and the plotter to the SI1287. When the connections have been made the instrument should then be initialized (section 4.2).

With the instrument in the default state the following parameters will be entered: {I Measure}, {DVM}, {Sweep}, {Data Output}, and {Plot}. Other parameters are left in the default state; see section 4.3.

{I Measure} - sets the current measuring resistor and protection levels.
{DVM} - set the display parameters.
{Sweep} - set the limits for the sweep.
(Data Output} - sets the output data.
(Plot} - sets the parameters for plotting, such as the grid coordinates, size of paper, grid on/off, etc.

4.1 EXTERNAL CONNECTIONS

For this example the three-terminal cell connection is used, using the 12861 Test Module to simulate the cell. The connection details for the 12861 Test Module can be seen in section 3. The equivalent circuitry for the test module can be seen in the following diagram :

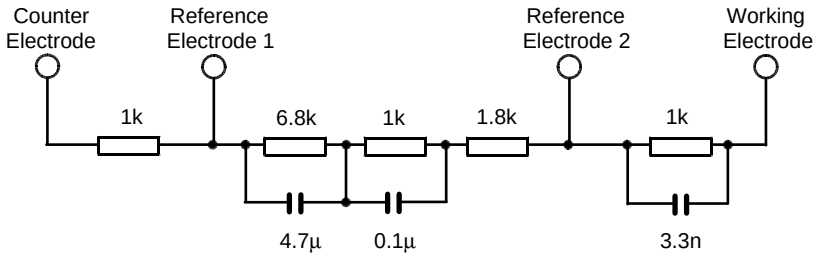


Fig 2.3 *12861 Test Module Circuit*

Connect an HP plotter via GPIB cable to the GPIB port on the rear panel of the SI1287. Set the SI1287 address to 'talk only' and the plotter to 'listen always'. Switch the plotter on, then set the plotter up, ie. with paper and pens, ready to plot.

4.2 INITIALIZING SI1287

When the SI1287 is switched on, the following will appear on the display:

[POWER RESTORED]

The following LEDs will be lit on power up:

- ON/STANDBY with STANDBY lit
- P STAT/G STAT with P STAT lit
- LIMIT BANDWIDTH lit
- LOCAL lit

The instrument should now be initialized so that all parameters are returned to their default states.

To do this press the "BREAK/SELF TEST" key. Then step through the menu selections by continually pressing the key or by pressing the "SELECT { }" keys. When the selection {initialise} is displayed press "ENTER" to initialize the instrument. The following will appear on the display:

[INITIALISED]

4.3 SETTING UP PARAMETERS

Press the "SET UP" key; the led will flash indicating that you are in the set up mode. Once this is pressed the display will change showing:

Key Press	*Resulting Display*
	[ΔRE] I

CURRENT MEASUREMENT

Select I Measure to set up the parameters for the current measurement. This is done by pressing the "ON/STANDBY" key which, in set up mode, is "I MEASURE" (indicated in small print above the key). The display now shows:

Key Press	*Resulting Display*
	{ RESISTOR [auto] } I

Pressing the "SELECT { }" keys you can step through the menu selections available. If an incorrect parameter is entered during this exercise, you can use the "SELECT { }" keys to step through until the menu selection reappears and then correct it.

With "RESISTOR" displayed, pressing the "RANGE/[ ]" keys steps through the available measuring resistor values (or by rotating the knob, on the front panel). This, however, can be left as its default, which is "[auto]". Now press ENTER. The display will now change showing:

Key Press	*Resulting Display*
ENTER	I LIMIT [2A]

Leave this to the default of "[2A]" and ENTER. The display will now change to the next selection:

Key Press	*Resulting Display*
ENTER	{ O/L TYPE [cut-out] } I

Press "RANGE/[ ]á " to select "[warning]".

Key Press	*Resulting Display*
RANGE/[ ] á	{ O/L TYPE [warning] } I

When "[warning]" has been selected continue as follows:

Key Press	*Resulting Display*
ENTER	{ STANDBY [all o/c] } I
RANGE/[ ] á	{ STANDBY [CE o/c] } I
ENTER	{ ON MODE [pol V/I] } I
ENTER	{ RESISTOR [auto] } I

When the display is returns to the "RESISTOR" selection, the set up for I Measure is complete.

POLARIZATION, IR/COMP, BANDWIDTH AND CONDITION

In this exercise the following parameters are left as their defaults:

- Polarisation
- IR/COMP
- Bandwidth
- Condition

For details of these parameters refer to Chapter 3. The remote commands and the parameter defaults can be found in Chapter 4, section 6.

DVM

Now press the "DVM" key to set up the parameters for measurement. The following will be displayed:

Key Press	*Resulting Display*
	{ DIGITS [5 × 9] } I

The parameters in this menu selection are to be entered as the default settings, except for {TRIGGER} which should be set to [recycle]. So, as before, use the "SELECT { }" keys until the {TRIGGER} is displayed. Then using the "RANGE/[ ]" keys to step through the menu until [recycle] appears, then press ENTER.

To view the display press the "SET UP" key to take the instrument out of set up mode. Then press the "DVM RUN" key; the following will be displayed (the values displayed may differ slightly):

Key Press	*Resulting Display*
	[ΔRE 0.054mV] I 3.153nA

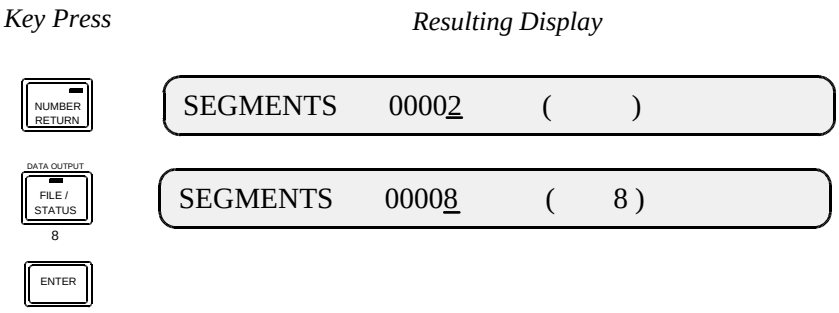
The two DVMs can measure and display a variety of parameters. At present the display is reading ΔRE and I, but these can be changed if other parameter readings are preferred. To do this position the [ ] brackets to the left or right reading using the "DIGIT/[ ]" keys. Then step through the menu list using the "RANGE/[ ]" keys until the preferred reading appears, see section 5 for further details.

SWEEP

Press the "SET UP" key to take the instrument back to set up mode. Now press the "SWEEP" key to set the sweep parameters. The following will be displayed:

Key Press	*Resulting Display*
	{ SEGMENTS 00002 } I 3.188nA

The segments parameter defines how many steps there will be in the sweep. To enter a numeric value press the "NUMBER RETURN" key. This now allows you to enter a number as dictated below the keys. Select 8, (the "FILE STATUS" key):



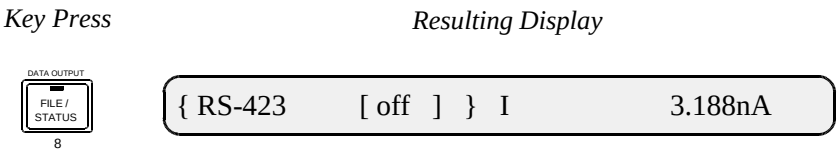
Set the other sweep parameters to the following:

- {OFF MODE} to [standby]
- {DELAY} to 1 second
- {V1 RMP} to -1 volt
- {T1 RMP} to 10 seconds
- {V2 RMP} to 1 volt
- {T2 RMP} to 15 seconds
- {V3 RMP} to 1 volt
- {T3 RMP} to 10 seconds
- {V4 RMP} to -1 volt
- {T4 RMP} to 15 seconds

The ramp rate can be calculated by: (V2-V1)/T1 in V/seconds.
For further details of the sweep parameters refer to Chapter 3, section 8.

DATA OUTPUT

Now press the "DATA OUTPUT" key. The following will be displayed:



Set the following parameters:

- {PAR1} to [I]
- {PAR2} to [POL]

Leave the other parameters as the default settings; refer to Chapter 3, section 15 further details of parameters and the defaults.

DVM

Now press the "DVM" key again, and change the {TRIGGER} from [Recycle] to [Sync.]

PLOT

Now press the "PLOT" key. The following will be displayed:

Key Press	*Resulting Display*
	{ XITEM [PAR1] } I 3.188nA

Set the plot parameters to the following. This first set of parameters will allow you to make a plot of the sweep that has been entered:

- {XITEM} to [TIME] ; at this point pressing the "SELECT {}" keys would step to YITEM. Pressing ENTER, however, allows you to set up the plot coordinates for XMIN, XMAX and XORIGIN. For details of the plot facility refer to Chapter 3, section 9.

- {XMIN} to 0
- {XMAX} to 100
- {XORIGIN} to 0

- {YITEM} to [PAR2]
- {YMIN} to -2
- {YMAX} to 2
- {YORIGIN} to 0

- {MODE} to [vector]

The other parameters can be left as the defaults, these are {Size} [A4], {Text} [on], {Title} [off], {Grid} [off], and {Device} [HPGL].

PLOTTING THE SWEEP

Now exit the set up mode by pressing the "SET UP" key and press the "PLOT" key. This now allows you to do a plot of the sweep parameters that you have entered.

Ensure that the plotter is ready then select the {Plot Axes} ENTER, to plot the frame. Then select {Plot Graph} ENTER, which will set the instrument ready to plot, once the sweep has been started.

Press the "ON/STANDBY" key so that the "ON" led is lit. Then press the "SWEEP" key and select {sweep ramp} ENTER.

The SI1287 will take a few seconds before the sweep/plot starts due to the instrument's own integration delay, plus the delay that you entered in the sweep parameters.

When complete the SI1287 will return to the "STANDBY" mode with the respective led lit. The plot should resemble figure 2.4.

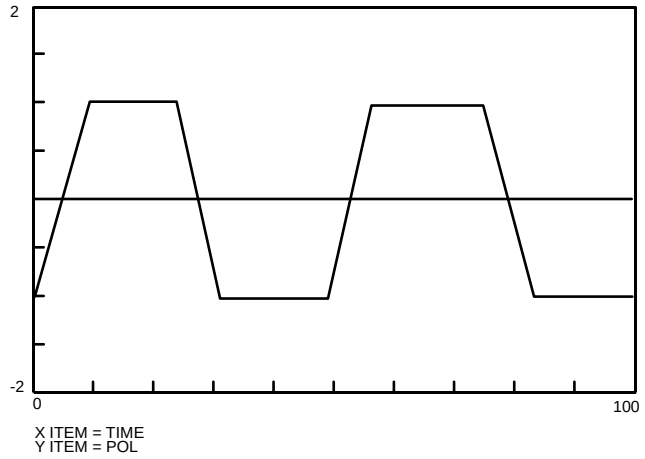


Fig 2.4 *Plot of the Sweep*

PARAMETERS FOR PLOTTING THE POLARIZATION CURVE

If you now go back into set up mode and select "PLOT" you can change the parameters to allow you to make a plot of the polarization curve. The parameters for the plot are as follows:

- {XITEM} to [PAR1]
- {XMIN} to -100.000E-06
- {XMAX} to 100.000E-06
- {XORIGIN} to 0
- {YITEM} to [PAR2]
- {YMIN} to -1
- {YMAX} to 1
- {YORIGIN} to 0
- {MODE} to [vector]

The other parameters can be left as the defaults, which are {Size} [A4], {Text} [on], {Title} [off], {Grid} [off], and {Device} [HPGL]. When the parameters have been entered continue as before when plotting the sweep. The plot should resemble figure 2.5

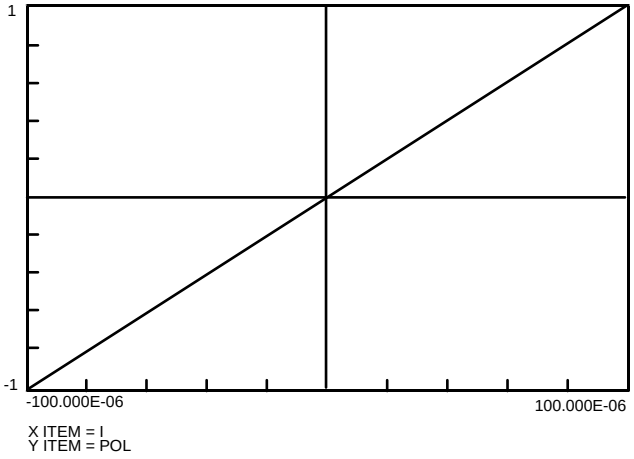
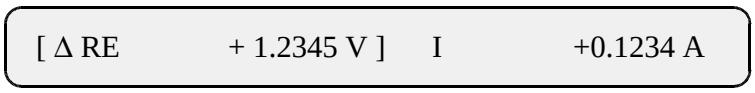


Fig 2.5 *Plot of the Potentiodynamic Polarisation Curve*

5 USING THE DISPLAY

SELECTING THE DISPLAY

In normal mode the display shows two readings measured by the internal DVM(s). For example:



To change the displayed parameters position the [ ] brackets to the left or right parameter using the "DIGIT/[ ]" keys. Then step through the list of parameters available for display, using the "RANGE/[ ]" keys, until the chosen reading appears between the brackets. Both halves of the display may show the same parameter if wanted.

The complete list of readings and functions which may be displayed are:

Symbol	Parameter
CE	Counter electrode (CE) voltage.
RE1	Reference electrode 1 (RE1) voltage.
RE2	Reference electrode 2 (RE2) voltage.
ΔRE	Total voltage across RE1 and RE2 (RE1-RE2).
ΔRE-Bi	ΔRE with bias rejected.
I	Total current flowing through the cell.
I-Bi	Total current flowing through the cell with d.c. bias rejected.
δΔRE/δI	Ratio of ΔRE increment to I increment (resistance).
δI/δΔRE	Ratio of I increment to ΔRE increment (conductance).
POL	Internal d.c. polarisation level (menu-set level).
∑POL	Total d.c. polarisation level (POL I/P + POL).
DVM I/P	External voltage input to internal DVM (rear panel).
TIME	Instrument Time (no DVM measurements are made).
(blank)	A blank space (no DVM measurements are made).

VARYING ONE PARAMETER WHILST OBSERVING ANOTHER

An example of varying one parameter whilst observing another would be adjusting POL V (polarisation voltage) to reduce I (total cell current) to zero, whilst the SI1287 is in 'on' mode.

Start by setting the DVM parameters back to recycle (in set up mode), then, in normal mode, switch the cell on by pressing the "ON/STANDBY" key. Next press the DVM Run.

Then press the "SET UP" key so that the instrument is again in set up mode. Then select the parameter that is to be changed; in this case the polarization. The key sequences and resulting displays for this exercise are:

Key Press	*Resulting Display*	
	[Δ RE + 1.2345 V]	I +0.1234 A
	{POL V + 0.2468 V}	I +0.1234 A
	{POL V + 0.2461 V}	I +0.1200 A

Vary the value of POL V, using the knob together with the "DIGIT/[ ]" and "RANGE/[ ]" keys, whilst observing the value of "I" in the right half of the display.

The displayed parameter values are set up immediately without having to press ENTER (except to terminate the set up).

Chapter 3
SI1287 Parameters and Commands

Section		*Page*
1	**Introduction**	3.5
2	**I Measure**	3.5
2.1	{Resistor}	3.5
2.2	{O/L Type}	3.6
2.3	{Standby}	3.6
2.4	{On Mode}	3.7
3	**Polarisation**	3.8
3.1	{POL V}	3.8
3.2	{POL I}	3.8
3.3	{POL I/P}	3.8
4	**IR Comp/RPC**	3.9
4.1	{IR COMP}	3.9
4.2	{RPC Ω}	3.12
5	**Bandwidth**	3.13
5.1	{P STAT BW}	3.13
5.2	{G STAT BW}	3.13
6	**SI1287 Output Conditioning**	3.15
6.1	{V Reject}	3.15
6.2	{I Reject}	3.15
6.3	{LP Filter}	3.15
6.4	{V×10}	3.16
6.5	{I×10}	3.16
7	**DVM**	3.17
7.1	{Digits}	3.17
7.2	{Range}	3.18
7.3	{Trigger}	3.18
7.4	{Drift Corr.}	3.19
7.5	{Averaging}	3.19
7.6	{Null}	3.20
8	**Sweep**	3.21
8.1	{Delay}	3.21
8.2	{Off Standby}	3.22
8.3	{Segments}	3.22
8.4	{V1 RMP}	3.22
8.5	{I1 RMP}	3.22
8.6	{V1 STP}	3.22
8.7	{I1 STP}	3.23

Continued on next page.

Section *Page*

8.8 Stepped Sweep 3.24
8.9 Commands not allowed durring sweep 3.24

9 Plot 3.25
9.1 {X Item} 3.25
9.2 {Y Item} 3.25
9.3 {Size} 3.25
9.4 {Text} 3.26
9.5 {Title} 3.26
9.6 {Grid} 3.27
9.7 {Mode} 3.27
9.8 {Device} 3.27

10 Data Output 3.28
10.1 {RS423} 3.28
10.2 {GPIB} 3.28
10.3 {File} 3.29
10.4 {File Size} 3.29
10.5 {PAR1}and {PAR2} 3.29
10.6 {FL O/P} 3.29
10.7 {Heading} 3.29
10.8 {Error Beep} 3.29

11 Direct Action Keys 3.30
11.1 On/Standby 3.30
11.2 P Stat/G Stat 3.30
11.3 IR Comp/RPC 3.30
11.4 Limit Bandwidth 3.30
11.5 Bias Reject 3.31
11.6 DVM Run 3.31
11.7 Store/Recall 3.31
11.8 Local 3.32

12 Indirect Action Keys 3.33
12.1 Sweep 3.33
12.2 Plot 3.33
12.3 File/Status 3.34
12.4 Break/Self Test 3.34

13 Menu Summary 3.36

Figure *Page*

3.1 *Four-terminal electrochemical cell* 3.5
3.2 *Three-terminal electrochemical cell and equivalent circuit* 3.9
3.3 *Example waveforms for sampled IR Compensation* 3.10
3.4 *Cell current in "sampled" IR Compensation* 3.11
3.5 *Effect of real part correction* 3.12
3.6 *Unity gain "cell"* 3.14
3.7 *Flow diagram showing SI1287 sweep menu key sequence* 3.21

Continued on next page.

Figure *Page*

3.8 *Analog Ramp sweep cycle* 3.22
3.9 *Digitally stepped sweep cycle* 3.23
3.10 *The plotting field* 3.25
3.11 *Coordinates of the plotting field* 3.26

Table *Page*

3.1 *Standard Resistor Selection* 3.5
3.2 *Polarisation ON sequence* 3.7
3.3 *Bandwidths available* 3.13
3.4 *Readings available* 3.17
3.5 *Minimum time/step values* 3.24

1 INTRODUCTION

This chapter describes all the facilities of the SI1287 Advanced Electrochemical Interface. The facilities appear under the names given to them on the front panel. The set-up parameters are detailed first, followed by the direct action keys. There is also a reference to the equivalent remote commands in Chapter 4.

In the following sections, as in Chapter 2, the { } brackets denote a choice via the SELECT {} keys, e.g. {RESISTOR}. The [ ] brackets denote choice via the RANGE/[ ] keys, or the rotary knob, e.g. [auto].

2 I MEASURE

The value of the current flowing through an electrochemical cell is measured by sensing the voltage developed across a standard resistor connected in series with the cell, and dividing this voltage by the resistance value. A positive current is said to be flowing when it passes into the counter electrode (CE) and out of the working electrode (WE).

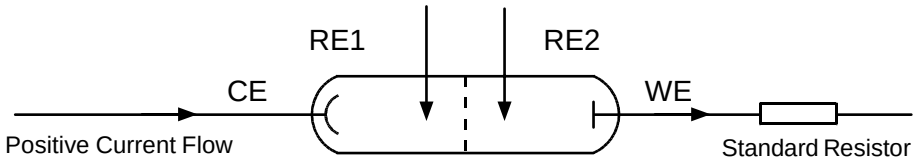


Fig 3.1 *Four-terminal electrochemical cell*

2.1 {RESISTOR}

ØØ Remote command **RR***I* . Refer to Chapter 4, Section 6.5.

The current range of the SI1287 is determined by selecting a standard resistor which develops 200mV at full scale current. See Table 3.1. This selection may be fixed, or made automatically.

Table 3.1 Standard Resistor Selection

Standard Resistor (Ω)	0.1	1	10	100	1k	10k	100k	1M
Full-Scale Current (±A) (At 200mV)	2	200m	20m	2m	200µ	20µ	2µ	200n

[auto]
On auto-range an appropriate standard resistor is switched in automatically, to suit the current presently being measured. However, slight discontinuities occur in the cell drive whenever the range changes: so, with sensitive cells, it is advisable to use a fixed range. The following limitations also apply:

- Auto-range is not suitable for a.c. work, i.e. with the FRA.
- Auto-range is not allowed with the following facilities in action: current bias rejection, IR compensation or real part correction.

- Auto-range operates by sensing the cell current and connecting the appropriate standard resistor just before a measurement is made. Therefore it is possible for a rapidly rising current to be measured on too low a range, resulting in an off-limit condition.

I Limit

ØØ The remote command is **IL***I* . Refer to Chapter 4, Section 6.6.

The current limit defines the highest current range to be used in auto range mode. Should the measured current exceed the full scale value of this range then an overload action is triggered (see section 2.2); enter after selecting [auto].

2.2 {O/L TYPE}

ØØ The remote command is **OL***n*. Refer to Chapter 4, Section 6.7.

If the current flow through the cell exceeds (by more than ~25% maximum) the full-scale value for that range, an overload condition is triggered. The action to be taken is selected by the user via this menu:

[warning]
A ’beep’ sounds, and a warning message is displayed.

Caution: [warning] does not itself limit the current in any way and so cannot prevent excessive current damaging a cell. If this is at risk select [limit] or [cut-out].

[limit]
The current is allowed to rise to the full-scale value, or ILimit if in auto, but it is inhibited from exceeding it by negative feedback.

[cut-out]
Current flow is cut off completely when the overload condition arises, by the SI1287 switching to the ’standby’ state.

2.3 {STANDBY}

ØØ The remote command is **BY***I*. Refer to Chapter 4, Section 6.2.

Selects which cell connections are isolated in the ’standby’ state. Either of two states may be selected: "full standby" and "half standby". Full standby is the default state. Should you require half standby, this must be selected prior to polarizing the cell.

[all o/c]
Known as "full standby", in which CE, RE1 and RE2 are isolated, leaving only WE connected. In full standby, only the following measurements are valid:

DVM I/P, POL, ∑POL, CE.

Invalid measurements are not displayed by the SI1287; the measurement title only is shown followed by a space.

[CE o/c]
Known as "half standby", in which only CE is isolated. In half standby, only the following measurements are valid:

RE1, RE2, ΔRE, ΔRE-Bi, DVM I/P, POL, ∑POL, CE, I, I-Bi.

Invalid measurements are not displayed, as stated in [all o/c].

2.4 {ON MODE}

ØØ The remote command is **ON***n*. Refer to Chapter 4, Section 6.3.

Selects the initial polarisation conditions of the cell when the SI1287 is switched from the 'standby' state to 'on' mode. The use of this parameter prevents the cell from experiencing high voltages or currents at switch on, in the short time before the SI1287 feedback loops gain full control.

On completion of the "polarization on" sequence the cell may be polarized either "at rest" or at a previously defined level. This is known as the polarization "on mode".

[pol V/I] selected with full standby
When the 'ON' action key is pressed, the SI1287 goes through a controlled polarization sequence, from full standby to the setup of POL V (or POL I) to the cell. The following Table 3.2 shows the sequences that occur, for both P STAT and G STAT modes, except where indicated.

Table 3.2 Polarization ON Sequence

Sequence Followed				Full Sequence
Pol V/I & Full Standby	Pol V/I & Half Standby	Rest V/I & Full Standby	Rest V/I & Half Standby	
1	-	1	-	1. Full Standby. (Initial state)
2	2	2	2	2. Half Standby.
3	-	3	-	3. One second pause. (RE1 and RE2 settle.)
4	4	4	4	4. ΔRE Measured. (Cell's rest potential)
5	5	5	5	5. Polarisation set to rest potential and bandwidth Type J* selected.
6	6	6	6	6. All electrodes connected.
7	7	7	7	7. 40ms pause (for polarization to stabilize).
8	8	8	8	8. Selected bandwidth is set.
9	9	-	-	9. Selected polarization applied to each cell.

* For the G STAT mode Polarisation current is set to zero and bandwidth Type C is selected.

[pol V/I] selected with half standby
The sequence starts from half standby and no pause is required.

[rest V/I] selected with full standby
The full sequence is performed, except step 9. This means that the polarisation will remain at the rest level.

[rest V/I] selected with half standby
The sequence starts at half standby and ends at the rest level.

Switching from 'ON' to 'STANDBY'
When the 'standby' action key is pressed, the cell is switched from its present 'on' state directly to either full or half standby (according to the STANDBY menu set up).

3 POLARIZATION

The polarization voltage, current and input of the cell are selected using this key in SET UP mode.

3.1 {POL V}

ØØ Remote command **PV***F*. Refer to Chapter 4, Section 6.1.

Polarization Voltage. In potentiostatic mode, the SI1287 applies a controlled d.c. potential difference across RE1 and RE2. This voltage is set up via POL V menu.

3.2 {POL I}

ØØ Remote command **PC***F*. Refer to Chapter 4, Section 6.1.

Polarization Current. In galvanostatic mode, the SI1287 drives a controlled d.c. current through the cell This current is set up via POL I menu.

The polarisation current selected must be within the range dictated by the standard resistor in use, as given in section 2.1.

3.3 {POL I/P}

ØØ Remote command **PI***I*. Refer to Chapter 4, Section 6.1.

Polarization Input. This is an externally generated polarization voltage signal, which may be added to the internal d.c. polarization voltage set.

The external signal (e.g. from the generator of an FRA) may be left at unity gain or attenuated by ×0.01 (40dB) by selecting the appropriate POL I/P menu option: [×1] or [×.01].

Selecting [×.01] improves the signal-to-noise ratio if the external signal noise is proportionally lower at high signal levels.

4 IR COMP/RPC

4.1 {IR COMP}

ØØ The remote commands are **CT***I* for selecting feedback or sampled and **CC***I* for selecting IR COMP on/off. Refer to Chapter 4, Section 6.8.

IR compensation may be used only with the SI1287 in potentiostat mode. It compensates for the voltage drop across the cell parasitic resistance (R_P) and allows the voltage across the cell double-layer impedance (Z_D) to approach the user-defined polarization voltage. (R_P is the resistance of the electrolyte between the reference and working electrodes. See Fig 3.2.)

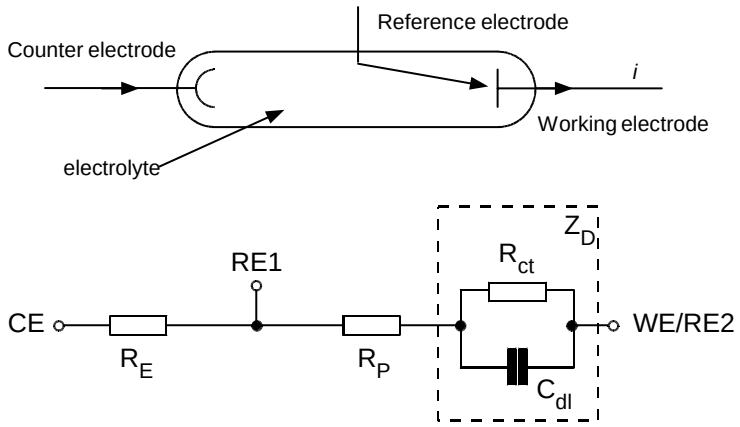


Fig 3.2 *Three-terminal electrochemical cell and equivalent circuit*

There are two types of IR compensation, "feedback" and "sampled".

[feedback]

ØØThe remote command is **IC***F*. Refer to Chapter 4, Section 6.9.

Feedback IR compensation requires the user to specify an estimated value for the parasitic resistance (R_P). To compensate for the voltage drop across R_P the SI1287 measures the cell current (I) and increases the polarization voltage by the value $I \times R_P$. If the value of R_P has been estimated correctly this results in the double layer voltage stabilizing at a value close to the user-defined polarization voltage. The value $I \times R_P$ is also subtracted from the ΔRE value, so that a close approximation of the double-layer voltage may be measured. The command for entering the estimated value of R_P is **IC***F*

A simple way to obtain an initial value in the estimation of R_P is to measure the cell impedance with the FRA, using a high frequency signal. For such a frequency Z_D is minimal. Therefore, the potential ΔRE is developed across R_P alone and the impedance measurement $\Delta RE \div I$ is a close approximation to R_P.

Care must be taken not to apply a value of IRCΩ which is so large that it causes the system to oscillate. The IRC value may range from $0.01 \times R_s$ to $10 \times R_s$ (where R_s is the current sense resistor).

[sampled]

Sampled IR compensation periodically interrupts the cell current. During the current off time the IR_p drop disappears immediately and allows the double-layer impedance voltage (which decays relatively slowly) to be sampled and held. The SI1287 feedback circuit monitors this voltage and maintains it at the user-defined polarization value.

Figure 3.3 shows an example of the cell voltage and current waveforms. Either the actual cell waveforms or the sampled-and-held ones may be selected for output to the FRA and the front panel display DVMs.

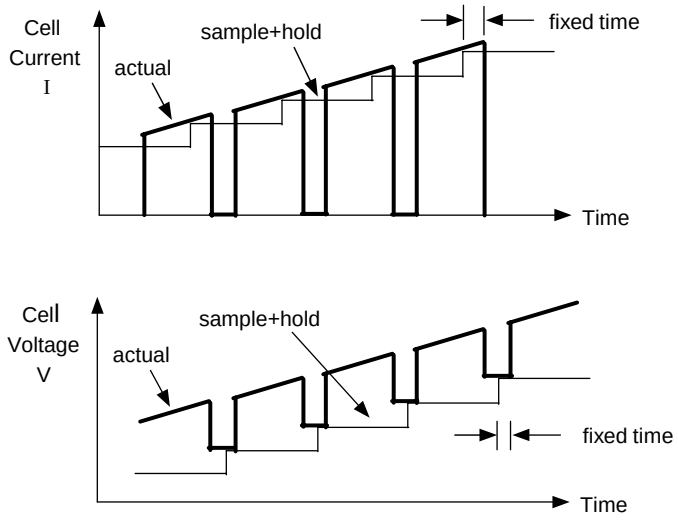


Fig 3.3 *Example waveforms for sampled IR compensation.*

Note: With a.c. impedance measurements the frequency of the a.c. perturbation signal is limited to about 10% of the interrupt frequency.

OFF TIME ØØRemote command is **IN***F*. Refer to Chapt 4, Sect. 6.10. Defines the cell current *off* time. Refer to figure 3.4.

OFF:ON ØØRemote command is **IP***F*. Refer to Chapt 4, Sect. 6.10. Defines the cell current *off:on* ratio. Refer to figure 3.4.

REAR O/P ØØRemote command is **RO***I*. Refer to Chapt 4, Sect. 6.10. Defines the output from the rear panel Vand I terminals. This selection also affects the front panel DVMs, which display the appropriate d.c. average levels.

[actual]
Selects actual (interrupted) current and voltage waveforms being applied to the cell for output.

[sample+hold]
Selects signals which have been sampled + held at the appropriate times in the interrupt cycle.

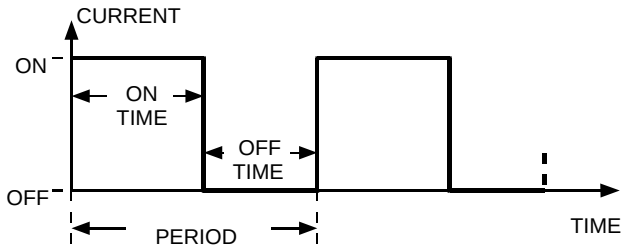


Fig 3.4 *Cell current in 'sampled' IR Compensation*

When working with IR compensation, be guided by the following constraints:

- In estimating R_{ct} (ohms) and C_{dl} (farads) for the cell under test, the off-time should be less than $0.1\times(R_{ct}\times C_{dl})$ seconds and greater than $1.5E\text{-}8\times(R_e+R_p)$ seconds. There will be cells for which these criteria cannot be met. For these cells sampled IR compensation is inappropriate and should not be used.

- The choice of loop bandwidth is important. The aim is to achieve stable cell polarization, and this may be checked by observing the CE with an oscilloscope. The waveform displayed should have two levels: a non-zero voltage of user-selected polarity during the on-time, and a decay to zero volts during the off-time. Should this simple pattern not be obtained, progressively reduce the loop bandwidth until it is. A further indication that a lower loop bandwidth should be used is given by the error message, 'RE1 O/L' or 'RE1-RE2 O/L'.

- The maximum value of parasitic resistance R_p that can be compensated for can be calculated from the following constraint:

  $\{POL\ V\}\times(R_e+R_p+R_{ct})\div R_{ct}$ should be less than 20V.

- The current measurement is a peak value. To obtain the average value, multiply the peak value by the following correction factor:

  $1\div(\text{off-on ratio} +1)$.

4.2 {RPC Ω}

ØØ The remote commands are **CC***I* for selecting RPC on/off and **RP***F* for the value of the parasitic resistance R_P. Refer to Chapter 4, Section 6.11.

Real part correction is an alternative to IR compensation and it is applicable both to potentiostatic and galvanostatic measurements. Whereas IR compensation is applied to the cell itself (via the polarization control loop), real part correction simply adjusts the measured cell voltage to offset the effect of parasitic resistance (R_P). Real part correction is thus a post-measurement function and does not effect polarization stability.

To set up real part correction you are required to enter an estimated value for R_P, with the command **RP***F*. For three terminal measurements this value is multiplied by the measured value of cell current to obtain the IR_P drop and the result subtracted from the measured cell voltage. For two-terminal measurements the same approach is used to eliminate the voltage drop across the electrolyte resistance R_E.

Real part correction is useful when measuring a.c. impedance in cases where the voltage across the parasitic resistance is significant compared to the double-layer voltage being measured. As shown in Figure 3.5, the IR_P drop displaces the cell impedance plot along the positive real axis, which lowers the measurement accuracy. Applying real part correction shifts the origin towards the imaginary axis, thus allowing a more sensitive FRA range to be selected and the measurement accuracy to be improved.

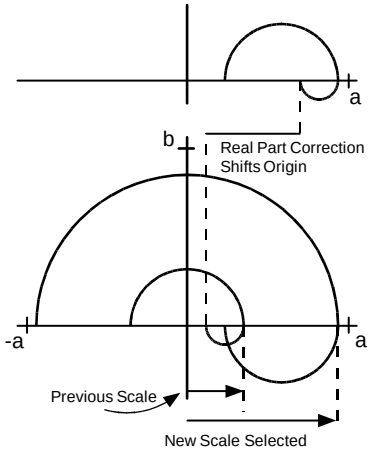


Fig 3.5 *Effect of real part correction*

5 BANDWIDTH

Various bandwidths may be selected for the cell polarization control loop. This is to ensure the stable operation of the SI1287, as a potentiostat or galvanostat, in the measurement of various cells.

5.1 {P STAT BW}

ØØ The remote command for the Potentiostatic Bandwidth is **PB***I*. Refer to Chapter 4, Section 6.4.

There is a selection of ten types of bandwidth ([type A] to [type J]) to suit the cell type; this is detailed in Section 5.3.

5.2 {G STAT BW}

ØØ The remote command for the Galvanostatic Bandwidth is **GB***I*. Refer to Chapter 4, Section 6.4.

There is a selection of three types of bandwidth ([type A] to [type C]) to suit the cell type; this is detailed in Section 5.3.

5.3 CONTROL LOOP BANDWIDTH SELECTION

The type and the approximate bandwidths are listed in Table 3.3. Note (from footnotes of Table 3.3) that some bandwidths are reduced when "limit" or "cutout" is selected for the overload type. (See Section 2.2.)

Table 3.3 Bandwidths Available

Type	Approx. Bandwidth
Galvanostat:	
[Type A]	150kHz**
[Type B]	100kHz**
[Type C]	>7.5kHz***
Potentiostat:	
[Type A]	600kHz*
[Type B]	360kHz*
[Type C]	>1MHz*
[Type D]	>600kHz*
[Type E]	24kHz*
[Type F]	8kHz
[Type G]	2.4kHz
[Type H]	800Hz
[Type I]	80Hz
[Type J]	8Hz

* 12Hz when limit or cutout selected for O/L type.
** 25kHz when limit or cutout selected for O/L type. Stable with capacitive cells when standard resistor ≤100Ω.
*** 5kHz when limit or cutout selected for O/L type.

Note also that the bandwidths quoted are approximate and are based on the unity gain cell configuration shown in figure 3.6.

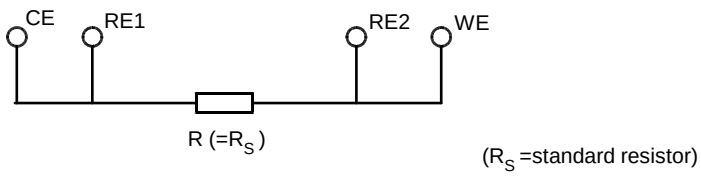


Fig 3.6 *Unity gain "cell"*

When in doubt as to the stability of the cell polarization, start with a low bandwidth, e.g. type J for the potentiostat, and increase the bandwidth for successive measurements until an unstable point (if any) is reached. Then reduce the bandwidth sufficiently to achieve stable operation. For particularly unstable systems, of course, you may have to reduce the bandwidth well below the stable operating point and start again.

6 CONDITION

The measured cell voltage and current outputs of the SI1287 can be conditioned so that useful information is emphasised in relation to noise and signal offsets. The facilities available for this are listed in Section 13.

6.1 {V REJECT}

ØØ Remote command for Voltage Bias Rejection is **VT***I*. Refer to Chapter 4, Section 6.12.

Voltage Bias Rejection may be used to cancel out the d.c. component of the measured voltage output of the SI1287. This allows a more sensitive FRA range to be used and thus improves the measurement accuracy. The level of bias rejection may be entered automatically or as a fixed value.

[auto]
Select prior to a single measurement, then switch on (using the Bias Reject action key) and perform the measurement. The d.c. bias detected during that measurement is rejected from all later readings. Assumes no subsequent drift of d.c. bias.

[fixed]
Allows a specific d.c. bias reject value (V VAL) to be entered for use when required.

6.2 {I REJECT}

ØØ Remote command for Current Bias Rejection is **IT***I*. Refer to Chapter 4, Section 6.12.

Current Bias Rejection. As for {V Reject} but operating on the current measurement channel.

Note: The [fixed] current bias rejection value selected (I VAL) must be within the range dictated by the standard resistor in use, as given in the section 2.1.

6.3 {LP FILTER}

ØØ Remote command for the Low Pass Filter is **FI***I*. Refer to Chapter 4, Section 6.12.

A 10Hz low-pass filter may be switched into the measured voltage and current outputs. This reduces wideband noise in low frequency and d.c. measurements and allows the more sensitive FRA ranges to be used for improved measurement accuracy. Do not filter a signal of frequency greater than 5Hz, however, otherwise it will be attenuated.

6.4 {V×10}

ØØ Remote command for the Voltage Amplification is **VX***I*. Refer to Chapter 4, Section 6.12.

Voltage Amplification. Measured voltage signals of very low amplitude may be amplified by a factor of ten.

6.5 {I×10}

ØØ Remote command for Current Amplification is **IX***I*. Refer to Chapter 4, Section 6.12.

Current Amplification. Measured current signals of very low amplitude may be amplified by a factor of ten.

7 DVM

Two DVMs are built into the SI1287: a 200mV fixed full-scale DVM dedicated to current measurement and a variable-range DVM dedicated to voltage measurement. The measurements taken by the DVMs can be shown on the display as they occur. They can also be sent to the GPIB or RS423 interfaces, and recorded in a history file for later review.

You can select which values are measured and shown on the display using the arrow keys as described in chapter 2 section 4.3 under the heading

ØØ The remote commands for this selection are **UR***I* and **UL***I*. Refer to Chapter 4, Section 6.23.

You can also select which values are to be measured and sent to the GPIB, RS423 or history file. This is described in Chapter 3 section 10.5.

The readings selected for display and for output may be different if required. Table 3.4 shows the readings which may be selected for display or output and the symbols used to describe them in the menus:

Table 3.4 Readings Available

Symbol	Parameter
CE	Counter electrode (CE) voltage.
RE1	Reference electrode 1 (RE1) voltage.
RE2	Reference electrode 2 (RE2) voltage.
ΔRE	Total voltage across RE1 and RE2 (RE1-RE2).
ΔRE-Bi	ΔRE with bias rejected.
I	Total current flowing through the cell.
I-Bi	Total current flowing through the cell with d.c. bias rejected.
δΔRE/δI	Ratio of ΔRE increment to I increment (resistance).
δI/δΔRE	Ratio of I increment to ΔRE increment (conductance).
POL	Internal d.c. polarisation level (menu-set level).
∑POL	Total d.c. polarisation level (POL I/P + POL).
DVM I/P	External voltage input to internal DVM (rear panel).
TIME	Instrument Time (no DVM measurements are made).
(blank)	A blank space (no DVM measurements are made).

7.1 {DIGITS}

ØØ Remote command is **DG***I*. Refer to Chapter 4, Section 6.16.

This menu enables the reading precision of the DVMs to be selected, from [3×9s] to [5×9s]. [4×9s. 50Hz] must be used in countries where the mains frequency is 50Hz; [4×9s. 60Hz] is for use with mains frequencies of 60Hz.

Precision	[3×9s]	[4×9s]	[5×9s]
Reading Rate (readings/second)	16	13	2

7.2 {RANGE}

ØØ Remote command is **DG*I***. Refer to Chapter 4, Section 6.16.

The voltage DVM may either be set for [auto] or any one of four fixed input ranges may be selected; [200mV], [2V], [20V] or [50V]. Autoranging allows an input range in keeping with the measured voltage to be selected automatically.

The current DVM has an input voltage range of 200mV. Various ranges of cell current are provided for by a choice of standard resistor values. (See Section 2.1.)

7.3 {TRIGGER}

ØØ Remote command is **TR*I***. Refer to Chapter 4, Section 6.16.

Measurements may be triggered in any one of four ways, single, recycled, external or sweep synchronized, as described below.

[single]
When single measurement triggering is selected, pressing the DVM RUN action key causes a single set of measurements to be started (within approximately 30ms). Single measurement triggering is always selected on initialization, e.g. on power up or after RECALL is used.

[recycle]
When recycled measurement triggering is selected, pressing the DVM RUN action key causes the DVMs to make measurements continuously at a reading rate corresponding to the DVM precision selected. Pressing DVM RUN again causes recycled measurements to be halted.

[external]
External measurement. A single measurement is performed whenever a triggering pulse is received via the BNC connector on the rear panel of the SI1287 (labelled TRIGGER). The trigger pulse may be a TTL pulse, or a short circuit.

The maximum triggering pulse frequency permitted depends on the precision selected and on how many voltages each of the two DVMs must measure per reading cycle. This, however, depends on what parameters have been selected for PAR1, PAR2 and the left and right display windows.

The highest maximum triggering rate occurs when only one voltage is being measured and equals the appropriate reading rate given in section 7.1. E.g. with 3×9s selected PAR1=PAR2=ΔRE, and TIME or ’blank’ (which do not involve DVMs) in each display window, the triggering rate can be upto 30Hz.

The lowest maximum triggering rate occurs when four different voltages must be measured per cycle, which is very often required in practice. In this case the rate is quartered. E.g. with 3×9s selected PAR1=RE1, PAR2=RE2, and displays set to ΔRE and CE, the triggering rate is only 7Hz maximum.

Another slowing factor might apply; whether or not the RS232 or GPIB ports are in use. This further reduces the maximum possible triggering rate, by an amount dependent on the particular configuration and peripherals being used. Maximum rates for specific set-ups must be determined by the user.

[sync.]
Synchronized measurement triggering is selected when the DVMs measure only during the actual sweep segments, not during sweep initialization or delay, etc.

During a ramp sweep the DVMs measure continuously, at a rate determined by the measurement resolution.

During a stepped sweep a measurement is made at each voltage level within the sweep. Each measurement is made as late as possible, to give the cell the maximum settling time. Any drift correction (see Section 7.4) is made just after the measurement and is applied before the result is output.

Should the requested sweep step time be too short for the DVMs to complete a measurement within each step, then an error code is made available for output and the original step time is retained.

The remedy is either to select parameters that will increase the measurement rate, or to increase the step time. See Section 8.8 for details of minimum step time versus the measurement resolution.

Problems may also arise if a GPIB controller, or peripheral equipment, is being used which operates too slowly for the chosen sweep step time. Eg. the controller cannot process a DVM measurement.

7.4 {DRIFT CORR.}

ØØ Remote command is **DC***I*. Refer to Chapter 4, Section 6.16.

With drift correct is switched [on], correction is applied every ten seconds to the DVM(s) presently engaged in measuring. For the voltage measuring DVM, correction is applied only to the particular range(s) in use. With drift correct [off] is selected, correction is no longer applied.

In either case, a drift correction is performed automatically whenever a greater reading precision is selected or a DVM range is changed.

7.5 {AVERAGING}

ØØ Remote command is **AV***I*. Refer to Chapter 4, Section 6.16.

With averaging is switched [on] the DVM results are output as a cumulative arithmetic mean. The mean value develops over the first ten measurements and thereafter is output, once per measurement cycle, as a running mean of the last ten results. (This is sometimes known as "walking window" averaging.)

7.6 {NULL}

ØØ Remote command is **NU***I*. Refer to Chapter 4, Section 6.16.

Nulling compensates for stray voltages induced in the cell leads. The three commands involved are:

[off]
Null values no longer applied, but retained for further use (when they are re-applied in accordance with the Null ON command). These values may be overwritten by another evaluate sequence.

[on]
Re-applies previously evaluated null values, after Null OFF has been selected.

[Evaluate]
This starts the nulling sequence in which the stray voltages are measured, stored and then applied as null values. The instruction;

GDN RE1&2 S/C DVM I/P O/C WE&CE ENTER

is displayed indicating that the user must:

1/ Ground RE1 and RE2
2/ Short circuit DVM I/P
3/ Open circuit WE and CE
4/ Press ENTER (to continue).

During the evaluation "NULLING" is displayed. Do not alter any connections or enter commands at this time.

A "NULL COMPLETED" message appears briefly and the SI1287 beeps, when the nulling offsets have been evaluates and stored for future use. The SI1287 switches to standby, and the NULL is left set to 'on'.

8 SWEEP

The d.c. polarisation signal may be applied to the cell as a specified number of smooth analog ramps, or as a number of digitally stepped 'staircase' voltages or currents. A cycle of four sweep "segments" is defined by the user and this cycle is repeated in accordance with a user-defined number of segments (1 to 99,999). At the end of the sweep the SI1287 switches automatically to 'Standby'or 'freeze' depending on the setting of "OFF MODE", see section 8.2.

To run a sweep, set the SI1287 to the appropriate mode (P STAT or G STAT) and enter the required SWEEP action key selection (sweep ramp or sweep step). The third SWEEP selection (off) may be used to step a sweep before its normal end. The following figure 3.7, shows the key sequences for selecting and entering sweep parameters:

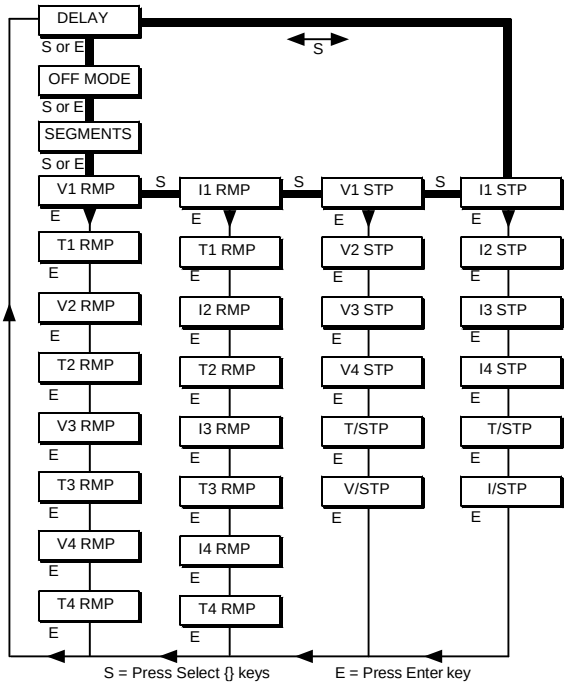


Fig 3.7 *Flow Diagram showing SI1287 sweep menu key sequences*

8.1 {DELAY}

ØØ Remote command is **DL***F*. Refer to Chapter 4, Section 6.13.

A selectable delay may precede the sweep cycle, to allow the cell to settle at the starting voltage or current level.

Note: There is also an additional delay of approx. 10 seconds preceding the user selected delay, see figure 3.8. (This delay occurs while the ramp integrator is setup).

8.2 {OFF MODE}

ØØ Remote command is **OF***I*. Refer to Chapter 4, Section 6.13.

This menu selects whether the cell polarisation will be maintained (freeze) or

whether the cell will be disconnected (standby), when the sweep ends or is stopped by the user.

8.3 {SEGMENTS}

ØØ Remote command is **SM***F*. Refer to Chapter 4, Section 6.13.

This menu selects the number of segments, ie. distinct ramps, or 'staircases' to be applied to the cell during the sweep. After segment number 4 the cycle begins to repeat itself.

8.4 {V1 RMP}

ØØ Remote command is **VA***F* to **VD***F*. Refer to Chapter 4, Section 6.14.

This menu enables the analog ramp voltage sweep to be set up for use in potentiostatic mode. The significance of the delay, the four RMP voltage levels (V1 to V4) and RMP time periods (T1 to T4), is shown in figure 3.8. In this example, five segments of the sweep cycle have been specified. At the end of the sweep, POL V is left set at the 'final level' defined by this menu.

Limits on Ramp Rate
The Ramp Rate (i.e., [V{n+1} - Vn]/Tn) must be in the range 100µV/s to 100V/s.

8.5 {I1 RMP}

ØØ Remote command is **JA***F* to **JD***F*. Refer to Chapter 4, Section 6.14. This menu enables the analog ramp current sweep to be set up for use in galvanostatic mode.

It is exactly analogous to V1 RMP (figure 3.8), with four current (instead of voltage) levels (I1 to I4), and four time periods (T1 to T4) to be entered. At the end of the sweep, POL I is left set at the 'final level' defined by this menu.

Note: It is not possible to set up the V1 RMP menu totally independently of the I1 RMP menu, because the two sets of time periods (T1 to T4) are stored at shared locations in the SI1287 memory.

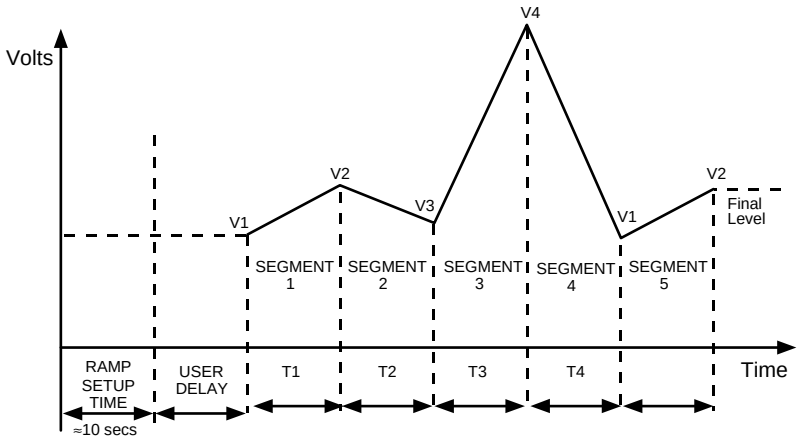


Fig 3.8 *Analog ramp sweep cycle*

8.6 {V1 STP}

ØØ Remote command is **SA***F* to **SD***F*. Refer to Chapter 4, Section 6.15.

This menu enables the digitally stepped voltage sweep to be set up for use in potentiostatic mode.

Figure 3.9 shows the significance of the delay, the four STP voltage levels (V1 to V4), the time per step (T/STP) and the voltage change per step (V/STP). In this example, four segments have been specified.

Limits on V/STP Values
There are minimum permitted values of V/STP which depend on the maximum voltage excursion of any part of the sweep from STP V1. These limits are as follows:

When max. excursion from RMP V1 > 200mV:
V/STP (or I/STP × standard resistor) must be >100µV;

When max. excursion from RMP V1 < 200mV and >20mV:
V/STP (or I/STP × standard resistor) must be >50µV;

When max. excursion from RMP V1 < 20mV:
V/STP (or I/STP × standard resistor) must be >5µV;

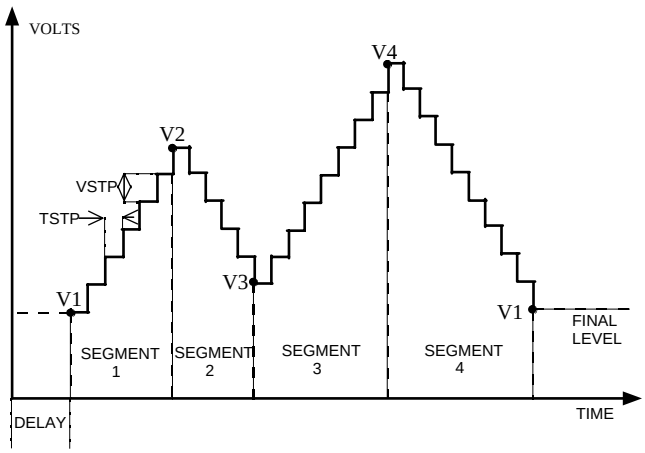


Fig 3.9 *Digitally stepped sweep cycle*

8.7 {I1 STP}

ØØ Remote command is **KA***F* to **KD***F*. Refer to Chapter 4, Section 6.15.

This menu enables the digitally stepped current sweep to be set up for use in galvanostatic mode.

It is analogous to V1 STP (Figure 3.9), with four current levels (I1 to I4), a time per step (T/STP), and a current change per step (I/STP) to be entered. The limits on I/STP values are also analogous as in section 8.5.

Note: The V1 STP menu cannot be set up totally independently of the I1 STP menu because the T/STP values are stored at a shared memory location.

8.8 STEPPED SWEEP: MINIMUM PERMITTED VALUES OF T/STP

The minimum permitted values of T/STP (seconds) for a stepped sweep, with the DVM TRIGGER set to sync, are shown in Table 3.5. If these limits are not observed then error 52 will appear indicating 'Measurement rate not achievable in sync. sweep'.

A maximum of four different DVM measurements can be made per sweep step; the SI1287 left-hand display window, right-hand display window, PAR1 and PAR2. This number may be reduced by either selecting 'blank' for a display window, or by selecting any of the four measurements to be the same quantity.

For example, if PAR1 and PAR2 are both POL, with both display windows set to 'blank', the 'number of measurements' would be 1.

Table 3.5 Minimum Time/Step Values

Number of Measurements	DVM Digits			
	5×9	4×9	3×9	fast 3×9
1 or 2	2.22	0.82	0.52	0.12
3 or 4	4.32	1.52	0.92	0.32

Fast measurement, 'fast 3×9', rely on setting the DVMs for their optimum measurement rate, as follows :

For 1 or 2 measurements;

(i) Use as a fixed DVM input range.
(ii) Use a fixed standard resistor.
(iii) Set DVM drift correct to OFF.
(iv) Left-hand and right-hand DVM displays both TIME.

For 3 or 4 measurements;

As above but excluding number (iv).

8.9 COMMANDS NOT ALLOWED DURING SWEEP

The following menu-change commands (via SI1287 front panel or Remote control) are not allowed whilst a sweep is in progress. Error code 51 is made available in each case.

I Measure: Resistor and I Limit (galvanostat),
DVM: Averaging,
Sweep: all settings.

The following action keys (or equivalent remote control commands) are not allowed whilst a sweep is in progress. Error code 51 is made available in each case.

P'STAT/G'STAT, **BIAS REJECT** and **STORE/RECALL**.

Updating the left-hand or right-hand front panel DVM displays, or PAR1 or PAR2, during a stepped sweep (with DVM TRIGGER set to'sync') may cause Error 52 to be signalled.

9 PLOT

The measurement results may be plotted on a suitable digital plotter via the GPIB port of SI1287.

Note: During plotting, set the DATA OUTPUT {GPIB} menu to [off], to prevent corruption of the signals to the plotter.

9.1 {X ITEM}

ØØ Remote command is **XI***I*. Refer to Chapter 4, Section 6.21.

The item to be plotted along the X-axis is selected via this menu. Item selections are in terms of PAR1 and PAR2 (see section 9.5). Any item choice requires the entry of values for X MIN, X MAX and X ORIGIN, which are defined below:

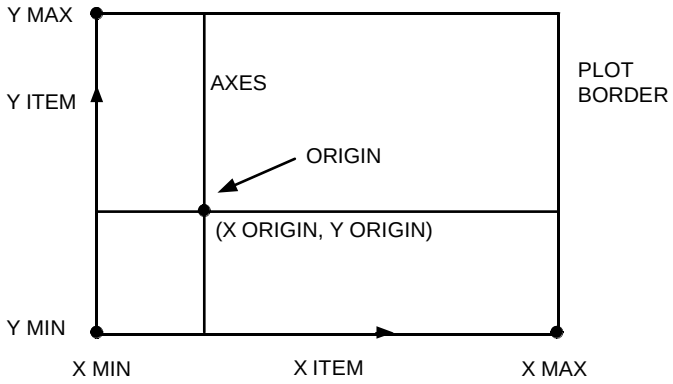


Fig 3.10 *The plotting field*

9.2 {Y ITEM}

ØØ Remote command is **YI***I*. Refer to Chapter 4, Section 6.21.

Corresponds to the X ITEM menu.

9.3 {SIZE}

ØØ Remote command is **PZ***I*. Refer to Chapter 4, Section 6.21.

Two standard plot sizes are avaliable for selection: [A4] or [A3].

Alternatively, the size, aspect ratio, and plot position may be selected via the [variable] menu.

Figure 3.11 defines the plotting field coordinates VX MIN, VY MIN, VX MAX and VY MAX. They are measured in units of 0.025mm from a reference origin which is nominally at the lower left-hand limit of the plotting area.

9.4 {TEXT}

ØØ Remote command is **PT***I*. Refer to Chapter 4, Section 6.21.

With TEXT selected as [ON] during axes plotting, the X- and Y-axis are annotated with their minimum and maximum values, items and units if appropriate. Otherwise, axes appear without any annotation.

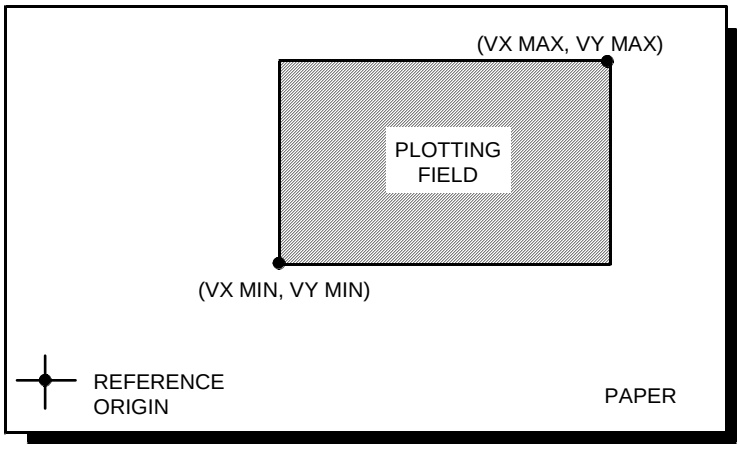


Fig 3.11 *Coordinates of the plotting field*

9.5 {TITLE}

ØØ Remote command is **PH***I*. Refer to Chapter 4, Section 6.21.

This menu enables a title of upto 20 alphanumeric characters to be printed at the top of the plot, just above the border.

The title appears on the top left-hand side or the top right-hand side of the plot, according to whether the selected plot X ORIGIN is nearer the left-hand or the right-hand side, respectively. This feature enables two plots, with separate titles and Y ITEMs, to be superimposed on a share X-axis.

[off]
No title is printed.

[on]
A title is printed according to what is selected for STRING:

1. [old]
   The title already stored in this menu appears.

2. [new]
   A new title may be entered and stored in CHARACTERS. It is displayed between the < > brackets. Use the DIGIT/[ ] keys to move the cursor, and the rotary knob to select the character required at each cursor position. Finally press ENTER to store the title.

3. [copy]
   The title printed is a copy of the last title to be called up via the STORE/RECALL {RECALL} menu.

9.6 {GRID}

ØØ Remote command is **GT***I*. Refer to Chapter 4, section 6.21.

With GRID selected [off] during axes plotting, the divisions along the X- and Y-directions of the plot borders are marked by short lines only. With GRID selected [on], the division marks are extended completely across the graph in both dimensions to form a grid superimposed on the plot.

9.7 {MODE}

ØØ Remote command is **VE***I*. Refer to Chapter 4, Section 6.21.

[point]
Plotted points are left unconnected.

[vector]
Adjacent plotted points are joined by straight lines.

9.8 {DEVICE}

ØØ Remote command is **PD***I*. Refer to Chapter 4, Section 6.21.

The plotter type is selected via this menu. The GPIB plotter section of the SI1287 is compatible only with digital plotters using either of the following two systems:

[HPGL]
Hewlett-Packard Graphics Language.

[ESGL]
Enertec Schlumberger Graphics Language.

10 DATA OUTPUT

This section of the menu allows the user to enable or disable any of the possible devices, configure the GPIB for remote control and set up the filing of measurements. The various output formats are described in Chapter 4.

10.1 {RS-423}

ØØ Remote command is **RS***I*. Refer to Chapter 4, Section 6.19.

The RS-423 serial interface port. Two selections are possible, other than [off]: [on] and [dump] (see chapter 4 for descriptions of these output formats).

10.2 {GPIB}

ØØ Remote command is **GP***I*. Refer to Chapter 4, Section 6.19.

General Purpose Interface Bus. Four selections are possible, other than [off]: [long on], [short on], [long dump], and [short dump] (see chapter 4 for descriptions of these output formats).

After selecting one of these four options, further selections are made available ;

- **Serial Poll** ØØ Remote command is **SV***I*.
  Enter an integer to configure the SI1287 to interrupt the GPIB controller when a particular event (defined by the integer) occurs.

- **Parallel Poll** ØØ Remote command is **PP***I*.
  Enter an integer to define which of the eight GPIB data lines is to be used by the SI1287 to give a parallel poll response, indicating whether it is requesting service or not.

- **PP Sense** ØØ Remote command is **SE***I*.
  Parallel Poll Sense.

  [true]
  signifies that when the data line carries a "1" the SI1287 is requesting service.

  [false]
  signifies that when the line carries a "0" the SI1287 is requesting service.

- **O/P Terminator** Ø Ø Remote command is **OT***I*.
  Output Terminator. The character terminating each line of data.

  cr = carriage return
  lf = line feed
  EOI = end or identify.

- **O/P Separator** Ø Ø Remote command is **OS***I*.
  Output Separator. The character separating the line of data into fields.

  If [term.] is selected, the separator character is set to be the same as the terminator character.

10.3 {FILE}

ØØ Remote command is **FL***I*. Refer to Chapter 4, Section 6.18.

A section of memory used to store DVM measurement results, for later recall or further external processing if required. Each result is stored as a block of three items; parameter 1, parameter 2, and time. Parameters 1 and 2 should be chosen before the file is switched on, form the list of possible parameters (via the PAR1 and PAR2 menus, see section 10.5).

10.4 {FILE SIZE}

ØØ Remote command is **FS***I*. Refer to Chapter 4, Section 6.18.

The number of memory blocks (up to ~ 450) allocated to the file.

File memory is shared with up to 10 menu set-up stores, which use 16 memory blocks each. Thus the maximum number available to the file varies with how many stores are in use.

A result is sent to the file whenever it is switched [on] and a measurement has been completed. If more results are sent to the file than its size permits, the earliest filed results are discarded to make room for the latest.

10.5 {PAR1} and {PAR2}

ØØ Remote command is **PX***I* and **PY***I*. Refer to Chapter 4, Section 6.17.

These select the two items to be filed as parameter 1 and parameter 2, respectively. 'Time' is always filed.

PAR1 and PAR2 also limit the choice of X ITEM and Y ITEM in the PLOT menu and what can be transmitted via the SI1287 output ports to external devices.

10.6 {FL O/P}

ØØ Remote command is **FD***I*. Refer to Chapter 4, Section 6.18.

This menu selects which two of the three measurement items stored in each file block are to be displayed.

10.7 {HEADING}

ØØ Remote command is **RH***I*. Refer to Chapter 4, Section 6.19.

Controls the output of headings above the columns of measurements sent to the RS423 port and to the GPIB when it is in Talk Only mode. When selected [on] column headings are printed above a set of measurements and also whenever menu changes are made which invalidate the existing column headings.

10.8 {ERROR BEEP}

ØØ Remote command is **EB***I*. Refer to Chapter 4, Section 6.25.

Error tone switch. Selecting [off] stops the error 'beep'.

11 DIRECT ACTION KEYS

This section refers to the action keys, which apply previously set up parameters to the cell, as soon as they are pressed.

11.1 ON/STANDBY

ØØ Remote command is **PW***I*. Refer to Chapter 4, Section 6.1.

Controls connections to three of the cell terminals: CE, RE1 and RE2.

/on/ all connections made and polarisation drive applied, in a sequence determined by what has been selected for the I MEASURE {STANDBY} and {ON MODE} menus.

/standby/ connections isolated, as determined by what has been selected for the I MEASURE {STANDBY} menu.

11.2 P STAT/G STAT

ØØ Remote command is **PO***I*. Refer to Chapter 4, Section 6.1.

Selects potentiostatic or galvanostatic cell drive.

11.3 IR COMP/RPC

ØØ Remote command is **CC***I*. Refer to Chapter 4, Section 6.8 & 6.11.

In potentiostatic mode, this key is three-state and selects IR Compensation, or Real Part Correction (as set up via the IR COMP/RPC menu), or neither. In galvanostatic mode the key becomes two-state, selecting RPC or 'off'.

11.4 LIMIT B'WIDTH

ØØ Remote command is **SY***I*. Refer to Chapter 4, Section 6.4.

Applies the reduced bandwidth operation (as set up via the BANDWIDTH menu) to the cell drive amplifier. With limit bandwidth 'ON' (LED illuminated) the bandwidth setup via the BANDWIDTH menu will be used. With limit bandwidth 'OFF' a default bandwidth type C is used.

11.5 BIAS REJECT

ØØ Remote command is **BR***I*. Refer to Chapter 4, Section 6.12.

Rejects the d.c. component from the SI1287 voltage and current outputs (as set up via the CONDITION menu).

[fixed] rejection set up: key has 'on'/'off' action.

[auto] rejection set up: switching 'on' (with the SI1287 is 'on' mode) causes the d.c. component of the measurement presently being made to be evaluated, stored, and rejected from all subsequent measurements, until BIAS REJECT is switched 'off'.

To re-evaluate the biases, switch 'off' then 'on' again.

11.6 DVM RUN

ØØ Remote command is **RU***I*. Refer to Chapter 4, Section 6.16.

Operates the DVMs according to what has been selected via the DVM {TRIGGER} menu. Pressing the DVM RUN key has no effect if [external] or [sync] have been selected for the TRIGGER menu. The LED on the key glows only whilst a measurement is actually taking place; this includes measurements triggered externally or during a sweep cycle.

11.7 STORE/RECALL

Allows up to ten menu selections to be stored and recalled. Each stored selection may be titled with a string of up to 20 characters and spaces chosen from the following:

ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz
%+-,./:0123456789

Note: This facility shares memory with the history file, so its use affects the {FILE SIZE}.

{STORE}

ØØ Remote command is **SR***I,S*. Refer to Chapter 4, Section 6.25.

Enter an integer 'n' to copy existing menu selections to store number 'n'. The sequence after selecting STORE is:

NUMBER RECALL	{ STORE ( ) }
(e.g.) 8	{ STORE (8) }
ENTER	{ STORE 8 <_ > }

Use the DIGIT/[ ] keys to move the cursor, and the rotary knob to select the character required at each cursor position. Finally, press ENTER to store the existing menu setup.

{RECALL}

ØØ Remote command is **RC***I*. Refer to Chapter 4, Section 6.25.

Enter an integer 'n' to recall the contents of store 'n' to set up the stored menu selections.

The sequence is then similiar to that for STORE, except that ENTERing the required store number, the relevant title is displayed to confirm the user's choice. Press CLEAR to exit from the sequence if the wrong store has been selected. Otherwise, press ENTER to recall the stored menu setup.

RECALL also erases the file contents and sets {FILE SIZE} to 200 blocks, switches the SI1287 to 'standby', DVM RUN to 'off', PLOT to 'off', DVM NULL to 'off' and DVM TRIGGER to 'single'.

{CLEAR}

ØØ Remote command is **CL***I*. Refer to Chapter 4, Section 6.25.

Enter an integer 'n' to erase the contents of store 'n'.

As in {RECALL}, the title of the store (if any) is displayed as a check before any erasure takes place.

11.8 LOCAL

ØØ Remote command is **LL**. Refer to Chapter 4, Section 6.25.

Returns the SI1287 to local control (i.e. via the front panel) from the remote state provided Local Lockout has not been asserted by an external controller.

12 INDIRECT ACTION KEYS

This section refers to the action keys, which are pressed repeatedly to step through a list of selections until the one required is displayed.

12.1 SWEEP

ØØ Remote command is **SW***I*. Refer to Chapter 4, Section 6.13.

Applies the sweep polarisation to the cell (as set up via the SWEEP menu). A voltage or current sweep is initiated, if the SI1287 is in P STAT or G STAT mode, respectively. Selecting **{sweep ramp}** or **{sweep step}** initiates an analog ramp or a digitally stepped sweep, respectively.

When the SWEEP action key is pressed, its LED flashes on and off during a sweep initialisation period (possibly several seconds), and continues to flash during the user-selected delay (if any). It glows steadily, only when the sweep itself starts, switching off at the end. For stepped sweeps the initialisation period may be too short to cause the LED to flash.

Selecting {sweep off} will cause the sweep to halt. The polarisation will be held at the current level if OFF MODE is set to freeze. Otherwise the cell will be disconnected.

CAUTION: During the sweep initialisation period the existing value of POL V (or POL I) applied briefly to the cell before the sweep generator has settled to the proper starting value. To avoid risk of damage to sensitive cells, set ON MODE, in the I MEASURE menu, to **rest V/I**.

12.2 PLOT

ØØ Remote command is **PL***I*. Refer to Chapter 4, Section 6.21.

Allows the selection of a plotting action (as set up via the PLOT menu).

{graph} Causes measurements to be plotted, if available. Only the graph itself is drawn by means of this selection; plot borders, axes, title, grid and annotations are not output.

{axes} Draws the plot borders, division marks (or grid if GRID is 'on'), annotations (if TEXT is 'on'), title (if TITLE and TEXT are 'on') and axes. If the origin is set to coincide with a corner of the plotting field, the axes are not separately visible in the plot.

{min.} & **{min.}** These selections move the plotter pen (in the 'up' position) to the lower left-hand corner, or to the upper right-hand corner respectively, of the plotting field set up via the PLOT {SIZE} menu. These two selections can be used to check the size and position of the plotting field before a plot is run.

{zero} 'Parks' the plotter pen currently in use in its home position.

{off} Stops the plotting of the graph (not the axes), and 'parks' the pen.

12.3 FILE/STATUS

ØØ Remote command is **VF***I*. Refer to Chapter 4, Section 6.18 & 24.

{display file} Displays the first line (according to the {FL O/P} menu setup). The SELECT { } á â keys, or rotary knob, are used to step up or down the file.

{clear file} Erases the file contents.

{list file} Lists every line of the file in quick succession. The sequence is too fast to follow on the display, and is intended for listing the file to an external device via the SI1287 output ports.

This selection is used to plot data from the file. First enter PLOT {graph} to enable plotting; then enter {list file} to plot the filed data (according to the PLOT menu selections in operation).

{status} Displays nine lines of SI1287 status information. The lines are stepped to, in either direction, as for {display file}:

- [Free memory blocks. Last three error codes]
- [Upper limit of last floating point parameter entered]
- [Lower limit of last floating point parameter entered]
- [History file status: number of readings; number filed]
- [Menu set up stores in use]
- [RS423: baud rate]
- [GPIB: mode, state]
- [GPIB: address, control]
- [GPIB: STB, I/P terminator]

The DVM(s) must not be running when the file is displayed, cleared, or listed, otherwise Error 45 occurs; stating illegal file access.

12.4 BREAK/SELF TEST

ØØ Remote command is **BK***I*. Refer to Chapter 4, Section 6.20.

{break} Halts the present operation and transfers the SI1287 to the standby state (as set up via the I MEASURE {STANDBY} menu). DVM RUN, SWEEP and PLOT are switched 'off'.

{check} Starts a self test routine on all SI1287 digital circuitry, displays pixels and symbols, keyboard LEDs and key functioning. The user presses ENTER at appropriate stages to move to the next group of checks. On completion the standby state is entered; DVM RUN, SWEEP and PLOT are switched to 'off'.

Any failure causes the test routine to abort and a fail code is generated. A successful check results in a 'PASS' message, which also shows the SI1287 software issue number in use.

{test} **Note**: The 12861 Test Module must be connected to the SI1287 before this selection is entered.

Starts a self test routine which includes the entire {check} sequence. Additionally, the SI1287 analog circuitry is self tested.

Success or failure of the test routine is the same as {check}. On completion the standby state is entered.

{reset} Clears any existing menu set ups, returning all parameters to their default states except the file and stores, which are retained.

{initialise} As for {reset}, but the file and stores are also cleared.

{time} Ø Ø Remote command is **TM***I,I*. Refer to Chapter 4, Section 6.24.

The SI1287 internal clock stops whenever the power is switched off and restarts from zero at every power up, or when the instrument is initialized or reset.

This selection allows the clock to be reset to a specific time whenever required:

{ HOUR ( ) }
Enter the required hour between the round brackets.

{ HOUR MIN. ( ) }
Enter the required minute between the round brackets.

Note: After break, check, test, reset, or initialize has been commanded (via the front panel or remotely), a 1 second pause must be allowed before the next command. This is to give the SI1287 time to execute the BREAK/SELF TEST command.

13 MENU SUMMARY

This summary is intend as a memory aid for experienced users.

The following tables summarise all the SI1287 menus and action keys.

Note: a) Bold typeface denotes default value.

b) Braces denote a choice via the SELECT {} keys, e.g. {RESISTOR}.

c) Square brackets denote choice via the RANGE/[ ] keys, or the rotary knob, e.g. [auto].

d) Round brackets denote that a numerical entry is required, e.g. (0). Limits are shown for numerical values.

SET UP MENU	PARAMETER	SELECTION	
I MEASURE	{RESISTOR}	[**auto**] I LIMIT [2μA] [20μA] [200μA] [2mA] [20mA] [200mA] **[2A]**	
		[0.1Ω] [1Ω] [10Ω] [100Ω] [**1kΩ**] [10kΩ] [100kΩ] [1MΩ]	
	{O/L TYPE}	[**cut-out**] [limit] [warning]	
	{STANDBY}	[**all o/c**] [CE o/c]	
	{ON MODE}	[**pol V/I**] [rest V/I]	
POLARISATION	{POL V}	(**0**) -14.5 TO +14.5V [**V**] [mV] [μV]	
	{POL I}	(**0**) -2 TO +2A [**A**] [mA] [μA] [nA]	
	{POL I/P}	[×**.01**] [×1]	
IR COMP/RPC	{IR COMP}	[**feedback**] IRC Ω (**0**) 0 TO 1E+6Ω [mΩ] [Ω] [kΩ] [MΩ]	
		[sampled]	OFF TIME (**27μs**) 27E-6 TO 1.3E-3s [μ**s**] [ms]
			OFF:ON (1:**1**) 1 TO 255
			REAR O/P [**actual**] [sample + hold]
	{RPC Ω}	(**0**) 0 TO 1E+6Ω [mΩ] [Ω] [kΩ] [MΩ]	
BANDWIDTH	{P STAT BW}	[type A] [type B] [**type C**] [type D] [type E] [type F] [type G] [type H] [type I] [type J]	
	{G STAT BW}	[type A] [type B] [**type C**]	
CONDITION	{V REJECT}	[**auto**]	
		[fixed] V VAL (**0**) -14.5 TO +14.5V [V] [**mV**] [μV]	
	{I REJECT}	[**auto**]	
		[fixed] I VAL (**0**) -2 TO +2A [A] [**mA**] [μA] [nA]	
	{LP FILTER}	[**off**] [on]	
	{V×10}	[**off**] [on]	
	{I×10}	[**off**] [on]	
DVM	{DIGITS}	[**5×9**] [4×9 50Hz] [4×9 60Hz] [3×9]	
	{RANGE}	[**auto**] [200mV] [2V] [20V] [50V]	
	{TRIGGER}	[**single**] [recycle] [external] [sync]	
	{DRIFT CORR.}	[off] [**on**]	
	{AVERAGING}	[**off**] [on]	
	{NULL}	[**off**] [on] [evaluate]	

SWEEP	{DELAY}	(**0**) 0 TO 1E+5s	[**s**] [ms]	
	{OFF MODE}	[**standby**] [freeze]		
	{SEGMENTS}	(**2**) 1 TO 99999	integer	
	{V1 RMP}	RMP V1 TO V4	(**0**) -14.5 TO +14.5V	[**V**] [mV] [µV]
		RMP T1 TO T4	1E-2 TO 1E+5s	[**s**] [ms]
	{I1 RMP}	RMP I1 TO I4	(**0**) -2 TO +2A	[A] [**mA**] [µA] [nA]
		RMP T1 TO T4	1E-2 TO 1E+5s	[**s**] [ms]
	{V1 STP}	STP V1 TO V4	(**0**) -14.5 TO +14.5V	[**V**] [mV] [µV]
		T/STP	(**0**) 1E-2 TO 1E+5s	[**s/stp**] [ms/stp]
		V/STP	(**0**) 100E-6 TO 29V	[V/stp] [**mV/stp**] [µV/stp]
	{I1 STP}	STP I1 TO I4	(**0**) -4 TO +4A	[A] [**mA**] [µA] [nA]
		T/STP	(**0**) 1E-2 TO 1E+5s	[**s/stp**] [ms/stp]
		I/STP	1E-9 TO 4A	[A/stp] [**mA/stp**] [µA/stp] [nA/stp]
SET UP MENU	**PARAMETER**	**SELECTION**		
PLOT	{X ITEM}	[**PAR1**] [PAR2] [TIME] [log PAR1] [log PAR2] [log TIME] [√ TIME] X MIN X MAX X ORIGIN (**0**) -1E18 TO 1E+18		
	{Y ITEM}	[PAR1] [**PAR2**] [TIME] [log PAR1] [log PAR2] [log TIME] [√ TIME] Y MIN Y MAX Y ORIGIN (**0**) -1E18 TO 1E+18		
	{SIZE}	[**A4**] [A3]		
		[variable] VX MIN VY MIN VX MAX VY MAX (**0**) 0 TO 32000 steps (×.025mm)		
	{TEXT}	[off] [**on**]		
	{TITLE}	[**off**]		
		[on] STRING	[**old**]	
			[new] CHARACTERS < > 20 character title	
			[copy]	
	{GRID}	[**off**] [on]		
	{MODE}	[**point**] [vector]		
	{DEVICE}	[**HPGL**] [ESGL]		

DATA OUPUT	{RS-423}	[**off**] [on] [dump]		
	{GPIB}	[**off**]		
		[long on] or [short on] or [long dump] or [short dump]	SERIAL POLL	(**0**) 0 TO 255 integer
			PARALLEL POLL	(**0**) 0 TO 8 integer
			PP SENSE	[**true**] [false]
			O/P TERMINATOR	[**cr lf**] [cr lf+EOI] [cr] [cr+EOI]
			O/P SEPARATOR	[**comma**] [term.]
	{FILE}	[**off**] [on]		
	{FILE SIZE}	(**200**) 1 TO ~450 blocks		
	{PAR1}	[CE] [RE1] [RE2] [∆**RE**] [∆RE-Bi] [I] [I-Bi] [δ∆RE/δI] [δI/δ∆RE] [POL] [∑POL] [DVM I/P]		
	{PAR2}	[CE] [RE1] [RE2] [∆RE] [∆RE-Bi] [**I**] [I-Bi] [δ∆RE/δI] [δI/δ∆RE] [POL] [∑POL] [DVM I/P]		
	{FL O/P}	[**par1, par2**] [time, par1] [time, par2]		
	{HEADING}	[off] [**on**]		
	{ERROR BEEP}	[off] [**on**]		

SET UP MENU	**SELECTION**	
ON STANDBY	«**standby**» «on»	
P STAT G STAT	«**P stat**» «G stat»	
IR COMP RPC	«**neither**» «IR COMP» * «RPC» *P STAT only	
LIMIT BANDWIDTH	«off» «**on**» (setting limit bandwidth to off causes a default bandwidth 'c' to be used).	
BIAS REJECT	[fixed] set up : «**off**» «on»	
	[auto] set up : «**off**», measure, «on»	
DVM RUN	«**off**» «on»	
SWEEP	{**sweep off**} {sweep ramp} {sweep step}	
PLOT	{graph} {axes} {min.} {max.} {zero} {**off**}	
FILE/STATUS	{display file} {clear file} {list file} {status}	
STORE/RECALL	{STORE} ( ) 0 TO 9 < > 20 character title	
	{RECALL} ( ) 0 TO 9	
	{CLEAR} ( ) 0 TO 9	
LOCAL	«go to local»	
BREAK/ SELF TEST	{**break**} {check} {test} {reset} {initialise}	
	{time}	{HOUR ( ) } 0 TO 99
		{HOUR MIN ( ) } 0 TO 59

Chapter 4
Remote Control

Section *Page*

1 **Introduction** 4.3

2 **RS423 Interface** 4.4
2.1 RS423 Connector 4.4
2.2 Serial Link Settings 4.4
2.3 Baud Rate Settings 4.4
2.4 Input Terminator 4.4

3 **GPIB Interface** 4.5
3.1 GPIB Capability Codes 4.5
3.2 GPIB Connector 4.5
3.3 GPIB Switches 4.6
3.3.1 Device Address 4.6
3.3.2 Input Terminator 4.6
3.3.3 Talk Only 4.6
3.4 Serial Poll/Parallel Poll 4.7
3.4.1 Serial Poll 4.7
3.4.2 Parallel Poll 4.8
3.5 GPIB Plotting 4.9

4 **Remote/Local Facility** 4.10
4.1 Local Lock-out 4.12

5 **Output Formats** 4.13
5.1 RS423 Port : Tabular Output Format 4.13
5.2 GPIB Port : Tabular Output Format 4.13
5.3 GPIB Port : Compressed ASCII Output 4.13
5.4 GPIB & RS423 Ports : Dump Mode (Binary) Format 4.14
5.4.1 4-Byte Floating Point Format : Dump Mode 4.15
5.5 Output Terminators & Separators 4.16
5.5.1 RS423 Port 4.16
5.5.2 GPIB Port 4.16

6 **SI1287 Remote Commands** 4.17

Figure

4.1 *RS423 Serial Interface Connector* 4.4
4.2 *Baud Rate Switches* 4.4
4.3 *GPIB Interface* 4.5
4.4 *GPIB Switches* 4.6
4.5 *Remote/Local state diagram* 4.10
4.6 *Remote/Local state diagram with Local Lock-out* 4.11

1 INTRODUCTION

The instrument is fitted, as standard, with a GPIB interface and an RS423 interface for communication with remote devices.

The RS423 is intended mainly for data output to a printer, VDU, etc, but may be used for instrument control if required. The RS423 Serial Interface is also compatible with RS232.

The GPIB allows full control and data input/output. For those unfamiliar with the GPIB, here are the meanings of the more commonly used terms.

- A "Device" is any instrument compatible with GPIB operation.
- The term "Interface", with regard to a GPIB device, means the logic circuitry and bus drivers that deal with the signals sent on the bus, in accordance with the GPIB protocol.
- A "Talker" is a device that can send information via the GPIB, whilst a "Listener" is a device that can receive this information.
- A "Controller" is a device that is able to assign Talker and Listener roles to itself and to other devices on the GPIB. This allows the controller to send control messages to devices on the GPIB and to receive measurement and control status information from them. The overall purpose of a controller is to coordinate the operation of all devices on the GPIB, in accordance with a control program.

The documents which fully define the GPIB are the IEEE Standard 488-1978, the IEC 625-1 and the ANSI Standard MC1.1 (from the first standard, the GPIB is also widely known as the IEEE 488 Interface).

2 RS423 INTERFACE

2.1 RS423 CONNECTION DETAILS

Connection to the RS423 Serial Interface port is made via the 25-way sub miniature D-type connector on the rear panel. The pin connections are shown in Figure 4.1. The SI1287 is configured as DCE (Data Communication Equipment).

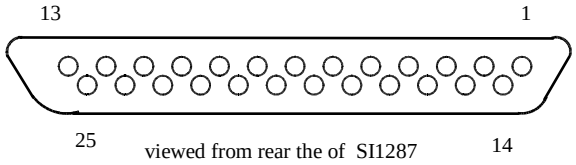


Fig 4.1 *RS423 Serial Interface Connector*

Pin 1 = Ground
Pin 2 = Serial Data to SI1287
Pin 3 = Serial Data from SI1287
Pin 4 = RTS (Request to Send) to SI1287
Pin 5 = CTS (Clear to Send) from SI1287
Pin 6 = DSR (Data Set Ready) from SI1287
Pin 7 = Ground
Pin 8 = DCD (Data Carrier Detect) from SI1287
Pin 20 = DTR (Data Terminal Ready) to SI1287

RTS is biased active within the SI1287. If this signal is left unconnected then the SI1287 will output data when available. DCD is always active while the instrument is on. The DSR output follows the state of the DTR input.

2.2 SERIAL LINK SETTINGS

- Data Bits: 8
- Stop Bits: 1
- Parity: None
- Baud Rate: 110 to 9600 (switch selectable)
- Handshake: Hardware (CTS, RTS)

2.3 BAUD RATE SETTINGS

The Baud Rate is set to the required value (from 110 to 9600) via the 8-way switch block on the SI1287 rear panel.

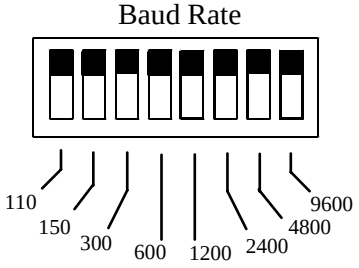


Fig 4.2 *Baud Rate Switches*

Only one of the eight switches should be set in the down position, towards the required baud rate.

2.4 INPUT TERMINATOR

The Command Code terminator character is fixed as CR (Carriage Return).

3 GPIB INTERFACE

3.1 GPIB CAPABILITY CODES

The capability of a device interface can be identified by the series of alphanumeric codes, which normally appear against the bus connector. The alphabetic part of the codes represent a basic interface function, such as a talker or listener, whilst the numeric part represents the capability of that function.

The GPIB Interface in the instrument conforms to the following sub-functions within the standard, as listed on the rear panel:

SH1	Source handshake.
AH1	Acceptor handshake.
T5	Basic talker, Serial poll, Talk only selectable, unaddressed if MLA (My Listener Address).
TE0	No Extended talker capability.
L4	Basic listener, no listen only mode, unaddressed if MTA (My Talker Address).
LE0	No extended listener capability.
SR1	Complete service request capability.
RL1	Complete Remote/Local capability, with Local Lock-Out.
PP2	Parallel poll with Local configuration.
DC1	Complete device clear capability, including selective device clear.
C0	No controller capability.
DT0	No device trigger capability.
E1	Open Collector drivers.

3.2 GPIB CONNECTOR

Connection to the GPIB is made via the 24-way connector on the IEEE 488/GPIB interface; see Figure 4.3. The pin connections conform to the IEEE 488, 1978 standard.

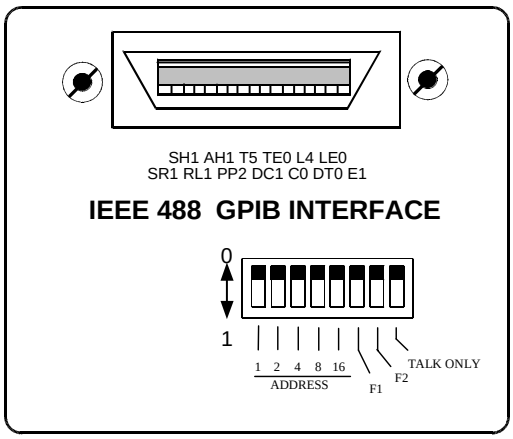


Fig 4.3 *GPIB Interface*

3.3 GPIB SWITCHES

Some interface functions are set by miniature toggle switches on the rear panel of the instrument. These functions are described in the following sections.

Once the GPIB switches have been set the instrument must read them, so that their settings can be implemented. The switches are read automatically at power-on, or when an INITIALIZE or RESET instruction is given. The GPIB switch functions are as follows :

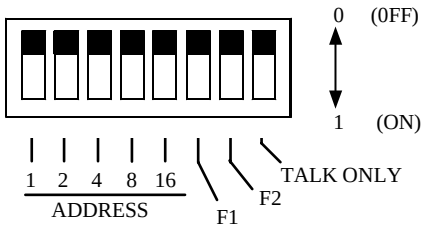


Fig 4.4 *GPIB switches (all switches shown in off position)*

3.3.1 Device Address

The ADDRESS switches select the GPIB address for the SI1287. To avoid problems associated with mixing binary and ASCII information, two GPIB ports are provided. The two ports are serviced through the same GPIB connector, but each has its own software address.

The address for the ASCII input/output port is the Major address. This address should always be an even number, so the left-hand switch "1" should always be in the 'off' position. If an odd address is selected on the switches, the SI1287 responds to the preceding even address. This address +1 is the Minor address and is assigned automatically, for high speed binary dump outputs.

3.3.2 Input Terminator

Switches F1 and F2 select the terminating character for the GPIB input commands to the SI1287 as follows :

Switch F1	Switch F2	Terminator Selected
0	0	LF (Line Feed).
1	0	CR (Carriage return).
0	1	; (Semicolon).
1	1	EOI (End or Identify).

The choice of command terminator is usually determined by the type of controller used and should be defined in the relevant controller handbook. Any command terminator other than the one selected is ignored by the interface. The output terminator is set by the command **OT***I* see section 6.19.

3.3.3 Talk Only Switch

The Talk only mode can be selected for the GPIB interface by switching the Talk Only switch to the 'on' position. When switched on the instrument can act as a talker only, to drive a listen-only device, such as a plotter, without the aid of a GPIB controller. When switched off the instrument can act as a listener or as a talker, as commanded by the GPIB controller.

3.4 SERIAL POLL/PARALLEL POLL

The instrument can be configured to request service from a GPIB controller when a particular event has occurred, e.g. on end of operation, or measurement ready. The controller may then poll the devices on the GPIB to find the source of the request. Two types of polling can be used, serial or parallel.

3.4.1 Serial Poll

A serial poll interrogates each device in turn, to examine its *status byte*. The status byte holds the status of all events for which it is possible to request service.

Status Byte

To display the contents of the status byte (STB) on the SI1287 front panel, press the FILE/STATUS action key and select {status}. The ninth line of status 'GPIB: STB, I/P terminator' shows the STB bit values, updated every second.

128 Data Ready	64 RQS	32 {Spare}	16 End of File	8 End of Plot	4 End of Sweep	2 End of Measure	1 Error

When an event occurs the corresponding bit is set to '1'. The events represented are:

Bit	Event	Comment
128	Data Ready.	Set when data is available for ASCII or binary output to the GPIB.
64	Request for service.	Set to '1' when the instrument requests service. This bit allows the controller to identify the source of the request. All 8 bits of the status byte appear on the DIO lines when the instrument is serial polled.
32	Not Used.	
16	End of File.	Final result written to, or read from, history file.
8	End of Plot.	Instrument has finished a plot..
4	End of Sweep.	Intrument has finished a sweep.
2	End of Measure.	Instrument has finished a measurement.
1	Error.	Set when an error affecting the other bits in the STB is detected. It does *not* register all possible SI1287 errors.

The values of all the bits, except bit 1 and bit 64, continuously follow status changes. If, for example, the instrument is measuring repetitively RECYCLE bit 2 is set to '1' as each measurement is completed, then reset to '0' as a new measurement starts.

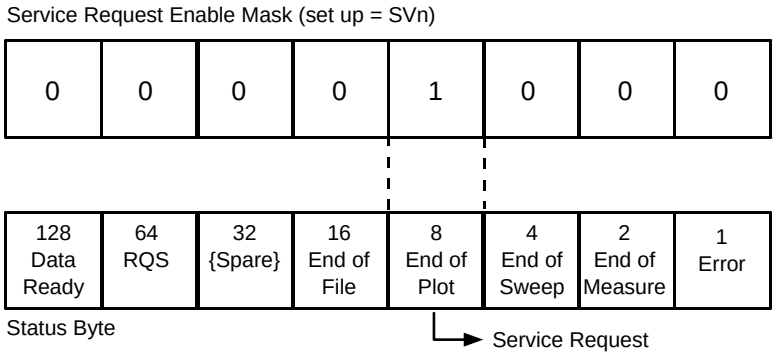
Setting up a Service Request

The instrument can be enabled to request service (and set the RQS bit) for one or more specified events. Alternatively, if several of the status bits must be monitored simultaneously, the controller can be programmed to serial poll at regular intervals without using a SRQ at all.

To enable a service request, send the remote command :

SVn

where n is an integer, in the range 1 to 255, which represents an event, or combination of events, for which service is to be requested.



For example, SV8 (STB = 00001000) results in a service request at the next end of plot whilst SV25 (STB = 00010101) results in a service request at whichever event occurs first out of end of file, end of sweep, or error.

Once the instrument has requested service, it must be reconfigured before it can request service again. The query commands ?SV read the status request mask.

Code SV0 unconfigures an existing interrupt, and also clears bit 1 (’error’).

3.4.2 Parallel Poll

For parallel poll operation previously assigned devices are allocated a specific data line (out of 8 available) such that, upon a parallel poll instruction, only those devices allocated to specific lines are able to energise them. In this way the controller may separate up to 8 instruments in a unique fashion; or by sharing the 8 lines amongst two or more devices, provide unlimited polling facilities.

In practice the user program would use a parallel poll to establish which device is requesting service, and then a serial poll to find out the reason.

Setting up a Parallel Poll

The instrument can be configured to give a parallel poll true/false response on a selected GPIB data line, to indicate whether or not the instrument is requesting service. However, the instrument must first be configured for serial poll.

To set up a parallel poll configuration send the remote command :

PPn

where n is an integer from 1 to 8, defining which GPIB data line is to carry the response.

Sending PP0 unconfigures parallel poll.

To select the sense of the parallel poll line send the remote command SEn, where n=1 signifies true and n=0 signifies false.

The parallel poll response is also cleared by any change to the serial poll value, and by power-off. Unlike serial poll, parallel poll need not be reconfigured after each service request.

3.5 GPIB PLOTTING

The GPIB plot facility is compatible only with plotters using Hewlett-Packard Graphic Language (HPGL), or Enertec Schlumberger Graphics Language. These plotters require that the SI1287 output has ’comma’ as the output separator and ’cr lf’ as the output terminator; both are default characters.

If the GPIB plotter can be put into Listen Only mode, it can be driven directly from the SI1287 without needing a controller on the bus. To operate in this way, ensure that the DATA OUTPUT {GPIB} menu is set to [off], the default state, so that only plotter commands are passed to the GPIB. Set the plotter to Listen Only, and the SI1287 rear panel switch to Talk Only.

However, if the plotter has no Listen Only mode, a controller is necessary to instruct the plotter to ’listen’ to the SI1287. To operate using a controller on the GPIB, set both plotter and SI1287 to normal Talker/Listener modes, and switch the DATA OUTPUT {GPIB} menu to [off]. SRQ can be used to signal the end of plotting. In this case, configure the SI1287 to set bit 8 of the status byte at ’End Plot’.

The PLOT menu is detailed in Chapter 3, section 9.

4 REMOTE/LOCAL FACILITY

The REMOTE/LOCAL facility enables the SI1287 to receive commands from either a *remote* or a *local* source. The remote facility is provided via the GPIB Interface and has priority over other devices.

The SI1287 offers two forms of control under the heading LOCAL:

LOCAL 1 Commands accepted from the SI1287 front panel and/or from the RS423 port; the two sources have equal priority.

LOCAL 2 Commands accepted from the RS423 port only. No settings can be changed from the front panel, but the LOCAL key and the main ON/OFF switch are still operative. The menu keys can be used to verify, but not alter, the state of the controls.

The status display shows "remote" when the instrument is in LOCAL 2 mode.

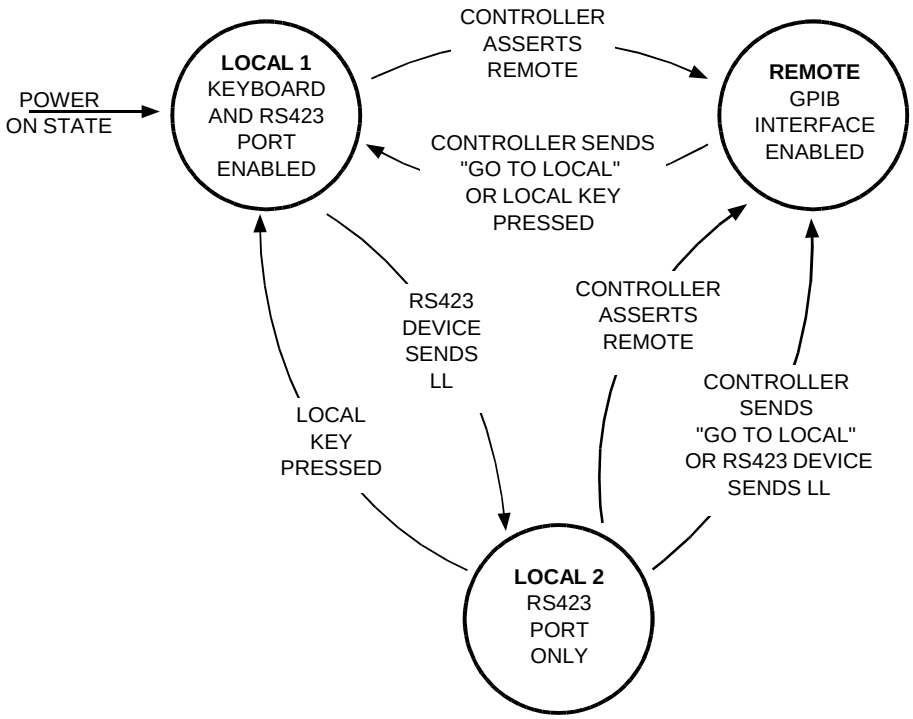


Fig 4.5 *REMOTE/LOCAL state diagram.*

On power up the SI1287 adopts LOCAL mode. The state diagram indicates how control can be transferred from LOCAL 1 to LOCAL 2 to REMOTE and back again.

Note: If the controller sends a REMOTE command, then the LOCAL state which was previously in force is resumed, once the REMOTE mode is relinquished.

The full set of instructions to transfer from LOCAL to REMOTE and vice-versa is given in the IEEE Standard, where LOCAL 1 and LOCAL 2 are simply referred to as LOCAL.

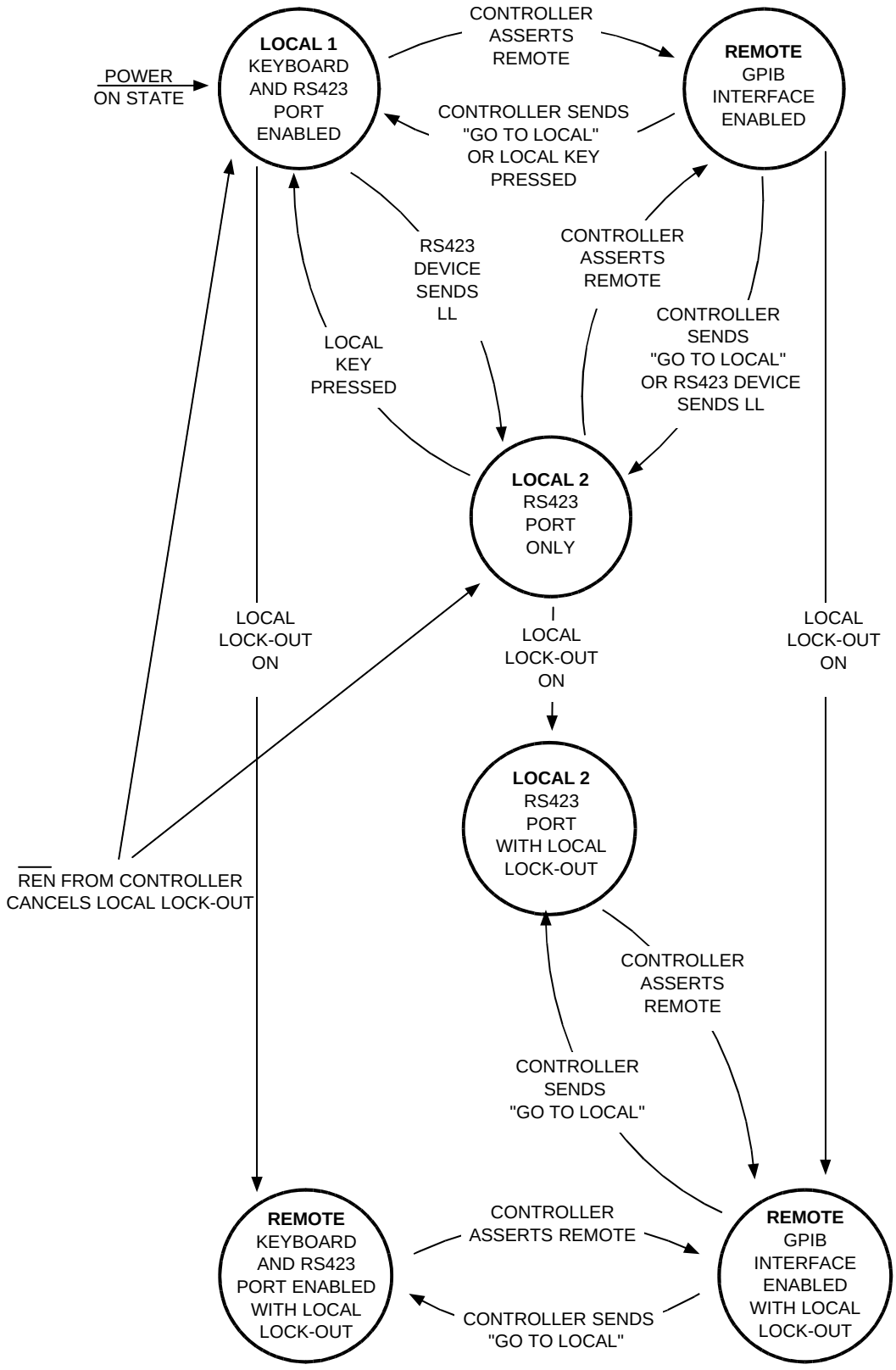


Fig 4.6 *REMOTE/LOCAL state diagram with LOCAL LOCK-OUT*

4.1 LOCAL LOCK-OUT

The REMOTE/LOCAL facility described above can also have a LOCAL LOCK-OUT condition superimposed by a command from the controller. Once LOCAL LOCK-OUT is on, transfer of control from one device to another can be accomplished only by the GPIB controller.

This facility can be used, for example, to prevent unauthorised front panel manipulations affecting the settings of the SI1287. The state diagram in figure 4.6 shows the relationship between the LOCAL LOCK-OUT feature to the REMOTE and LOCAL states previously shown in figure 4.5.

The LOCAL LOCK-OUT state is cancelled when the REMOTE ENABLE signal from the controller is false, i.e. the controller sends $\overline{\text{REN}}$.

Note that if the controller sends "GO TO LOCAL", then the LOCAL state which was previously in force is resumed.

5 OUTPUT FORMATS

Measurement results can be output as ASCII characters or as Binary data. The ASCII output can be interpreted by a controller or a printer whereas the binary can only be interpreted by a controller. These outputs have the following formats.

5.1 RS423 PORT: TABULAR OUTPUT FORMAT

In this mode, the ASCII coded results are presented in the form of a table, suitable for use with an RS423 compatible printer having a line width of 80 characters or more. Carriage return plus line feed, plus several ASCII 'nul' characters (delay for carriage return), are automatically added as the output terminator. Column headings may be either printed or suppressed.

To obtain tabular output, set the DATA OUTPUT {RS423} menu to [on].

A 5 column sequence of headings is output:

(PARAMETER 1) (units)	(PARAMETER 2) (units)	ERROR 1	ERROR 2	TIME

Parameters 1 and 2 (with appropriate units) are chosen under DATA OUTPUT {PAR1} and {PAR2}. Error 1 and 2 relate to PAR1 and PAR2 respectively, and report any measurement errors (e.g. error 31, voltage DVM Overload). Time is given as hours, minutes, seconds and hundredths of seconds.

A sixth column, 'FILE No.', is output when the file is listed via the RS423 port, and indicates the index number of the result.

5.2 GPIB PORT: TABULAR OUTPUT FORMAT

To obtain a tabular output, set the DATA OUTPUT {GPIB} menu to either [long on] or [short on] and the Talk Only switch on the SI1287 rear panel to 'ON'. The SI1287 then sends data to the GPIB ASCII port in a format suitable for GPIB compatible printers. The [long on] column format is the same as for the RS423 port and the column headings may either be printed or suppressed. With [short on] selected, the TIME column is omitted.

For both long and short GPIB formats, the output terminator must be selected as described in section 5.5.

5.3 GPIB PORT: COMPRESSED ASCII OUTPUT

In this mode the ASCII coded results are output in relatively compressed from, suitable for interpretation by a controller on the bus.

The SI1287 gives each parameter a constant field width of 12 ASCII characters (bytes), comprising a 6-digit fixed point part with polarity sign, and a 2-digit exponent with polarity sign :

±n.nnnnnE±nn

Time is coded as four pairs of digits for hours (h), minutes (m), seconds and hundredths of seconds (s) respectively.

h h / m m / s s / s s

To obtain compressed ASCII output, set the DATA OUTPUT {GPIB} menu to either [long on] or [short on] and the Talk Only switch on the SI1287 rear panel to 'OFF'.

With [long on] selected, each set of readings is output with the format:

±p.pppppE±pp / ±q.qqqqqE±qq / e_1 / e_2 / hh/mm/ss/ss//

PAR1 PAR2 ERRORS TIME

where errors 1 and 2 relate to PAR1 and PAR2, respectively; / represents the output separator, and // the output terminator. Select the required separator and terminator via the DATA OUTPUT {GPIB} menu; as described in section 5.5.

With [short on] selected, the TIME data are omitted and the output terminator is sent after error 2.

5.4 GPIB & RS423 PORTS: DUMP MODE (BINARY) FORMAT

Dump Mode format, in which results are compressed into a binary form to occupy fewer bytes, is the fastest way to output data from the SI1287.

Each parameter consists of a four-byte floating-point number, compared with the twelve bytes needed for ASCII.

Error codes and time output are expressed in BCD format. Thus each two digit error code uses one byte and time uses four bytes giving tens and units of hours, tens and units of minutes, tens and units of seconds, and tenths and hundredths of seconds:

h h m m s s s s

To obtain dump mode output, set the DATA OUTPUT {GPIB} menu to either [long dump] or [short dump], and the Talk Only switch on the SI1287 rear panel to 'OFF' (for GPIB operation). Set the {RS423} menu to [dump], which produces the same format as the GPIB [long dump] selection.

With [long dump] selected, each set of readings is output with the format:

p p p p q q q q e_1 e_2 h h m m s s s s

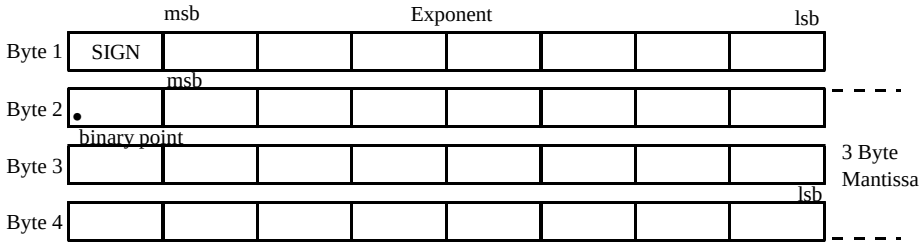
PAR1 PAR2 ERRORS TIME

The following section 5.4.1 explains how to decode the four parameter bytes from binary to decimal notation. Output separators and terminators are not sent in dump mode format. However, in the case of GPIB operation only, EOI (End Or Identify) is automatically asserted simultaneously with the last byte if either [cr + EOI] or [cr lf + EOI] has been selected via the DATA OUTPUT {GPIB} menu.

With [short dump] selected, the bytes representing TIME are omitted, but the output format is otherwise identical.

5.4.1 4 - Byte Floating Point Format : Dump Mode

A parameter is output in dump mode as a group of four 8-bit bytes. Encoded in these bytes are the **sign** of the parameter, a binary **exponent**, and a **mantissa**:



The sign bit is 0 for a positive number, 1 for a negative number. The remaining seven bits of byte 1 give the binary exponent, in 2's complement format. (Therefore negative exponents are indicated by the first of the seven bits being 1).

$011\ 1111_2 \equiv 2^{63} = 9.2 \times 10^{18}$

$\vdots \qquad\qquad \vdots$

$000\ 0010_2 \equiv 2^{2} = 4$
$000\ 0001_2 \equiv 2^{1} = 2$
$000\ 0000_2 \equiv 2^{0} = 1$
$111\ 1111_2 \equiv 2^{-1} = 0.5$
$111\ 1110_2 \equiv 2^{-2} = 0.25$

$\vdots \qquad\qquad \vdots$

$100\ 0000_2 \equiv 2^{-64} = 5.4 \times 10^{-20}$

Bytes 2, 3 and 4 contain the mantissa part of the floating point number. The mantissa is always less than unity, so the 'binary point' is shown preceding the first bit of byte 2.

Converting a four-byte binary number to decimal.

Example:

Byte 1	11111110	$(=254_{10})$
Byte 2	10000000	$(=128_{10})$
Byte 3	00000000	$(=0_{10})$
Byte 4	00000000	$(=0_{10})$

The msb of Byte 1 is 1, so the number is negative. The remaining bits of Byte 1 gives a binary exponent of -2. The mantissa is formed as:

$$\frac{(\text{Byte 2})_{10}}{256_{10}} + \frac{(\text{Byte 3})_{10}}{256_{10}^{\,2}} + \frac{(\text{Byte 4})_{10}}{256_{10}^{\,3}}$$

$$= 0.5 + 0 + 0$$

The complete number is: $- [\ 2^{-2} \times (0.5 + 0 + 0)]$

$$= - 0.25 \times 0.5 = - 0.125$$

5.5 OUTPUT TERMINATORS & SEPARATORS

5.5.1 RS423 Port

In tabular output mode, each line of data sent from the SI1287 via the RS423 port is automatically terminated with ’carriage return line feed’, plus padding ’nul’ characters.

In dump mode, neither output terminators nor separators are sent via the RS423 port.

5.5.2 GPIB Port

Each line of data output by the SI1287 via the GPIB port must be closed by an output terminator (except in dump mode). The requirements of the external device govern the choice of terminator. The instrument generates ’carriage return line feed’ as the default terminator, but others may be selected via the DATA OUTPUT {GPIB} O/P TERMINATOR menu or the OT command.

Each line of data consists of several ’fields’ which require output separator characters between them (except in dump mode). The instrument defaults to ’comma’, but others may be selected via the DATA OUTPUT {GPIB} O/P SEPARATOR menu or the OS command.

6 SI1287 REMOTE COMMANDS

This section lists the instruments remote commands. The commands are the same for both RS423 and GPIB operation. The majority of codes are qualified by a numeric arguement. In the following list:

I is an integer of up to 3 digits.
I,I is two integers of up to 2 digits each, separated by a comma.
F is a floating point number +*n.nnnn*E±*xx*.
S is a string of up to 20 ASCII characters.

Note that the underlined commands relate to the default settings.

6.1 CELL POLARIZATION

Command	Function
PO0 **PO**1	Sets SI1287 to operate as a potentiostat. Sets SI1287 to operate as a galvanostat.
PV*F* **PC***F*	Defines the d.c. potential, in volts, that is to be applied across RE1 and RE2 for the potentiostat. (F=-14.5 to +14.5) Defines the direct current, in amps, that is to flow through the cell for the galvanostat. (F=-2 to +2)
PI0 **PI**1	An external signal (typically from an FRA) is added to the polarization selected by PV*F* or PC *F*, at a gain of ×1. An external signal (typically from an FRA) is added to the polarization selected by PV*F* or PC *F*, at a gain of ×0.01 (-40dB)
PW1 **PW**0	Selects polarization ON. (assumes ON mode.) Selects polarization OFF. (assumes standby mode.)

6.2 STANDBY STATE

Command	Standby State	Measurements possible
BY0	Full Standby	POL, ∑POL, CE
BY1	Half Standby	RE1, RE2, ΔRE, ΔRE-Bi, POL, ∑POL, CE, I, I-Bi

6.3 POLARIZATION ON MODE

Command	On Mode
ON0	Prepares the instrument for the **Pol V/I** mode. When polarization ON is selected the cell is polarized at its previously defined level. By default, this is zero volts for the potentiostat and zero current for the galvanostat; otherwise, it is the level defined by the last **PV***F* or **PC***F* command (see Table 6.1).
ON1	Prepares the instrument for the **Rest V/I** mode. When polarization ON is selected the cell is held at its rest potential (potentiostat) or at zero current (galvanostat). Changing to ON0 will then cause the polarization voltage/current to take up the value defined by PVF or PCF

6.4 CONTROL LOOP BANDWIDTH

Command	Bandwidth	
SY0	Bandwidth set to that defined by GB or PB.	
SY1	Bandwidth set to type C.	
	Galvanostat:	
GB0	Type A	150kHz**
GB1	Type B	100kHz**
GB2	Type C	>7.5kHz***
	Potentiostat:	
PB0	Type A	600kHz*
PB1	Type B	360kHz*
PB2	Type C	>1MHz*
PB3	Type D	>600kHz*
PB4	Type E	24kHz*
PB5	Type F	8kHz
PB6	Type G	2.4kHz
PB7	Type H	800Hz
PB8	Type I	80Hz
PB9	Type J	8Hz

*12kHz when limit or cutout selected for O/L type.
** 25kHz when limit or cutout selected for O/L type. Stable with capacitive cells when standard resistor ≤100Ω
*** 5kHz when limit or cutout selected for O/L type.

6.5 STANDARD RESISTOR SELECTION

Command	Standard Res. Value	Full-Scale Current (At 200mV)
RR0	Auto-range	
RR1	0.1Ω	2A
RR2	1Ω	200mA
RR3	10Ω	20mA
RR4	100Ω	2mA
RR5	1kΩ	200µA
RR6	10kΩ	20µA
RR7	100kΩ	2µA
RR8	1MΩ	200nA

6.6 CURRENT LIMIT SELECTION *(In conjunction with Auto-range RR0)*

Command	Full-Scale Current (At 200mV)
IL0	2µA
IL1	20µA
IL2	200µA
IL3	2mA
IL4	20mA
IL5	200mA
IL6	2A

6.7 CURRENT OFF-LIMIT ACTION

Command	Overload Action	
OL0	Cutout.	The SI1287 goes to the "standby" state and the cell current is cut off completely.
OL1	Limit.	The cell current limits at the full-scale value of a fixed range (or the I LIMIT value).
OL2	No Limit.	The cell current is uncontrolled and may rise to >±2A. **Caution:** Some cells may be damaged by an excessive current flow.

6.8 IR COMPENSATION TYPE AND ON/OFF

Command	Function
CT0 **CT**1	Selects feedback IR compensation. Selects sampled IR compensation.
CC0 **CC**1	IR compensation OFF (also RPC off). IR compensation ON.

6.9 FEEDBACK IR COMPENSATION

Command	Function
IC*F*	Defines the value of the parasitic resistance R_P (0Ω to 10MΩ) Legal range = (0.01 to 10) R_s

6.10 SAMPLED IR COMPENSATION

Command	Function
IN*F*	Defines the cell current *off* time (26.6µs to 1.36ms).
IP*I*	Defines the cell current *off:on* ratio (1:*I*) where *I*=integer 1 to 255.
RO0 **RO**1	Selects actual waveforms for output to FRA. Selects sampled and held waveforms for output to FRA.

6.11 REAL PART CORRECTION

Command	Function
CC0 **CC**2	Real part correction OFF. (Also IR compensation OFF). Real part correction ON.
RP*F*	Defines the value of the parasitic resistance R_P (0Ω to 10MΩ)

6.12 SI1287 OUTPUT CONDITIONING FACILITIES

Command	Function
VT0 **VT**1 **VR***F*	Voltage bias reject, auto. Voltage bias reject, fixed. Fixed rejection voltage. (F= 0V to ±14.5V)
IT0 **IT**1 **IR***F*	Current bias reject, auto. Current bias reject, fixed. Fixed rejection current. (F= 0A to ±2A)
BR0 **BR**1	Bias reject OFF. Bias reject ON. For auto bias reject the signal bias is measured, stored, and subtracted from all subsequent measurements. For fixed bias reject a user-defined value is subtracted.
FI0 **FI**1	Filter OFF. Filter ON. A 10Hz low-pass filter is switched into the measured voltage and current outputs.
VX0 **VX**1	Voltage amplification OFF. To rear outputs. ×10 voltage amplification. " " "
IX0 **IX**1	Current amplification OFF. To rear outputs. ×10 current amplification. " " "

6.13 SWEEP DEFINITION

Command	Function
DL*F*	Delay in seconds (F= 0 to 100,000s)
SM*F*	Number of segments (F= 1 to 99,999; default=2)
OF0 **OF**1	Off mode - Standby - Freeze
SW0 **SW**1 **SW**2	Standby or freeze (depending on setting of **OF***I*.) Start ramp sweep. Start stepped sweep.
?ST	Returns the sweep status.

6.14 RAMP SWEEP: SEGMENT DEFINITION

Command	Function
VA*F*	Voltage level V_A (F= 0 to ±14.5V)
JA*F*	Current level I_A (F= 0 to ±2A)
TA*F*	Segment time T_A (F= 10ms to 100,000s)
VB*F*	Voltage level V_B (F= 0 to ±14.5V)
JB*F*	Current level I_B (F= 0 to ±2A)
TB*F*	Segment time T_B (F= 10ms to 100,000s)
VC*F*	Voltage level V_C (F= 0 to ±14.5V)
JC*F*	Current level I_C (F= 0 to ±2A)
TC*F*	Segment time T_C (F= 10ms to 100,000s)
VD*F*	Voltage level V_D (F= 0 to ±14.5V)
JD*F*	Current level I_D (F= 0 to ±2A)
TD*F*	Segment time T_D (F= 10ms to 100,000s)

6.15 STEPPED SWEEP: SEGMENT DEFINITION

Command	Function	
SA*F*	Voltage level V_A	(F= 0 to ±14.5V)
KA*F*	Current level I_A	(F= 0 to ±2A)
SB*F*	Voltage level V_B	(F= 0 to ±14.5V)
KB*F*	Current level I_B	(F= 0 to ±2A)
SC*F*	Voltage level V_C	(F= 0 to ±14.5V)
KC*F*	Current level I_C	(F= 0 to ±2A)
SD*F*	Voltage level V_D	(F= 0 to ±14.5V)
KD*F*	Current level I_D	(F= 0 to ±2A)
TE*F*	Time per step	(F= 10ms to 100,000s)
VS*F*	Volts per step	(F= 5µV to 29.0V)
IS*F*	Current per step	(F= 1nA to 4A)

6.16 DVM CONTROL FUNCTIONS

Command	Function	
DG0	Number of Digits	5×9
DG1		4×9 (50Hz a.c. supply)
DG2		4×9 (60Hz a.c. supply)
DG3		3×9
RG0	Input Range*	Autorange
RG1		200mV
RG2		2V
RG3		20V
RG4		50V
TR0	Measurement Trigger	Single measurement.
TR1		Continuous measurements.
TR2		External measurements.
TR3		Sweep synchronised measurements.
DC0	Drift correction ON.	
DC1	Drift correction OFF.	
AV0	Averaging OFF.	
AV1	Averaging ON.	
NU0	Null OFF.	
NU1	Null ON.	
NU2	Null evaluate.	
RU0	Digital voltmeter HALT.	
RU1	Digital voltmeter RUN.	

* For voltage measurement only.

6.17 OUTPUT PARAMETER SELECTION

Command		Parameter	
Par 1	**Par 2**		
PX0	**PY**0	CE	Counter electrode.
PX1	**PY**1	RE1	Reference electrode 1.
PX2	**PY**2	RE2	Reference electrode 2.
PX3	**PY**3	ΔRE	V_{RE1}-V_{RE2}.
PX4	**PY**4	ΔRE-Bi	ΔRE-V_{BIAS}.
PX5	**PY**5	I	Cell Current.
PX6	**PY**6	I-Bi	Cell current - bias current.
PX7	**PY**7	δΔRE/δI	Polarization resistance.*
PX8	**PY**8	δI/δΔRE	Polarization conductance.*
PX9	**PY**9	POL	D.C. polarization.
PX10	**PY**10	∑POL	POL + D.C. bias.
PX11	**PY**11	DVM	Zero (for nulling).

* Available only with sweep.

6.18 HISTORY FILE FUNCTIONS

Command	Function
FL0	Closes the file.
FL1	Opens the file.
FS*I*	Defines the file size (number of results). *I*=1 to ~450 (default=200)
UF*I*	Defines the location from which the file is to be updated and outputs record to i/f.
VF1	Clears the file, i.e. erases the file contents.
VF2	Outputs the contents of the file to the interface(s).
?FP0	Returns the number of results filed. (0 to 450).
?FP1	Returns the file pointer (=location of last result filed).
?NR	Returns the number of readings taken. (0 to 99999).
FD0	Controls the format of the data output to the display by the 'VF2' command. Outputs file to display as : par1, par2.
FD1	as time, par1.
FD2	as time, par2.

6.19 DATA OUTPUT FUNCTIONS

Command	Function
RH0	On, headings are pre-pended to results sent to the RS423 and GPIB in talk only mode.
RH1	Off, all headings are suppressed.
RS0	RS423 Output off.
RS1	Output on, Compressed ASCII format with time.
RS2	Dump, Binary format with time.
	Note: for all full description of RS423 output formats, see Chapter 4.
GP0	GPIB Output off.
GP1	Long on: Compressed ASCII format, with time.
GP2	Short on: Compressed ASCII format, without time.
GP3	Long dump: Binary format, with time.
GP4	Short dump: Binary format, without time.
	Note: for all full description of GPIB output formats, see Chapter 4.
OS0	Output separator=comma (,)
OS1	Output separator same as terminator.
OT0	GPIB Output terminator=cr lf.
OT1	GPIB Output terminator=cr lf and EOI.
OT2	GPIB Output terminator=cr.
OT3	GPIB Output terminator=cr and EOI.
SV*I*	Specifies which serial poll bit(s) may initiate a service request. I=1, 2, 4, 8, etc, to define a specific bit, or several such integers may be added together to define several bits, e.g. 10 defines bits 2 and 8, see Chapter 4.
PP*I*	Specifies which GPIB data line the SI1287 is to assert, to identify itself in a parallel poll. I=0 to 8, see chapter 4.
SE0	Parallel poll sense true: "1" (Low on bus)=service request.
SE1	Parallel poll sense false: "0" (High on bus)=service request.

6.20 BREAK AND SELF-TEST FUNCTIONS

Command	Function	
BK0	Break	Halts the present operation of the SI1287 and returns it to the standby state, as defined by the BY command.
BK1 or **BK**2	Check	Starts a self-test of the SI1287 digital circuitry. On completion of this test, the instrument is set to the standby state; the DVM and sweep are switched off. Any failure causes the test routine to abort and a fail code is generated.
BK3	Reset	Returns all control setups to the default state, but retains the content of the history file.
BK4	Initialize	Returns all control setups to the default state and clears the history file.

6.21 PLOT

Command	Function
PL0 **PL**1 **PL**2 **PL**3 **PL**4 **PL**5	Plot - plot graph. - plot axes. - pen moves to min. X and Y. - pen moves to max. X and Y. - zero, pen parked. - off
XI0 **XI**1 **XI**2 **XI**3 **XI**4 **XI**5 **XI**6	X Item - PAR1. - PAR2. - TIME. - log PAR1. - log PAR2. - log TIME. - root TIME.
XL*F* **XH***F* **XO***F*	X min. value (-1E18 to 1E18) X max. value (-1E18 to 1E18) X origin value (-1E18 to 1E18)
YI0 **YI**1 **YI**2 **YI**3 **YI**4 **YI**5 **YI**6	Y Item - PAR1. - PAR2. - TIME. - log PAR1. - log PAR2. - log TIME. - root TIME.
YL*F* **YH***F* **YO***F*	Y min. value. (-1E18 to 1E18) Y max. value. (-1E18 to 1E18) Y origin value. (-1E18 to 1E18)
PZ0 **PZ**1 **PZ**2	Size - A4. - A3. - variable.
XB*F* **YB***F* **XT***F* **YT***F*	VX min. - No. of steps. (**0** to 32000) VY min. - No. of steps. (**0** to 32000) VX max. - No. of steps. (**0** to 32000) VY max. - No. of steps. (**0** to 32000)
PT0 **PT**1	Text (axes) - off. - on.
PH0 **PH**1	Title - off. - on.
SG2	Title String - copy title of last recalled settings to be title string.
CH*S*	Set new title string (upto 20 ASCII characters).
GT0 **GT**1	Grid - off. - on.
VE0 **VE**1	Plot mode - point. - vector.
PD0 **PD**1	Device type - HPGL. - ESGL.

6.22 SELF-TEST RESULTS

Command	Function
?TS	Overall results of self-test. (01=fail, 00=pass)
?TS1	RAM. (01=fail, 00=pass)
?TS2	ROM. (01=fail, 00=pass)
?TS3	Timer, 1, 2, 3. (01, 02, 03=fail, 00=pass)
?TS4	GPIB.

6.23 Display

Command	Function
UL0	LHS display - CE
UL1	- RE1
UL2	- RE2
UL3	- ΔRE
UL4	- ΔRE-Bi
UL5	- I
UL6	- I-Bi
UL7	- δΔRE/δI
UL8	- δI/δΔRE
UL9	- POL
UL10	- ΣPOL
UL11	- DVM I/P
UL12	- TIME
UL13	- (blank)
UR0	RHS display - CE
UR1	- RE1
UR2	- RE2
UR3	- ΔRE
UR4	- ΔRE-Bi
UR5	- I
UR6	- I-Bi
UR7	- δΔRE/δI
UR8	- δI/δΔRE
UR9	- POL
UR10	- ΣPOL
UR11	- DVM I/P
UR12	- TIME
UR13	- (blank)

6.24 Last Error Query, Clear Error, Software Version, Time, Status

Command	Function
?ER	Returns the code of the last error detected.
CE	Clears the "last error" code and the two error codes on the status page.
?VN	Returns the status and issue of the SI1287 software.
TM *I,I*	Sets a starting value for the elapsed time. (*I,I*=hh,mm)
VF3	Output status page.

6.25 Other Commands

Command	Function
SR*I*,*S*	Store setting I, title S. 0 to 9 (S≤ 20 ASCII characters)
RC*I*	Recall setting. (*I= 0 to 9*)
CL*I*	Clear setting. (*I= 0 to 9*)
?WE*I*	Store existence. (*I= 0 to 9*) (0=store *I* does not exist, 1=store *I* does exist).
WL*I*	Load from remote device into menu setup store. (*I= 0 to 9*)
WS*I*	Save menu setup store to remote device. (*I= 0 to 9*)
LL	Local. When sent from RS423 causes all keys except "Local" to be disabled (see section 4).
EB0	Error Bell - on
EB1	- off

Chapter 5
Using the SI1287 with an FRA

Section *Page*

1 **Introduction** 5.3

2 **Hardware Connections: A.C. Sweep** 5.4

3 **Parameter Settings: A.C. Sweep** 5.5
3.1 SI1287 Menu Settings 5.5
3.2 1250,1254 or 1255 Menu Settings 5.5

4 **Running the A.C. Sweep** 5.6

Figure

5.1 *12861 Test Module Circuit* 5.3
5.2 *A.C. sweep plot* 5.3
5.3 *Cell Measurement System* 5.4

1 INTRODUCTION

This chapter provides an example on how to set up and run a.c. sweeps, in conjunction with an FRA; Solartron 1250, 1254, 1255 or 1260 (1255/60 recommended).

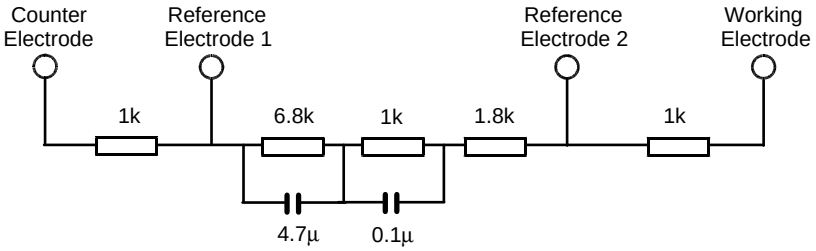


Fig 5.1 *12861 Test Module Circuit*

The 12861 Test Module, shown in Figure 5.1, is subjected to an a.c. sweep by an Frequency Response Analyzer, using the SI1287 as an interface. The SI1287 'V' and 'I' on the rear panel analog outputs are processed by the FRA and the resulting impedance values are simultaneously plotted as a complex plane (Nyquist) diagram.

The resulting impedance plot is shown in Figure 5.2.

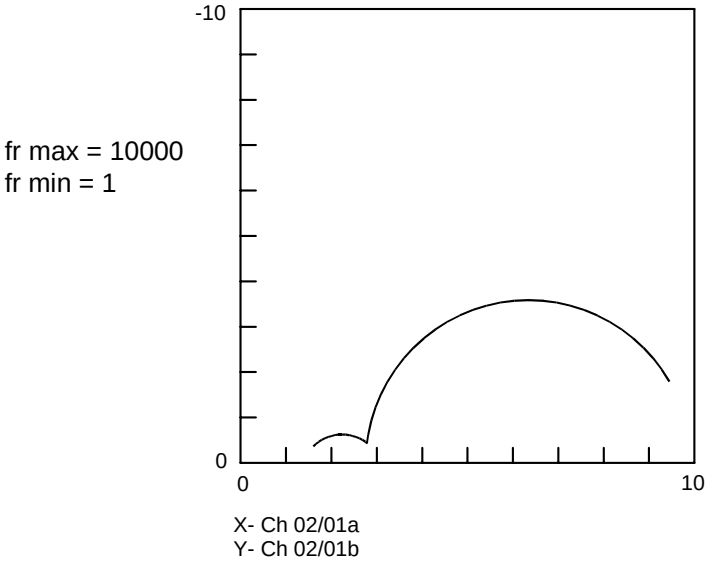


Fig 5.2 *A.C. sweep plot: imaginary impedance component (-b) vs. real impedance component (a) for the 12861 Test Module*

2 HARDWARE CONNECTIONS: AC SWEEP

Connect the four 12861 Test Module terminals to the corresponding SI1287 front panel sockets using the cables supplied. If, however, a real cell is to be used refer to the cell configurations, as detailed in Chapter 2, section 3.

Connect the SI1287 'V', 'I' and 'POL I/P' rear panel terminals to the FRA channel 2 (Hi), channel 1 (Hi), and the generator (Hi) rear panel terminals respectively. The 'LO' BNC terminals on the FRA rear panel must have their inner conductors short-circuited to the shields. This may be done inserting the special BNC plugs also supplied with the SI1287.

Connect the digital plotter (HPGL or ESGL types) and the FRA together via a GPIB cable. The SI1287 should not be connected to the GPIB for this sweep.

Set the FRA GPIB to 'Talk Only' and the plotter to 'Listen Only'.

Figure 5.3, Cell Measurement System, summarises these and other hardware interconnections.

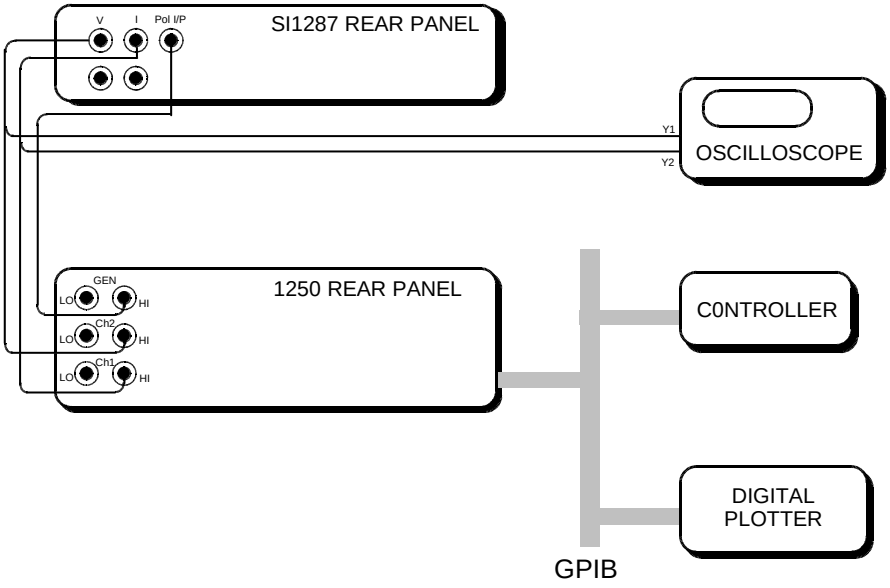


Fig 5.3 *Cell Measurement System*

3 PARAMETER SETTINGS: A.C. SWEEP

3.1 SI1287 MENU SETTINGS

Use of the SI1287 front panel has been explained previously in Chapter 3.

Step 1. Initialize the SI1287.

Step 2. Press **SET UP** to select parameter set-up mode.

Step 3. Press **I MEASURE** and select:

RESISTOR = 100Ω
O/L TYPE = warning

Step 4. Press **SET UP** (again) to return the SI1287 to normal mode.

Note: All other menu settings are left to their default (initialized values).

3.2 1250, 1254, 1255 or 1260 MENU SETTINGS

Refer to the appropriate operating manuals for details of setting up menus.

Step 1. Initialize the 1255 (1250/54). This action also 'reads' the GPIB switch settings.

Step 2. In the **GENERATOR** menu, select:

AMPL = 10V

Note that for 1255 FRA the amplitude must be 3V or less.

Step 3. In the **ANALYZER** menu, select:

Note that the analyzer must be set to INPUT=Single-Ended; OUTER=Floating for the 1255 FRA.

(a) **ANALYZER COMMON**:

∫TIME = 5 cycles
DELAY = 1 cycle

(b) **ANALYZER 1**:

INPUT = rear

(c) **ANALYZER 2**:

INPUT = rear

Step 4. In the **SWEEP** menu, select:

FR MIN = 1Hz
FR MAX = 10kHz
Δ LOG =20st/dec

Step 5. In the **DISPLAY/PLOTTER** menu, select:

(a) **DISPLAY**:

SOURCE = Ch2/Ch1

(b) **PLOTTER COMMON**:

MODE = vector
SIZE = A4
DEVICE = (GPIB-HPGL or GPIB-ESGL depending on plotter type)

(c) **PLOTTER X-AXIS**:

MINIMUM = 0
MAXIMUM = 10

(d) **PLOTTER Y-AXIS**:

ITEM = b
MINIMUM = 0
MAXIMUM = -10

Note: All other 1255 (1250/54) menu settings are left at their default (initialized) values.

4 RUNNING THE A.C. SWEEP

Step 1. Plot the graph axes, by pressing the 1255 (1250/54) (DISPLAY/PLOTTER) PLOT key followed by the AXES soft key.

Step 2. Enable the plotting of the graph itself, by pressing the 1255 (1250/54) PLOT key (again), followed by the GRAPH soft key.

Step 3. Enable the logarithmic sweep, by pressing the 1255 (1250/54) START/CONTINUE key, followed by the á LOG softkey.

Step 4. Press the SI1287 ON/STANDBY key 'on'.

Step 5. Enable the 1255 (1250/54) analyzer by pressing (ANALYZER) RECYCLE.

Step 6. Start the 1255 (1250/54) generator (and hence the sweep) by pressing (GENERATOR) START.

Step 7. At the end of the a.c. sweep, stop the 1255 (1250/54) generator and switch the SI1287 to 'stand by'.

Appendix A
Installation

Section *Page*

1 **Safety Precautions** A.3
1.1 Grounding A.3
1.2 A.C. Supply voltage A.3
1.3 Fuses A.3
1.4 Explosive Atmospheres A.4
1.5 Safety Symbols A.4
1.6 Avoid Unsafe Equipment A.4
1.7 Live conductors A.4
1.8 Equipment Modification A.4

2 **A.C. Supply** A.5
2.1 Voltage Selector A.5
2.2 Power Cable A.6

3 **Accessories** A.7

4 **Environmental Information** A.7
4.1 EMC A.7
4.2 Ventilation A.7
4.3 Siting the Instrument A.7

5 **Rack Mounting** A.8
5.1 Rack Dimensions A.8
5.2 Rack Ventilation A.8
5.3 Fitting a Telescopic Slide Mounting A.9

Figure

A.1 *Line Voltage Selector* A.5
A.2 *IEC power socket connections* A.6
A.3 *Removal of trims, handle, feet and tilt bar* A.9
A.4 *Fitting rack ears and telescopic slide inner members* A.10
A.5 *Separating the inner and outer slide members* A.10
A.6 *Fitting a rear bracket* A.11
A.7 *Fitting a front bracket and support bracket* A.11
A.8 *Caged nut insertion in cabinets* A.12
A.9 *Fitting the outer slide members into the rack* A.13

Table

A.1 *Line Voltage Selector Settings* A.5
A.2 *Accessories* A.7

1 SAFETY PRECAUTIONS

The equipment described in this manual has been designed in accordance with IEC publication 1010 Safety Requirements for Electronic Measuring Apparatus, and has been supplied in a safe condition. To avoid injury to an operator or service technician the safety precautions given below, and throughout the manual, must be strictly adhered to, whenever the equipment is operated, serviced or repaired.

The equipment is designed solely for electronic measurement and should be used for no other purpose. Solartron accept no responsibility for accidents or damage resulting from any failure to comply with these precautions.

1.1 GROUNDING

To minimize the hazard of electrical shock it is essential that the equipment is connected to a protective ground whenever the power supply, measurement or control circuits are connected, even if the equipment is switched off.

A ***PROTECTIVE GROUND*** is connected via the a.c. supply cord. The cord must be plugged into an ac line outlet with a protective ground contact. When an extension lead is used, this must also contain a ground conductor. Always connect the a.c. supply cord to the supply outlet before connecting the control and signal cables; and, conversely, always disconnect control and signal cables before disconnecting the ac supply cord. The a.c. ground connection must have a continuous current rating of 25A.

A high quality ***SIGNAL GROUND***, for measurement purposes, is provided in the form of a binding post. This is linked internally to ***PROTECTIVE GROUND***.

Where both protective and signal grounds are used it must be ensured that these grounds are, and will remain, at the same potential.

1.2 AC SUPPLY VOLTAGE

Before switching on the equipment ensure that the a.c. voltage selector is set to correspond with the local a.c. supply voltage.

Never operate the equipment from a line voltage or frequency in excess of that specified for the voltage selector setting used. Otherwise, the insulation of internal components may break down and cause excessive leakage currents.

1.3 FUSES

Before switching on the equipment check that the fuses accessible from the exterior of the equipment are of the correct rating. The rating of the a.c. line fuse must be in accordance with the voltage of the a.c. supply.

Should any fuse continually blow, do not insert a fuse of a higher rating. Switch the equipment off, clearly label it "unserviceable" and inform a service technician.

1.4 EXPLOSIVE ATMOSPHERES

NEVER OPERATE the equipment, or any sensors connected to the equipment, in a potentially explosive atmosphere. It is NOT intrinsically safe and could possibly cause an explosion.

1.5 SAFETY SYMBOLS

For the guidance and protection of the user, the following safety symbols may appear on the equipment:



Refer to operating manual for detailed instructions of use.



Hazardous voltages.



Protective conductor terminal. This must be connected to ground before operating the equipment.

1.6 AVOID UNSAFE EQUIPMENT

The equipment may be unsafe if any of the following statements apply:

- The equipment shows visible damage.
- The equipment has failed to perform an intended operation.
- The equipment has been subjected to prolonged storage under unfavorable conditions.
- The equipment has been subjected to severe physical stress.

If in *any doubt* as to the serviceability of the equipment, don't use it. Get it properly checked out by a qualified service technician.

1.7 LIVE CONDUCTORS

When the equipment is connected to its measurement inputs or supply, the opening of covers or removal of parts could expose live conductors. The equipment must be disconnected from all power and signal sources before it is opened for any adjustment, replacement, servicing or repair. Adjustments, servicing or repair, must be done only by qualified personnel, who should refer to the Servicing Manual.

1.8 EQUIPMENT MODIFICATION

To avoid introducing safety hazards, never install non-standard parts in the equipment, or make any unauthorized modification. To maintain safety, always return the equipment to Solartron for service and repair.

2 A.C. SUPPLY

2.1 VOLTAGE SELECTOR

Check that the setting of the line voltage selector on the rear panel corresponds with the nominal line voltage of the local a.c. supply. (The setting in use is displayed in a small window in the selector flap.)

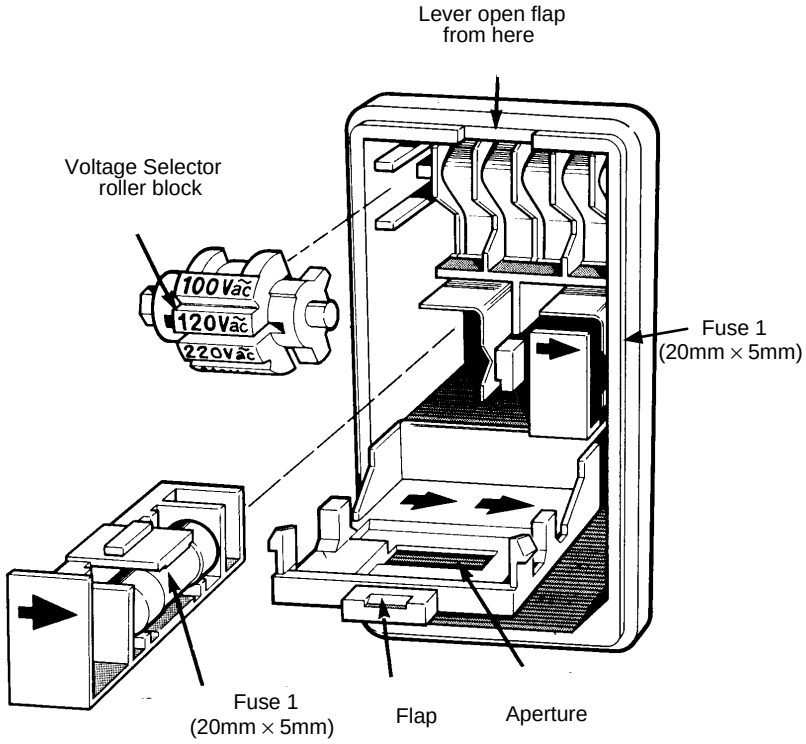


Fig A.1 *Line Voltage Selector*

Table A.1 lists the settings available and the corresponding line voltage ranges.

Table A.1 Line Voltage Selector Settings.

Selector Setting	Line Voltage Range
100V	90-110V
120V	108-132V
220V	198-242V
240V	216-264V

In some localities the nominal line voltage may not correspond exactly with any selector setting. In such a case, choose the selector setting whose line voltage range includes the nominal line voltage. Should the nominal line voltage be covered by two ranges, choose the lower of the two: this ensures that the d.c. supplies of the SI 1287 are fully attained.

For example: (a) in the case of a 110V supply choose the "100V" setting or (b) in the case of a 230V supply choose the "220V" setting.

Should you need to change the line voltage setting it is a simple matter to lift the selector flap with a thin-bladed screwdriver and turn the roller block so that the correct voltage appears in the window when the flap is closed. Figure A.1 shows the line voltage selector flap open to reveal the roller block inside.

Changing the line voltage selector setting sometimes necessitates inserting a.c. supply fuses of a different value. There are two fuses, one in the line and one in the neutral. Both fuses must be the correct rating for the voltage supply. These fuses are located below the roller block, as shown in Figure A.1. The fuse values are:

1.6A, SLO-BLO for 220V or 240V operation
2A, SLO-BLO for 100V or 120V operation

These fuses must be 20mm x 5mm cartridge type.

2.2 POWER CABLE

Connect the SI1287 to the a.c. supply with the power cord provided. At one end the power cord has an IEC socket, which fits into a mating connector on the SI1287, and at the other end is a power plug appropriate to the country of destination.

Some countries have no fixed preference of power plug and for these the power cord is provided only with an IEC socket. The wires at the other end of the cord should be connected to the user's power source, via a suitable connector, according to the following color code:

BROWN	=	LIVE
BLUE	=	NEUTRAL
GREEN/YELLOW	=	GROUND

An IEC socket and power cord other than the one supplied may be used, but it must be correctly wired as shown in Fig A.2.

The ground lead should be capable of carrying 25A.

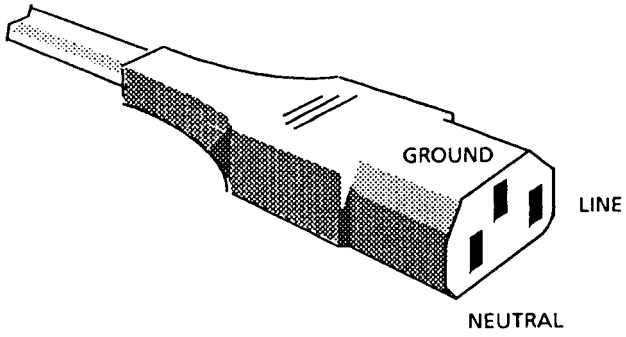


Fig A.2 *IEC power socket connections*

3 ACCESSORIES

Table A.2 lists the accessories which should be supplied with the instrument. If any accessories are missing contact your local supplier.

Table A.2 Accessories

Item	Qty
User Guide	1
12861 Test Module	1
Fuses: 1.6A; 20×5mm, slo blo for 220V to 240V	2
2A; 20×5mm, slo blo for 100V to 120V	2
7A; 0.625inch×0.187inch, fast blo as spares for the SI1287 internal pcb-mounted fuses.	4
Power Cord.	1
Color-coded leads, BNC to 4mm, 1m long, to connect a cell to the SI1287.	4
Crocodile clips to fit the ends of the measurement leads.	4

4 ENVIRONMENTAL INFORMATION

4.1 EMC

This instrument meets the requirement of EN50081-1 for emission and EN50082-1 for immunity but it should be noted that high levels of radiated or conducted interference may reduce the accuracy of low level measurements. See Appendix C, section 1.8 for details.

4.2 VENTILATION

The instrument has fan-assisted ventilation. Air is drawn in through slots in the front panel and exhausted through a vent in the rear.

To ensure that the instrument always runs cool, keep the air inlet and outlet clear. Leave a gap of at least 4 inches (100mm) between the rear panel and any vertical obstruction such as a wall. When the instrument is rack-mounted the rack itself should be well ventilated.

A thermal sensor monitors the internal temperature of the instrument. If this temperature approaches the working limit then error code 34 is generated. You should then check the ventilation path. If the temperature does not fall to a safe value within one minute then the instrument goes into the STANDBY state.

4.3 SITING THE INSTRUMENT

To ensure that the instrument remains in a safe and serviceable state it is important that its operating, and storage, environment conforms with the limitations stated in the SI1287 Specification. Although the instrument is contained in a ruggedized case and conforms to a high standard of safety, it should be afforded all the precautions normally taken with electrical equipment.

Should the SI1287 be required to operate in a hostile environment then it should be mounted in a protective enclosure. The instrument should always be operated within the limits of temperature, humidity and vibration stated in the SI1287 Specification. See Appendix C.

Note that the instrument is not proof against corrosive atmospheres or liquids.

5 RACK MOUNTING

The instrument can be rack mounted in two ways: either by using fixed rails in the rack to support the underside of the case, or by using telescopic slides to support the SI1287 and allow easy withdrawal for servicing.

With either method, the pair of rack mounting ears is substituted for the finisher trims on the SI1287; screws inserted through the ears and into the rack keep the unit in place.

Note 1: The rack mounting ears must be used only to prevent the SI1287 sliding out of the rack. They are not designed to support the whole weight of the instrument.

Note 2: If the SI1287 is rack mounted on telescopic slides, ensure that the rack will not tip over when the slides are fully extended.

5.1 RACK DIMENSIONS

The internal rack dimensions required for fitting the SI1287 are :

610mm (24ins) deep × 485mm (19ins) wide for fixed rail mounting, and
760mm (30ins) deep × 485mm (19ins) wide for telescopic slide mounting.

5.2 RACK VENTILATION

The instrument has fan-assisted ventilation. Air is drawn in through slots in the front panel and exhausted through a vent in the rear. To ensure that the instrument always runs cool, keep the air inlet and outlet clear. Leave a gap of at least 4 inches (100mm) between the rear panel and any vertical obstruction such as a wall. When the instrument is rack-mounted the rack itself should also be well ventilated.

5.3 FITTING TELESCOPIC SLIDE MOUNTING

5.3.1 Remove the following items from the unit, as shown in Fig A.3:

a. **Finisher Trim** (two off)
Keep the four M4 16 panhead screws and M4 crinkle washers for securing the rack ears.

b. **Handle** and **Handle Trim**

c. **Side Trim**
Located on the opposite side to the handle, it is normally secured by a pip on the finisher trim, and slides out backwards.

d. **Feet** (four off) and **Tilt Bar**
The tilt bar is secured by the two front feet.

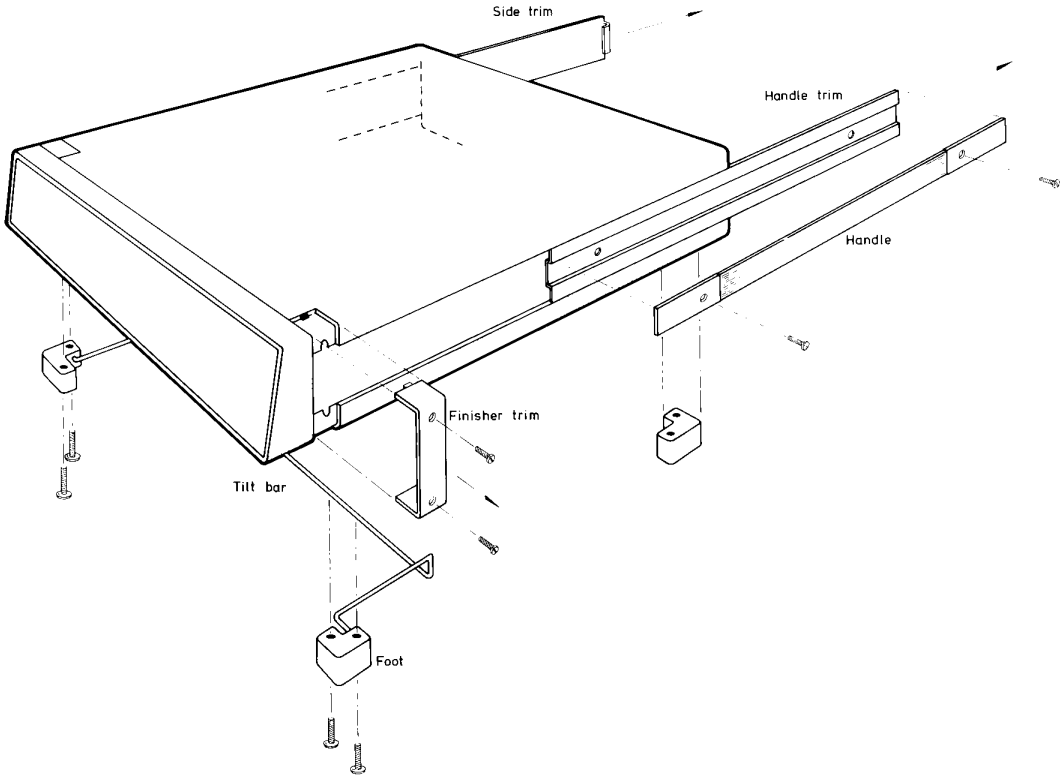


Fig A.3 *Removal of trims, handle, feet and tilt bar*

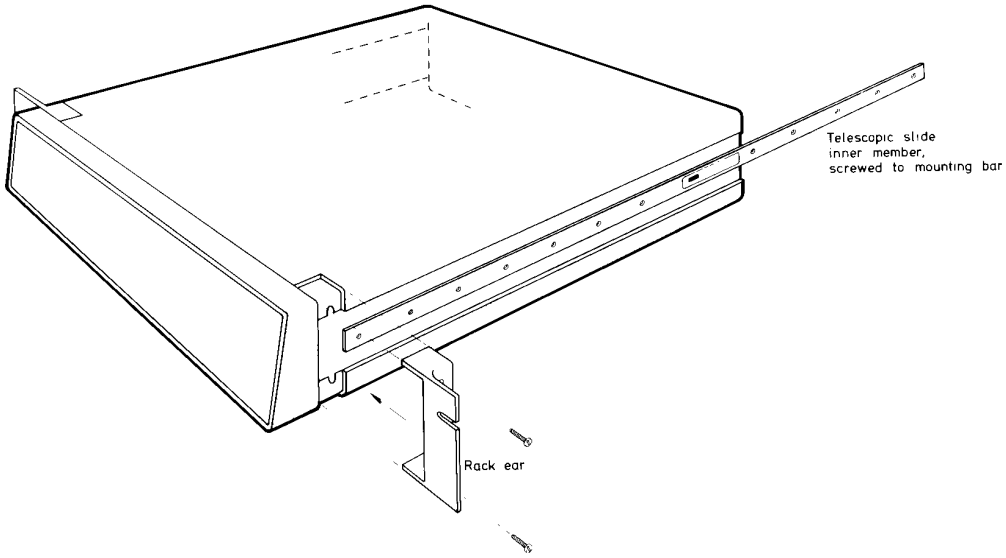
5.3.2 Fit the following items to the unit, as shown in Fig A.4:

a. **Rack Ears (Solartron part no. 12862010X)**
Fit the rack ears in place of the finisher trim, using the same fixings.

The ears may be fitted illustrated, or with their flanges facing the rear of the SI1287, which causes the unit to stand out further in the rack, allowing use of racks too shallow for normal mounting.

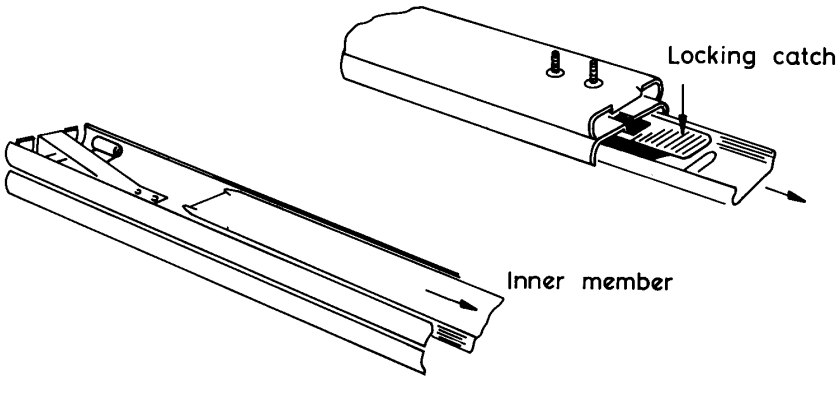
b. **Slide Mounting Bar (Solartron part no. 12862022A)**
Screw the bar to the chassis in the former position of the handle, using the four M4×12 csk screws. The bar only fits one way round; with the threaded holes nearest the front.

The corresponding mounting bar on the left hand side of the unit should aslo be fitted behind the side trim; it is slightly narrower than the right hand bar.



A.4 *Fitting rack ears and telescopic slide inner members*

c. **Telescopic Slide Inner Members** (two off)
The telescopic slides are supplied with inner and outer members slotted together. Slide out the inner member as shown in Figure A.5, depressing the locking catch at the halfway point.



A.5 *Separating the inner and outer slide members, prior to fixing*

Screw the slide inner members to the mounting bars using the 12 M4×6

panhead screws, 6 each side.

5.3.3 Fit the following items to the telescopic slide outer members, as shown in Figures A.6 and A.7:

a. **Adjustable Rear Brackets** (two off)
Fit one rear bracket to each outer member, but do not fully tighten the screws until the SI1287 is fitted into the rack (see section 5.3.6).

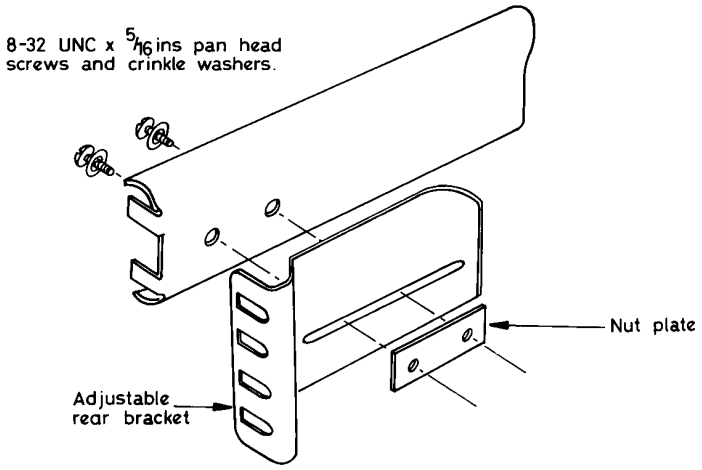


Fig A.6 *Fitting a rear bracket*

b. **Fixed Front Brackets together with Support Brackets** (two off each).

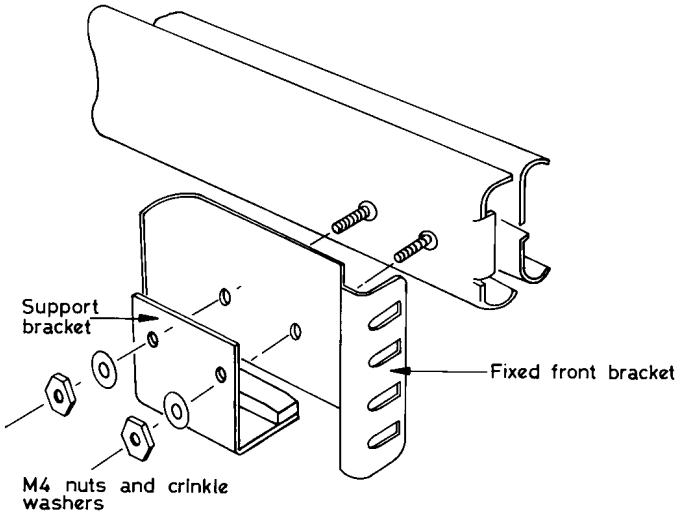


Fig A.7 *Fitting a front bracket and support bracket*

5.3.4 Fit the M6 caged nuts for outer slide members and rack ear fixing into the rack, in the positions shown in Figure A.8. Details on how to insert and remove caged nuts are also shown.

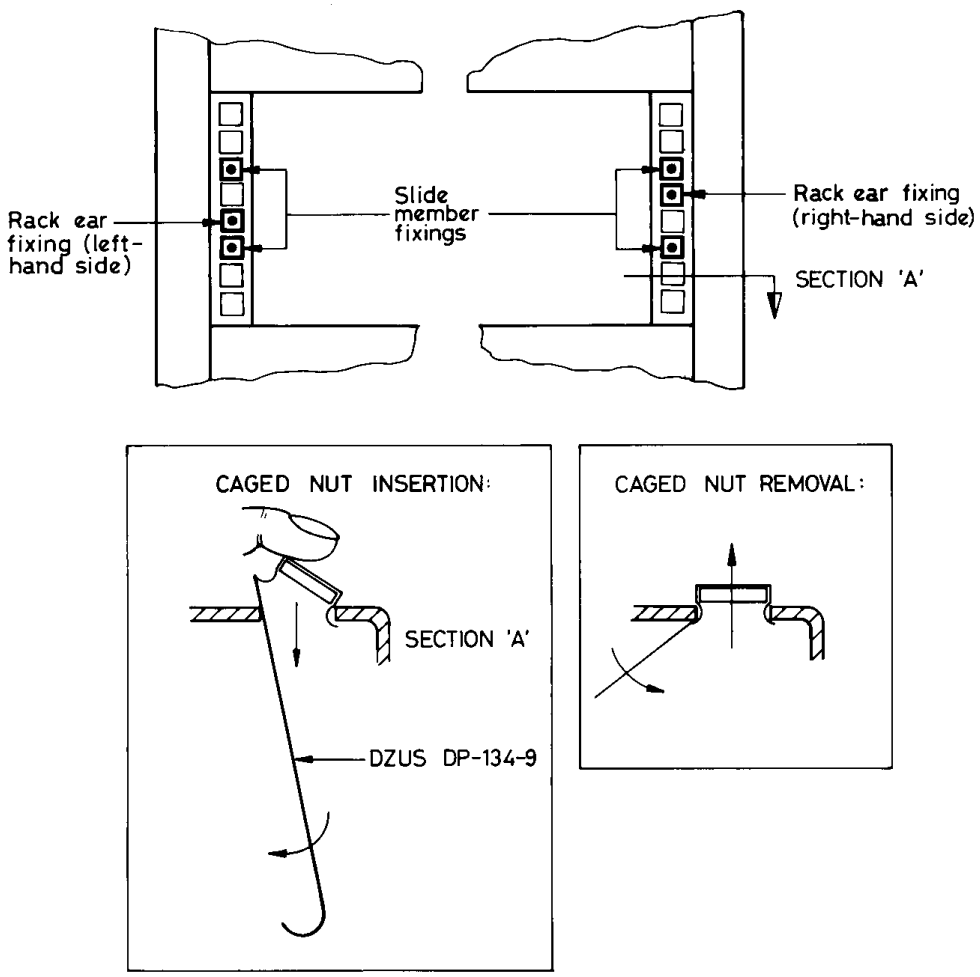


Fig A.8 *Caged nut insertion in cabinets*

5.3.5 Remove the following items from the unit, as shown in Fig A.3:

Note that the tapped holes in the nut plate are off center to provide maximum lateral adjustment. Fit the plates, as shown, with the holes offset towards the rack exterior.

Fitting one end of an outer member is made easier if the other end is supported, by hooking the bracket at the other end over an M5 screw pushed into the top caged nut.

Tighten the M5 screws securing each member until it is held moderately firmly in the rack, approximately in the centre of its travel. the members must, however, be free enough to take up any adjustment when the SI1287 is first fitted into the rack.

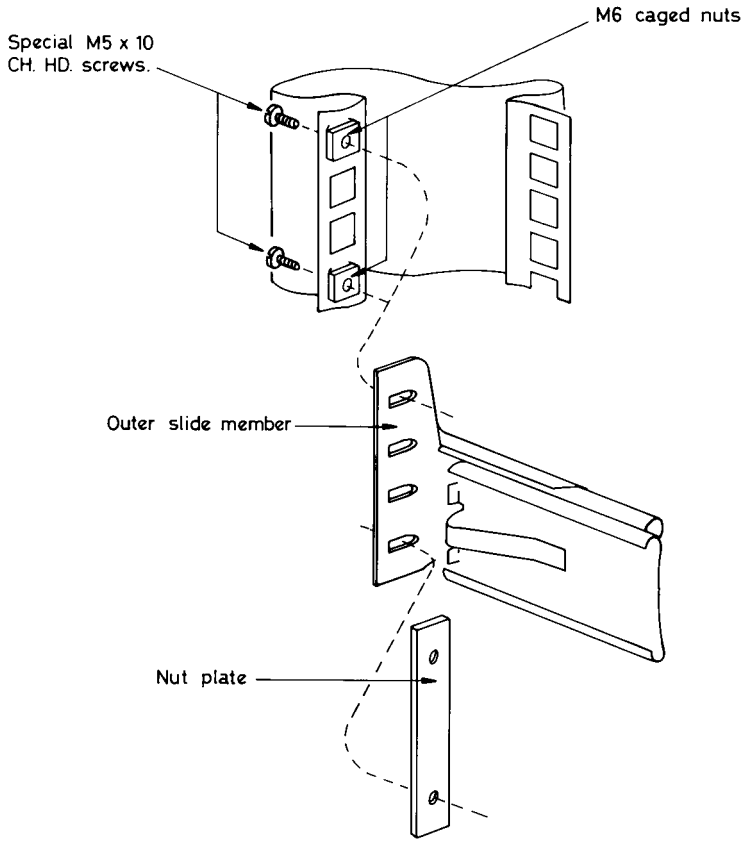


Fig A.9 *Fitting the outer slide members into the rack*

5.3.6 Finally, fit the SI1287 into the rack, as follows:

a. Offer the SI1287 up to the rack and feed the inner telescopic slide members into the outer members, pushing the unit into the rack until the locking catches engage and lock.

b. Depress both catches and push the unit fully into the rack, ensuring that no cables are trapped.

c. Tighten the screws on the outer slide members in the following order:

1. The M5 screws securing the rear bracket to the rack.
2. The M5 screws securing the front bracket to the rack.
3. The 8-32 UNC screws securing the rear bracket to the outer slide member.

Appendix B
Error Codes

Section		*Page*
1	**Error / Warning Code Summary**	B.3
1.1	Group 0 : Command Structure Errors	B.3
1.2	Group 1 : Store Errors	B.3
1.3	Group 2 : Parametric Interaction Errors	B.3
1.4	Group 3 : Overloads and Warnings	B.3
1.5	Group 4 : File Errors	B.5
1.6	Group 5 : Run-Time Errors	B.5
1.7	Group 6 : Illegal I/O Manipulation	B.5
1.8	Group 9 : Calibration Errors	B.5

1 ERROR / WARNING CODE SUMMARY

1.1 GROUP 0 : Command Structure Errors

01 Unknown command.
02 Argument mismatch.
03 Argument out of range.
04 Floating point format error.
05 Illegal request for value.

1.2 GROUP 1 : Store Errors

11 Store does not exist.
12 Store check sum error.
13 Not enough memory for store.
14 Requested store is not complete.
15 Linked list in store corrupted.

1.3 GROUP 2 : Parametric Interaction Errors

21 IRC not allowed in galvanostatic (G STAT) mode.
22 Polarisation current (POL I) and/or current bias rejection (I REJECT) inconsistent with standard resistor selected.
23 Necessary parameter in sweep not entered.
24 Zero or negative values not allowed in log plots or √TIME plots.
25 VX MIN > VX MAX and/or VY MIN > VY MAX in the PLOT SIZE menu.
26 IRCΩ or RPCΩ inconsistent with standard resistor selected.
27 GPIB echo not allowed in plotting.
28 Ramp sweep: ramp rate >100V/s
Step sweep: V/STP<100μV when maximum excursion from RMP V1>200mV; I/STP × standard resistor <100μV when maximum excursion (× standard resistor) from STP I1>200mV.
29 Ramp sweep: ramp rate <100μV/s
Step sweep: V/STP <50μV when maximum excursion from RMP V1≤200mV and >20mV;
I/STP × standard resistor <50μV when maximum excursion from STP I1≤200mV and >20mV.

1.4 GROUP 3 : Overloads and Warnings

31 Current DVM overload.
32 Voltage DVM overload.
33 Both DVMs overload.
34 Thermal cut-out. Over-heating of the amplifier output stage has been detected and the instrument has switched to standby. Over-heating may be caused by: a) excessive ambient temperature (>50C), b) cooling fan failure or blocked vents or c) prolonged high dissipation e.g. battery discharge testing. The output cannot be switched on again until a safe temperature is regained.
35 RE1 overload.
36 RE1-RE2 overload.
37 Current overload.
38 Current limit.
39 SI1287 standby.

The SI1287 can generate two types of overloads: measurement overloads and input overloads.

Measurement Overloads are reported when the voltage or current DVMs measure a value which is too large for the measurement range. This means that the overloads can only be reported when measurements are taking place.

The measurement overloads are :

Message	*Error Number*	*Meaning*
Current DVM O/L	Error 31	Readings from the current DVM have exceeded the range.
Voltage DVM O/L	Error 32	Readings from the voltage DVM have exceeded the range.
Both DVM O/L	Error 33	Readings from the voltage and current DVMs have exceeded their respective ranges.

Measurement overloads are reported in the following ways :

Display	*Message flashes on the display and the error beeper sounds (if enabled).*
GPIB	The error number appears in the output next to the result. (Note : The error bit in the serial poll register is NOT set, although the error can still be queried using the ?ER command.)
RS423	The error number appears in the output next to the result.

Input Overloads are detected by comparators in the instrument hardware and can be reported at any time provided the appropriate input is enabled internally (SI1287 in half-standby or ON). This ensures the instrument can report situations which may be damaging to the test cell even if measurements are not being taken.

The input overloads are :

Message	*Error Number*	*Meaning*
RE1 O/L	Error 35	Voltage on RE1 input exceeds a nominal 15.4V.
RE1-RE2 O/L	Error 36	Voltage between RE1 and RE2 exceeds a nominal 15.4V.
Current O/L	Error 37	Current into the WE terminal has exceeded the range selected by the sense resistor.
Current Limit	Error 38	Current into the WE terminal has exceeded the range selected by the sense resistor and the SI1287 is limiting the current.
SI1287 Standby	Error 39	Current into the WE terminal has exceeded the range selected by the sense resistor and the SI1287 has gone into standby.

Input overloads are reported in the following ways :

Display *Message flashes on the display and the error beeper sounds (if enabled).*

GPIB The error bit in the serial poll register is set. The SI1287 must be queried with "?ER" to establish the type of error.

RS423 If the RS423 is being used for output only, then these errors are not reported. If any commands have been sent via the RS423 then the error messages are sent to the RS423.

1.5 GROUP 4 : File Errors

44 File empty.
45 Illegal file access. Not allowed while the analyzer is running.
46 Illegal file size entry.
47 File position out of bounds.

1.6 GROUP 5 : Run-Time Errors

51 Commands not allowed during sweep.
52 Measurement rate not achievable in sync. sweep.
53 Null evaluation not performed or completed.

1.7 GROUP 6 : Illegal I/O Manipulation

61 Attempt to change operating conditions from a non-enabled I/O device.

1.8 GROUP 9 : Calibration Errors

91 Commands not allowed if not in calibration mode.
92 Offsets or multipliers out of range.
93 Calibration constants in error; recalibration recommended.
94 Calibration constants in error; recalibration necessary.
95 Calibration constants in error; Unit now totally uncalibrated.

Appendix C
SI1287 Specification

Section		*Page*
1	**SI1287 Specification**	C.3
1.1	Measurement Configuration	C.3
1.2	Polarisation	C.3
1.3	Digital Meters	C.4
1.4	Impedance Measurement	C.4
1.5	IR Compensation and Real Part Measurement	C.4
1.6	Bias Rejection	C.5
1.7	Interface	C.5
1.8	General	C.5
1.9	Ordering Information	C.6

1 SI1287 SPECIFICATION

1.1 MEASUREMENT CONFIGURATION

Cell connections	2, 3 or 4 Terminal, all floating
Working electrode	
current measurement resistor (R_s) range	0.1Ω to 1MΩ
full scale current ranges	2A to 200nA
limit of error	0.1%±0.05% of range
Counter electrode	
output voltage, wrt LO	>±30V
current, subject to thermal protection limits	2A
slew rate, potentiostatic control	>10V/µs
output short-circuit protected	
Reference electrodes	
input impedance	>10GΩ
capacitance	50pF
current	<1nA
limit of error	0.1%±100µV
rejection, f<10kHz:	75dB
f<1MHz:	40dB

1.2 POLARISATION

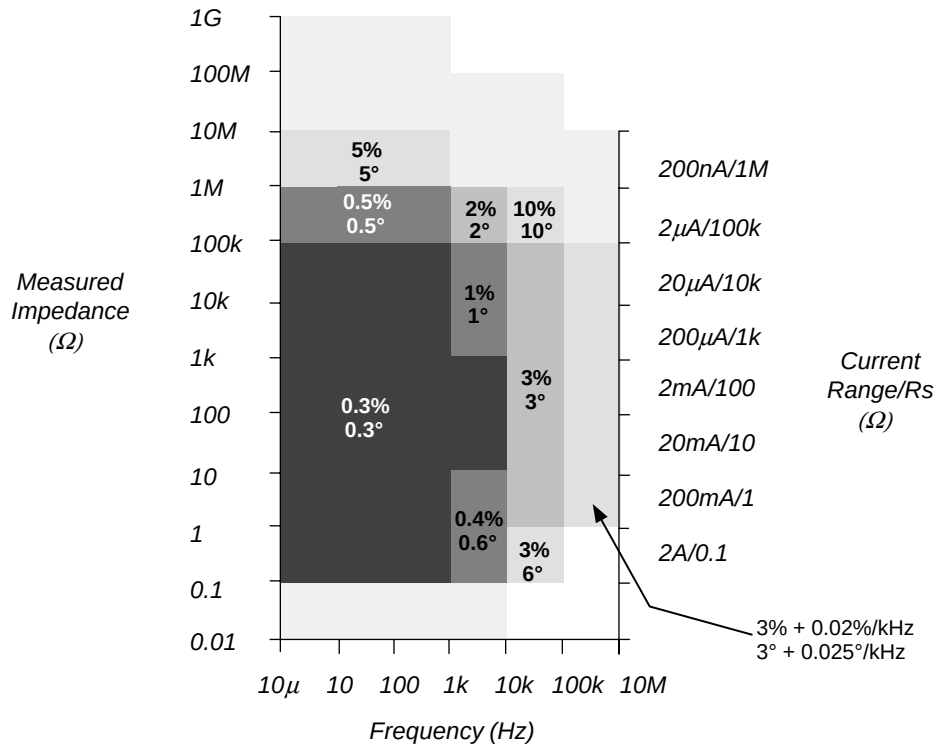
DC polarisation	
voltage range	±14.5V
limits of error V<3.2V	0.2%±200µV
V>3.2V	0.2%±2mV
maximum resolution	100µV
current range	±2A
limit of error	0.2%±0.1% of range
maximum resolution	100pA
DC sweep : analogue ramp	
ramp rate (voltage)	6mV/min to 6000V/min
minimum segment duration	10ms
maximum segment duration	10^5s
DC sweep : stepped ramp	
minimum step height	5µV/5pA
maximum step height	29V/4A
minimum step duration	10ms
maximum step duration	10^5s
AC input	
voltage range	±10V
gain	×1, ×0.01
impedance	10kΩ
Control Loop Bandwidth, 100Ω resistive load, unity gain	
potentiostatic mode, type C stabilility:	>1MHz
galvanostatic mode, type B stability:	>100kHz

1.3 DIGITAL METERS

Resolution	3½, 4½, 5½ digits
Accuracy (null in use),	
voltage (3½ digits)	0.05% rdg + 0.25% f.s.
voltage (4½ digits)	0.05% rdg + 0.025% f.s.
voltage (5½ digits)	0.05% rdg + 0.0025% f.s.
maximum resolution	1µV
current (3½ digits)	0.1% rdg + 0.25% f.s.
current (4½ digits)	0.1% rdg + 0.025% f.s.
current (5½ digits)	0.1% rdg + 0.0025% f.s.
maximum resolution	1pA

1.4 IMPEDANCE MEASUREMENT

Limits of error (for a unity gain cell, $Z_c=R_S$, measured with LO grounded) and no error due to reference electrode bandwidth. RE1 and RE2 input capacitance must be corrected to obtain accuracy at high frequency and impedance.



1.5 IR COMPENSATION AND REAL PART CORRECTION

Current interruption	
interruption time	26.6µs to 1.36ms
accuracy	±6µs
off:on range	1:1 to 1:255
Feedback compensation and real part correction	
range	0 to 1000%R_s
resolution	1%R_s
limit of error	
f<1kHz	0.2%±1%R_s ,0.2°
f<10kHz	2%±1%R_s ,2°

1.6 BIAS REJECTION

Voltage, range	±14.5V
limit of error	0.2%±10mV
resolution	5mV
Current, ranges (full scale)	200nA to 2A
limit of error	0.2%±1% of range
resolution	1% of range

1.7 INTERFACE

Serial Port	RS-423
Suitable for use with printers, display units and keyboards compatible with RS423 and RS232.	
Baud Rate	110 to 9600
Parallel port	IEEE 488 (1978)
Fully programmable talker/listener switch selectable talk only	
maximum data rate:	1kbyte/s

1.8 GENERAL

Power supply, Switch selectable	90-110V,108-132V,198-242v,216-264V 48 to 65Hz
Consumption	150VA
Temperature	
operating	0 to 50°C (32 to 122°F)
storage	-30 to 70°C (-22 to 158°F)
specification limits	10 to 30°C (50 to 86°F)
Humidity, non condensing	95% @40°C
Safety	
complies with	IEC 1010
Electromagnetic Compatibility	
complies with	EN50081-1 & EN50082-1

Note: The following additional errors apply to all voltage and current measurements and results derived from them when the instrument is subjected to high levels of radiated or conducted radiofrequency interference as defined in EN50082-1:

Voltage Measurement: additional offset error ± 10mV
Current Measurement: additional offset error ± 100µA

Dimensions	
height	108mm (4.25ins)
width	432mm (17ins)
depth	472mm (18.5ins)
weight	11kg (24lbs)

1.9 ORDERING INFORMATION

SI1287 Advanced Electrochemical Interface

Accessories included:

	12861 Test Module
	User Guide
	Power Cord
	Spare Fuses
	4 Leads, 1m long, BNC to 4mm
	4 Croc. Clips

Options:

Servicing Manual	(12876005)
Rack-mount Ears	(12862010X)
Slide-mount Bars	(12862022A)

SI1287 User Guide
Index

A

Accessories, A.7
AC Supply, A.5
AC Supply Voltage, A.3
Application Software, 1.7
Averaging, 3.19

B

Bandwidth, 3.13
  Control Loop Selection, 3.13
  Limit, 3.30
Baud Rate, 4.4
Bias Rejection, 3.31, C.5
  Current, 3.15
  Voltage, 3.15
Break, 3.34

C

Capability Codes (GPIB), 4.5
Cell Measurement System, 5.4
Condition, 3.15
Consumption, C.5

D

Data Output, 2.11, 3.28
Dimensions, C.5
Display
  selecting of, 2.14
  using of, 2.14
Drift Correct, 3.19
DVM, 1.5, 2.10, 3.17, C.4
DVM RUN, 3.31

E

Electrochemical Cell, 2.5
Electromagnetic Compatibility, C.5
EMC, A.7
Enviromental Information, A.7
Equipment Modification, A.4
Error Codes, B.3
Explosive Atmospheres, A.4
External Connections, 2.5, 2.7

F

File, 3.34
Floating Point Format, 4.15
Further Reading, 1.7
Fuses, A.3, A.7

G

Galvanostatic Cell Drive, 3.30
GPIB, 3.28, 4.5, C.5
  Connector, 4.5
  Output Separator, 3.28, 4.16
  Output Terminator, 3.28, 4.16
  Parallel Poll, 3.28, 4.8
  Plotting, 4.9
  Serial Poll, 3.28, 4.8
    setting up a service request, 4.8
  Switches, 4.6
Grounding, A.3
Grounding Working Electrodes, 2.5

H

Hardware Connections, 5.4
Humidity, C.5

I

Impedance Measurement, C.4
Initialisation, 2.4, 2.8
Input Overloads, B.4
Instrument Siting, A.7
IR Compensation, 3.9, 3.30
I Measure, 3.5

L

Live Conductors, A.4
Local Control, 3.32

Local Lock-out, 4.12
Low Pass Filter, 3.15

M

Measurement
  Current, 1.5, 2.8
  Voltage, 1.5
Measurement Configuration, C.3
Measurement Overloads, B.4
Menu Summary, 3.36
Modes of Operation
  Normal Mode, 2.4
  Number Entry Mode, 2.4
  Parameter Set-up Mode, 2.4

N

Null, 3.20

O

On/Standby, 3.30
Operating Temperature, C.5
Ordering Information, C.6
Output Format, 4.13
  GPIB, 4.13
  RS423, 4.13

P

Parameter Settings
  AC Sweep, 5.5
Plot, 2.12, 3.25, 3.33
Plotting Sweeps, 2.12
Polarization, 3.8, C.3
  Current, 3.8
  Input, 3.8
  Voltage, 3.8
Polarization Control, 1.5
Potentionstatic Cell Drive, 3.30
Power Cable, A.6
Power Restored, 2.4
Power Up, 2.4

R

Rack Mounting, A.8
Real Part Correction, 3.12, 3.30
Remote Commands, 4.17
Remote/Local Facility, 4.10
Reset, 2.4
RS423, 3.28, 4.4, C.5
  connection details, 4.4
  Settings, 4.4

S

Safety Precautions, A.3, after title page
Safety Symbols, A.4
Schematic, 1.4
Self Test, 3.34
Service Request, 4.8
Setting Parameters, 2.7, 2.8
Specifications, C.3
Status, 3.34
Status Byte, 4.7
Stepped Sweep, 3.24
Storage Temperature, C.5
Store/Recall, 3.31
Structure, 1.3
Sweep, 2.10, 3.21, 3.33

T

Test Module, 2.7, 5.3
Time
  setting of, 3.35
Time/Step Values, 3.24
Trigger, 3.18

V

Ventilation, A.7
Voltage Selector, A.5
  Settings, A.5

W

Warning Codes, B.3

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