Twickenham
Scientific Instruments

The Superconducting Magnet Controller (SMC)

Dual 60 A output variant

Instruction manual, release M1.4

Twickenham Scientific Instruments Ltd. Registered in England No 2991094
Registered Office: 61d St Margaret's Road, Twickenham, Middlesex, TW1 2LL, UK
Telephone +44 20 8892 7400; *Fax* +44 20 8892 7436; *Email* sales@twicksci.co.uk

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Contents

In this manual, different typefaces have been used to highlight specific details. Following is a list of the special typefaces used.

Text in this typeface refers to the front panel button, e.g. Heater, or a connector on the back panel; the word on the unit is also written in slanted text.

Text in this typeface is describing a message on the display

`Text in this typeface is describing a message available via the computer interface.`

Operating Precautions.

Superconducting magnet coils can have a substantial inductance and large energy storage capacity. To ensure safe operation, the leads from the power supply must be rigidly and permanently attached to the magnet. When the coil is energised the power supply must not be removed unless a suitable safety circuit has been fitted to the magnet. Any such safety circuit must be capable of absorbing the energy stored in the coil and prevent the occurrence of dangerous voltages at the magnet terminals or between magnet terminals and earth.

Serious damage to the power supply can only occur if a reverse current flow is forced through the unit. Under these conditions a very large voltage can be developed at the output terminals. If there is any possibility of such a condition arising, the power supply should be further protected with an external thyristor circuit available from Twickenham Scientific Instruments Ltd.

The unit must not be operated with any of the covers removed.

The seller shall not, under any circumstances, be liable
for any loss, damage or injury resulting from the
misuse of this equipment.

General Description.

The Twickenham range of Superconducting Magnet Controllers (SMC) provide a number of output current and drive voltage options. All models are based on the same fundamental design which has been specifically conceived for energising superconducting magnets. The frequency response of the double-stabilised analogue control loop, which operates in either voltage or current control modes, is tailored to ensure stability even when driving a purely inductive load. The switch mode power unit and the analogue output stage are both forced-air cooled.

The dual output variants incorporate two such systems in one case, one for each output, but share the front panel control and RS232 port.

The power supply incorporates a sophisticated microprocessor unit, with all operations controlled through the internal firmware. This provides great flexibility to respond to special requirements and for the evolution of high levels of 'intelligent' control. All operating functions are available either locally at the front panel or remotely via a standard digital interface.

Front panel control is via twelve push-button switches. Status indication is via an 80 character backlit alphanumeric liquid crystal display and eight LED indicators on the switches. Remote control is possible using the RS232 interface.

Adjustable parameters are held in a non-volatile memory. Configurations are therefore retained between runs but changes, to suit a different magnet system or a different mode of operation, are easily made by the user.

Two adjustable target current settings are available. Target currents can be set to 16-bit resolution (0.0015% of full output). The two set points are mutually limiting, such that the Upper point can never be set to less than a Lower point. These adjustable settings are in addition to the fixed zero target point and the arbitrary ramp pause facility.

A digital ramp generator, under software control, drives high stability sweep control circuitry. Any one of 65 preset ramp rates may be selected. The ramp can be halted indefinitely with a temperature related drift no greater than 15 ppm/°C or better.

An adjustable voltage limit controls both the positive (ramping up) and negative (ramping down) voltages. Voltage limiting overrides the ramp generator if necessary. The voltage limit can be set to a resolution of approximately 0.1 V.

The voltage limiting circuit can operate from an optional sense input. This enables voltage control directly from the magnet terminals to eliminate voltage drops in the connecting leads. When the sense input is connected, control from the power supply terminal voltage is automatically overridden. This feature is not available for units using the ECS reversing switch.

A passive voltage limiting circuit across the output stage provides quench protection even when no power is applied to the unit, allowing the magnet to discharge through the power supply circuit with the terminal voltage clamped to a safe level.

The reference current shunts are manufactured from a low temperature coefficient alloy (10 ppm/°C over the range 15 – 40°C or better). For precision monitoring of the output current, the shunt voltages is available at the 'DVM' outputs on the rear panel. The outputs are unbuffered for the single unit models. A calibration for the DVM output to 0.03% accuracy is marked on each individual power supply.

Preparing the unit for use

It is recommended that the packaging materials be retained as they serve as useful protection for possible future transportation of the unit.

A mains lead is supplied. The other end of this lead should be fitted to the available AC power line. Where appropriate, a lead with a moulded plug is supplied. If such a lead is not available, or suitable, the colour codes used in the lead are: Brown = Live, Blue = Neutral, Green/Yellow = Earth. Check that the input voltage rating matches the supply to which it is to be connected.

The output terminals are a 2 pin screw locking type, one set for each output. The mating connectors are supplied, and should be connected to suitable cables.

The power supply is designed to drive inductors with low DC series resistance. To enable a short circuit test to be performed, the far ends of the current leads should be bolted together. If an attempt is made to run the supply with open circuit terminals, no damage will result.

Before switching on the power supply, ensure that there is a minimum of 150 mm clear space behind the unit to allow a free flow of air, and that the side ventilation holes are unobstructed. When mains power is applied, check that, after the self checking messages, the sign-on message is written to the display, that the *Zero* indicator (only) is on, and that the cooling fans are delivering a strong flow of air to the back of the unit.

Rear Panel Connections.

Mains Input

This is an IEC CEE22 socket for connection to mains supply. Supply requirements are shown on the rear panel:

200–255 Volt 50/60 Hz, 8 Amp max.

Overall power line protection is provided by a circuit breaker integrated into the front panel power switch. This physically trips the switch to the off position if the input current exceeds 6 Amps. In addition, the main power unit, electronics power supply and the fan drive are protected by individual fuses.

A Output B

Two pairs of M12 bolts for to the two loads.

The recommended torque when fitting the leads to the terminal studs is 3–5 lbft or 4–7 Nm. This ensures a good contact without over stressing the terminal studs. Always hold the cable tags when tightening to ensure that the terminal blocks do not twist.

– DVM + (two sets, for channels A and B)

Two sets of 4 mm jack sockets for connection to external DVM. This provides direct reading of shunt voltage at 600 ohm source impedance A calibration for this output is marked on the rear panel.

RS232 Interface

A standard 9 way D type connector is fitted for remote control via the RS232 interface. The interface is optically isolated from the power supply output.

Local operation of the SMC

Front Panel Controls and Indicators

The front panel carries an illuminated main on/off switch (with integral circuit breaker), a 4 line by 20 character backlit liquid crystal display, and 12 engraved push-buttons (7 of which have LED status indicators). The push-buttons are arranged in a numeric keypad, and are therefore engraved with the numerals 0 - 9, decimal point and ENTER. Around the keys, the panel silkscreen shows the main function of these keys.

Reading from the top, and working clockwise, the main function of these keys are as follows:

Heater (L)	No function for this variant.
Up	Adjusts parameter values upwards.
Set	Selects parameters for adjustment.
Down	Adjusts parameter values downwards.
Remote/ENTER (LL)	Switches between remote and local control (see section 5).
Units (L)	No function for this variant.
Pause (L)	Suspends and releases ramp generation.
Zero (L)	Selects Zero Amps as the ramping target.
Lower (L)	Selects the Lower set point as the ramping target.
Upper (L)	Selects the Upper set point as the ramping target.

Buttons marked (L) have inbuilt red LEDs and are illuminated when active.

The button engraved 2 is used to select the foreground channel; pressing 2, holding in, and then pressing *Remote*/ENTER will toggle between the two channels, with a press selecting the current background channel to become the foreground. When this happens, the asterixes around the channel letter on the front panel display will change to be around the new foreground channel.

The button engraved 5 has no other function.

The *Remote*/ENTER button has a second, green, LED. This green LED lights up when the *Remote*/ENTER button is used to select the numeric keypad function.

Operation of two operational units from one system

The dual output units have separate control systems, but from necessity share some common features, in hardware and software. In order to make a description practical, the two channels are labelled A and B, and they have equal standing within the system as a whole.

For the purpose of operation, one channel is brought to the fore, i.e. is the foreground channel, and to which operations can be performed at that moment. The other channel is the background, continuing whatever task may have been assigned to it when last it was the foreground channel. Throughout this manual, the channels themselves will be referred to as 'A' and 'B', while in describing modes of operation, the term 'foreground' will refer to whichever channel is currently the active one as regards to operation, parameter changes etc; 'background' will refer to the other one.

The upper two lines on the front panel display show the output current and terminal voltage of channels A and B, with the letter identifying that channel in the centre of the appropriate line. The foreground channel is identified by the channel identification letter (A or B) having an * character either side of it.

The lower two lines will always refer to the foreground channel, in describing parameters, or displaying messages as to the current status of the unit; while the background channel will only have it's one line of the output current and terminal voltage on the display at any time.

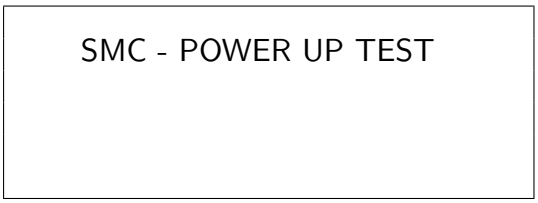
Similarly, the LEDs in the switches will indicate the status for the foreground channel, so the pattern of lit LEDs will change when the foreground and background channels are swapped around, if the two channels are performing different tasks.

Where a parameter has equal effect on both channels, due to the hardware or the firmware, it will be referred to as 'universal', to distinguish it from a parameter that can be set independently for each channel. However, the ramp rate is a 'universal' parameter when set from the front panel, that is changing the ramp rate via the front panel imposes that value for both channels; but these can be set independently for each of the two channels using the interface.

A channel may be brought to the fore from either the front panel controls or via the interface. When this occurs the * characters which are either side of the channel identifier will move to the other channel identifier on the other line of the display; at the same time, the bottom two lines of the display will change to those appropriate for this channel, and for whatever action it may be undertaking at that time; and the LEDs in the switches will change to their appropriate pattern for that action.

Power Up Conditions

When the unit is first switched on, a number of power-up checks are performed. While these are being done, the display shows



If these are all successful, the second line will show the model number of the unit, and the third line will show the version number of the controller firmware.

Shortly afterwards, the top two lines of the display will show the terminal current on the left, and terminal voltage on the right, the top line for channel A (which is indicated as being the foreground channel by having the * character either side of it); the second line for channel B.

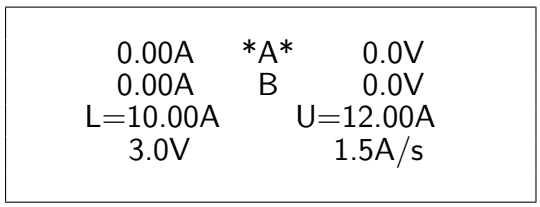
Power-up defaults are foreground channel A, *Zero* selected and *Pause* off for both channels.

Any other message on the display at power-up indicates that one of the initialisation checks failed (these messages are shown in Appendix 2). If a fault message appears, the unit will be inoperable. If the message is NOVRAM STORAGE FAULT Press "SET" & "UP", see Appendix 3 for recovery information. Otherwise please contact Twickenham Scientific Instruments Ltd. for advice if any of the fault messages are seen.

Quiescent Status

When the SMC is switched on, the bottom two lines remain blank.

If a button is pressed, then the bottom two lines will show the four important parameters; the *Zero* button is convenient to use as it is already active and will have no other effect.



Typical Quiescent Status Display

The lower two display lines will then show the three universal parameter settings, and the *Lower* set point for the foreground channel. The display shown above is a typical Quiescent status layout. On the third line down are then shown the (foreground) Lower set point value and the (universal) Upper set point value. On the bottom line the universal voltage limit value and ramp rate values are shown. These parameter values will be as on the previous power-down. Note that only the Lower set point value can be independantly set for each channel via the front panel, the other three 'universal' parameters being applicable for both channels (unless the ramp rates have been previously been set independently via the interface).

The** Set**, Up**, and** Down **Buttons

The four parameters shown in the normal quiescent status message may be changed by simple operation of the *Set* button, together with *Up* and *Down*. The first press of *Set* will enter the 'set mode' and bring the setting message for the last accessed parameter to the lower display line. Further presses of *Set* will cycle through the three universal primary parameters, and the *Lower* set point for the foreground channel. When the message for the required parameter has been selected in this manner, the *Up* and *Down* buttons may be used to change the value.

A single short press of *Up* or *Down* will change the value by the standard step size. Holding the button in will, after a short delay, cause the value to auto-step. The changed value is not entered into the controller until the button is released. When the new value is entered, it comes into immediate effect to change any active or pending operation.

There are two methods available to prevent the entry of an incorrect value. Firstly, if both the *Up* and *Down* buttons are pressed simultaneously, stepping will halt. This

provides a means of changing the stepping direction without entry of the intermediate value. Secondly, if *Set* is pressed simultaneously with either *Up* or *Down*, the parameter will return to its starting (last entered) value to cancel all previous stepping. These facilities are only of importance if settings are being changed while the power supply is in active operation.

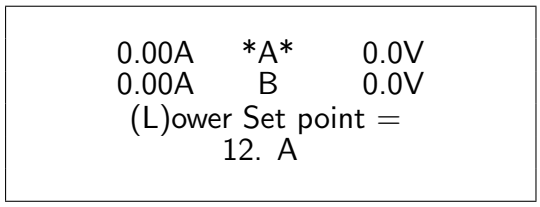
The standard step sizes are 0.1 A for the *Lower* and *Upper* set points, and 0.1 V for the voltage limit. The ramp rate is stepped in a logarithmic fashion at 16 steps per decade.

For a finer setting of the *Lower* and *Upper* set points, or if a large change is required in these parameters, is it more suitable to use the numeric keypad to alter the values. The numeric keypad can also be used to set the voltage limit and the output of the persistent mode switch heater supply.

Set mode may be entered at any time during operation of the power supply. When *Set* is pressed, the setting messages replace any other messages on the lower display line. With no activity on the setting buttons (*Set*, *Up* or *Down*), the lower line will revert to the normal display after 10 seconds. Set mode will also be cancelled by operation of any of the non-setting buttons. Pressing of the currently active ramp selector button (*Zero*, *Lower* or *Upper*) will therefore force restoration of the normal display before the setting time-out with no other effect.

Setting the parameters with the Numeric keypad

If a finer setting of a parameter is required, or else a large change needs to be made, then the numeric keypad can be used. The parameter to be changed is called up on the lower two lines as described in the previous section. Instead of altering the parameter with the *Up* and *Down* buttons, the ENTER/*Remote* key is pressed. The green LED will light up, and while this LED is lit, all the buttons have the function that is engraved on the buttons, i.e. entering of a numeral. The bottom line of the display will also change, with the current numerical value of the parameter shown being replaced by 0.



Typical Set Mode Display using Numeric key functions
(part way through this operation)

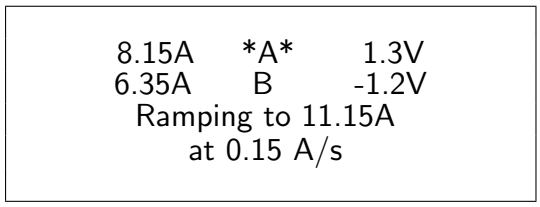
The value of the parameter is entered in the same way as a number is entered into a calculator with one exception. If the value entered is wrong, for whatever reason, then the way to clear the number to start again (the Clear Entry function of a calculator) is to ensure the decimal point is pressed for a **second** time. If the decimal point has not been pressed at all during this entry, it will need to be pressed twice; if the decimals were already being entered when the error was spotted, then the decimal point only needs to be pressed once more.

Note that it is the number as shown on the display that will be entered when leaving the numeric keypad function; if nothing has been entered when the numeric keypad was active, then that parameter will be set to zero, unless other factors as discussed put a lower limit on the value (for example the *Upper* set point value).

Once the value is entered, the ENTER/*Remote* key is pressed again. The green LED will go out, and all the buttons will return to their normal functional state. The display will return to the initial 'Set mode' display, with the new value showing, subject to any limits on the value entered. If the value entered is greater than that possible, it will be substituted for the maximum possible value when returning to the 'Set mode' display.

The** Zero**,** Lower **and** Upper **Buttons

A ramp from zero is initiated by pressing the *Lower* or *Upper* button. The *Zero*, *Lower* and *Upper* buttons are interlocked, with the currently selected target being shown by the appropriate LED indicator. While ramping to one of these target settings, the lower two display lines will show the target current and the ramp rate.



Typical Active Ramp Display

If the selected ramp rate causes the terminal (or sense) voltage to rise to the set voltage limit, the ..at x.x A/s message will change to the ..at +ve volt limit or at -ve volt limit message as appropriate.

Any changes to the set points, voltage limit or ramp rate will have an immediate effect on any active or pending ramp, and so may cause the Ramping.. message to be changed (when this is returned to the display after the setting operation). The message will also be changed if a different ramp target is selected before the ramp has completed. When the power supply is holding on a target (other than zero) and the value of that set point is changed, this will re-activate ramping and produce a new ramping message on the display (but, again, this will not be seen until set mode is terminated).

The completion (or halting) of a ramp will be indicated by the return of the quiescent status message to the display (this is normally the four parameter values).

The** Pause **Button

A ramp may be halted before the selected target has been reached by use of the *Pause* button. *Pause* alternately enables and disables the ramp generator, with the indicator being illuminated when ramping is disabled (i.e. *Pause* on). Any Ramping.. message will disappear from the display, as if the ramp had completed.

When *Pause* is on, the ramping target may be reselected and/or parameters adjusted with no effect until the *Pause* is released. When *Pause* is switched off, the Ramping.. message will reappear on the display (if appropriate).

The digitally implemented *Pause* function has excellent long-term stability, equivalent to that achieved when holding normally on a set target current. However, the *Pause* will not provide an instantaneous holding of the magnetic field value, or necessarily of the displayed output current on the front panel, for reasons such as magnetic induction, time constants within the SMC and the external circuit etc.

The** Remote **Button

The *Remote* button will not normally be used, as switching between remote and local control modes is performed automatically via interface signals (pressing this button when the interface is not being driven will have no effect). The red LED on this button indicates the current mode. If the LED is on, control is from the interface and none of the other buttons will be operative.

However, if remote control is selected without being locked, the *Remote* button may be pressed to seize local control temporarily. The red LED will turn off and the other buttons will be operable. As long as the remote device maintains the nominal remote enabled state, the *Remote* button may be pressed again to return control to the remote device. The remote device may issue a command to prevent this use of the *Remote* button (locking ALL buttons, instead of all buttons except *Remote*).

Do not confuse the red LED in the *Remote*/ENTER button, indicating remote control with or without full local lock-out of all other buttons, with the green LED within the same button, which is only accessible when in Set mode and local control, and indicates the numeric keypad function of all the buttons. Note that either the red, or the green LED, on, or neither of them on, are valid states.

Similarly, do not confuse the function of this button of *Remote*, ENTER, and, with the use of the 2 button, it's use in selecting the foreground channel.

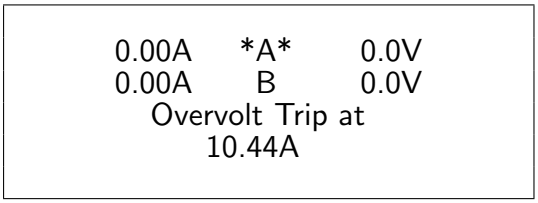
Reporting of external events and problems during the normal operation of the SMC

Introduction

There are a number of events that could occur during the normal operation of the SMC unit, to which The response of the SMC to these events is to protect itself, and to go into a 'shut-down' mode; specific action by the user must be performed before the SMC can be restored to normal operation again.

The Overvoltage Trip

The Overvoltage Trip is a condition brought on by non-intentional external events, that issignificant difference is thatincreasing negative voltage across the terminals of the SMC. The power supply must be reset by switching off and on again after the trip.



Typical 'Overvoltage Trip' Event Display

The Overtemperature Trip

When de-energising a superconducting magnet, the stored energy is dissipated from the internal energy absorber as heat, which exhausts from the rear of the unit. If, for this or any other reason, the temperature of the energy absorber gets close to exceeding safe working limits, a built in heat switch opens, which will generate the Overtemperature Trip.

When this occurs, the SMC unit will short out the output terminals so as to continue to run down the magnet, and otherwise shut down. On the display, the Overtemperature Trip message will be seen.

This condition cannot be cancelled until the internal energy absorber has cooled down sufficiently.

It should be stressed that this is a rare event, only likely to happen in four circumstances:

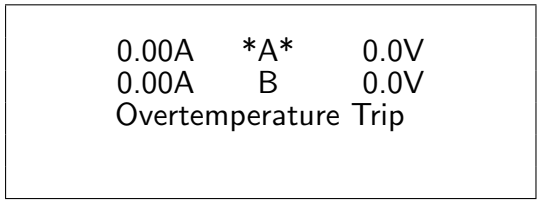
1 If the SMC has been installed into a cabinet with insufficient ventilation and/or external cooling, under the circumstances described above, all the heat is held within the cabinet. This raises the local ambient temperature around the SMC unit to beyond is rated maximum (40°C), and hence the temperature of the energy

absorber will rise accordingly and exceed its maximum. The cure for this is to ensure sufficient ventilation around the SMC unit.

2 The ventilation holes in the side panels and in the back panel have become covered or blocked. It is simple to ensure that all the ventilation holes are clear.

3 The cooling fan for the energy absorber has become ineffective or has failed. The air flow from the fan can be felt at the back of the SMC unit, with the air blowing through the obvious heat sink assembly. If no air flow can be detected, do not use the unit until further checks have been made.

4 With a high output voltage model of the SMC (for example the SMC80-20 and its multiples) when trying to de-energise a very large magnet faster than the recommended maximum rate when not situated in a free-airflow environment. The cure for this is to de-energise the magnet at a slower rate.



The Overtemperature Trip Display

Remote operation of the SMC.

Concept

The remote interface concept is one of 'Speak only when asked' and brief mnemonics as commands. Commands and responses are restricted to printable ASCII characters. Where a response is sent from the instrument then strings are kept to defined lengths to simplify the control software. The baud rate of serial port interfaces can be selected using the SETUP procedure from the front panel buttons.

The interface will interpret commands which are equivalent to operating the front panel buttons. In addition there are commands that will cause the instrument to send status reports over the interface. Strings returned after these commands are made up of the read back of a number of alpha commands followed by the numeral they are currently set to; this is to aid readability. The strings are terminated by <CR><LF> (0Ah, 0Dh).

There are a number of points to be aware of in the operation of the interface.

1. Leading zeros are optional on received data but are always included on responses.
2. If a command that requires a numeric argument is transmitted without an argument then it is assumed to be zero.
3. Commands which change any of the SMC internal parameters will take immediate effect. These are indicated in the tables following.
4. Concatenation of commands will be ignored; only the first will be acted upon.

Description of the Command set

Operation of Foreground and Background channels of the SMC

For the dual output SMC units, some parameters are common to both channels, while other parameters set specifically the foreground channel only (whichever one has currently been selected to be the foreground). The ramp rate is the exception, this can be set, *via the interface only*, for each channel independently and at any time, whether or not that channel is the foreground channel. This means that there are two values for some parameters within the unit as a whole, one for each channel.

In a similar way to the front panel 2 and *Remote*/ENTER is used to toggle whether channel A or B is in the foreground, the single character `@` sent via the interface will perform the same function; consequently, the channel indicator on the front panel display will move the highlight the foreground channel, and either via the interface or the front panel controls, the actions for that channel will be indicated by the bottom two lines of the display. This command will not generate a response from the SMC.

Alternatively, sending the `@` command with an arguement, `A` or `B` will force the selected channel to become the foreground channel. Again, this will not generate a response from the SMC.

Commands with arguments

Commands with arguments are mostly those that change an internal parameter, either one that would normally be used in an initial set–up of the SMC, or one that is frequently used, for example the value of the *Lower* set point. A command consists of an alpha character followed by a number of numeral characters. The alpha characters define the command, and the numeral characters define the argument. There are four types of argument, which depend upon the structure of the command:

1 Simple commands, such as those that operate in the same way as the front panel controls, take a single numeral character argument. The single numeral value then represents which mode is being selected. For example, the command `P1` selects the Pause status on.

2 Parameter commands, many of which are usually set on initial set-up only, take a multiple numeral character argument. The number thus formed is the same as that which would be entered in any of the set menus selected via the front panel controls. For example, the command `L10.000` sets the *Lower* set point to 10.000 in Amps.

3 Channel changing command. This is the `@` command, when followed by the alpha character `A` or `B`, and is used to force that channel of the SMC unit to be the foreground channel.

4 Ramp rate command. The simple ramp rate command, Ann.nnnn will set the ramp rate for both channels, just like setting via the front panel. However, the two character commands, AAnn.nnnn and ABnn.nnnn will set the ramp rate for the two channels independently.

Commands without arguments

Commands without arguments are those which generate a response from the SMC. The exception is the `@` (without an arguement) command. A single such command will generate a string which contains the current values of a number of parameters, prefixed by either the command code which is used to set that parameter, or an identification single alpha character code, for ease of identification.

For example, the command `A` is used to set the current Ramp rate (common for both channels). The command `O` returns a string which includes, as the first parameter in the string, the entered ramp rate factor, prefixed by the alpha character `A`.

Each string that is returned from the SMC always have the same defined length, that is the same number of characters. All parameters are prefixed by a single alpha character.

Three commands have the characters `A` and `B` in strategic parts of the string, to indicate which parts of the returned string refer to channel A only, and which to channel B. These are in fixed places in the strings, and should not be confused with the commands `A` and `B`, and nor with the suffix `A` on the string to the `G` command, to indicate the type of ramp generation. Where the `A` and `B` are used for channel identification, the parameters that follow the `A` in the string are repeated after the `B`, altough, of course, the arguements may be different.

For example, the `K` command returns the string `ARnMnPnEnnnBRnMnPnEnnn`. In this case, the first character `A` refers to the channel A, and the parameters `RnMnPnEnnn` refer to channel A only; then the `B` indicates channel B, and the parameters after it refer to channel B only.

There are two 'dual' commands, `GG` and `OO`, which report the parameters in an analogous manner to the commands `G` and `O` commands, but with the two channels independently reported within the string. It is necessary to use these two 'dual' commands when the ramp rates have been set independantly for the two channels.

Returned characters with no command function

There are some alpha characters which appear in returned strings from the SMC, but do not appear in the command list. These alpha characters are used to identify the particular parameter which is being returned within the whole string.

Special considerations for command parameters

In the following, the character 'n' refers to a numeral character between 0 and 9, but may be restricted in range in some cases. The character 's' refers to the characters '+' or '–'. Some parameters change the location of the decimal point between the 40 A and 60 A variants; for example `Lnn.nnnn` and `Lnnn.nnn` respectively. The tables below show only the 60 A variant.

All of the commands are also listed in tables 5.4 to 5.6.

Simple Commands

The following commands take the single numeral 0 or 1 as an argument:

`Bn` Lock out of front panel;
`Pn` Pause ramp generator;
`Dn` Direction; 0 = Forward, 1 = Reverse.

The command `Dn` (Direction) is only effective if the ECS reversing switch option is connected, otherwise it has no effect. Without the ECS unit connected, it will always be reported back as `D0`. Although the Direction command is set and read back using the numerals 0 or 1, the effect of the command on the direction of current flow or magnetic field is shown by the '+' and '–' characters.

The `Rn` Ramp to target command takes the single numeral 0, 1 or 2 as an argument, for target = *Zero*, *Lower* and *Upper* respectively.

Parameter setting commands

The following commands take a string of numerals as an argument, and sets the internal parameter to that value. If no string follows the command, then it is ignored. If the numeral after the command is beyond a limit, the parameter will be set to that limit unless indicated below.

`Ann.nnnnn` Ramp rate, set in Amps per second, and internally rounded to the nearest value of the 65 preset values.

Its two variants, to set the ramp rates for the two channels independently are:

`AAnn.nnnn` for channel A and

`ABnn.nnnn` for channel B.

`Ynn.n` Sets the maximum terminal voltage of the SMC. Depending on which model of SMC is selected, there is a specific maximum value which will be selected if a greater value is entered.

`Lnnn.nnn` Sets the Lower set point to nnn.nnn A

`Unnn.nnn` Sets the Upper set point to nnn.nnn A

Reporting characters with no command function

The following characters are used when reporting back parameters. These are connected with input and output information concerning the SMC unit.

`Ennn` This gives and error code. The three numerals separately indicate type of possible fault, as given in the following table. The first digit refers to ECS reversing switch faults, and is zero if this option is not installed. The second code refers to internal faults in the SMC unit.

The meaning of the first digit is given in table 5.1 below, the meaning of the second digit in table 5.2, and the third in table 5.3.

First digit	Error description
0	No error or option not fitted.
1	Attempt to change direction when either I or V is not zero
2	ECS did not switch correctly
3	ECS not in a valid state

Table 5.1. The meanings of the first digit of the Error code parameter – ECS Reversing switch faults.

Second digit	Error description
0	No error.
4	Brick Trip
5	Heatsink Overtemperature Trip
6	Slave trip
7	Heatsink Overvoltage Trip

Table 5.2. The meanings of the second digit of the Error code parameter – Power unit trip.

`Isnnn.nnn` This gives the output current of the SMC in Amps at the moment the command `G` was issued.

Third digit	Error description
0	No error.

Table 5.3. The meaning of the third digit of the Error code parameter – No error reporting for version 1.0 of the operating firmware.

`Mn` This states whether the ramp generator has made target or not; 0 means not made target, that is the ramp generator is still ramping, and 1 means that the ramp generator has made target. Note that although the ramp generator has made target, various time constants, for instance the inductive lag of the magnet, within the entire system mean that it will take some time for the current in the superconducting magnet to be equal to the set point that has just be ramped to.

`Vsnn.n` This is the terminal voltage of the SMC unit.

Read-back strings

The above should explain the meaning of each of the segments that are used to make up the four possible strings returned by the SMC upon request. There has been some deliberate duplication of the information within these strings, so that the reading of any particular string will not contain any ambiguity.

At the end of the strings generated by the `G` and `GG` commands, there is a single alpha character without an argument. Normally, this will be an `A`, which signifies that the unit will be performing any current ramping at the set Amps per second rate; however, if the character is a `V`, then the unit is ramping at constant voltage, possibly by user choice, indicating that the terminal voltage has reached and been clamped at the voltage limit (either as set or the maximum value).

Command List

Commands that generate no response from the SMC

Mnemonic	Action
`@`	Toggles the foreground channel between channel A and channel B.
`@X`	Selects channel X (either A or B) as the foreground channel.
`Ann.nnnnn`	Sets the common Ramp rate in Amps per second.
`AAnn.nnnn`	Sets only channel A Ramp rate in Amps per second.
`ABnn.nnnn`	Sets only channel B Ramp rate in Amps per second.
`Bn`	Front panel lock-out: 0 = Off, 1 = On.
`Dn`	Sets the reversing switch direction: 0 = Forward, 1 = Reverse (⋆)(†)
`Lnnn.nnn`	Sets the Lower Set point in Amps. (⋆)
`Pn`	Pause: 0 = Off, 1 = On. (⋆)
`Rn`	Sets Ramp Target: 0 = Zero, 1 = Lower, 2 = Upper. (⋆)
`Unnn.nnn`	Sets the Upper Set point in Amps.
`Ynn.n`	Sets the terminal voltage limit to nn.n V.

Table 5.4. The remote interface commands than do not generate a response from the SMC.

† Only operates when ECS option fitted.

⋆ Commands which only affect a parameter of, or the operation of, the foreground channel.

Commands that generate a response from the SMC.

Mnemonic	Response
`G`	Returns the output parameters as `Isnnn.nnnVsnn.nRx[A][V]`. (⋆)
`GG`	Returns the output parameters split by channel as `AIsnnn.nnnVsnn.nRx[A][V]BIsnnn.nnnVsnn.nRx[A][V]`
`K`	Returns the current status as `ARnMnPnEnnnBRnMnPnEnnn`.
`O`	Returns operating parameters as `Ann.nnnnnADnBDnBn`. (⋆)
`OO`	Returns the operating parameters split by channel as `AAnnn.nnnnDnBAnnn.nnnDnBn`
`S`	Returns the set point status as `Unnn.nnnALnnn.nnnBLnnn.nnnYnn.n`.

Table 5.5. The Mnemonics that generate a response from the SMC.

(⋆) The returned string from the `G` and `O` commands depends upon which channel is the foreground channel.

Mnemonics read back from the SMC only.

Mnemonic	Description
`Ennn`	Error code; See tables 5.1 to 5.3.
`Isnnn.nnn`	Output current value (`G`) (⋆)
`Mn`	Whether ramp generator has made target, or ramping. (⋆)
`Vsnn.n`	Terminal voltage of SMC unit.

Table 5.6. The read-back Mnemonics generated by the SMC.

(⋆) The value of this parameter depends upon which channel is the foreground channel at the time the command is sent to the dual output unit.

Standard Product Warranty

All products manufactured by Twickenham Scientific Instruments Ltd. ('the company') are warranted to be free from defects in materials and workmanship for a period of one year after the date of dispatch. At no expense to the purchaser, the company will repair or replace (at our option) any parts which at the sole opinion of the company prove to be defective with the scope of this guarantee. Transportation costs of goods returned to the company for repairs will be prepaid by the purchaser. Goods must not be returned without prior consultation with the company to decide whether an on-site inspection and possible repair should be made. If the defect is determined to be as a result of misuse, improper repair, unauthorised user modification of abnormal operation conditions, then the repairs will be invoiced at cost.

This warranty does not apply to equipment not manufactured by Twickenham Scientific Instruments Ltd., for which the relevant manufacturer's warranty is passed on whenever possible.

General disclaimer

The seller, Twickenham Scientific Instruments Ltd., shall not, under any circumstances, be liable for any loss, damage or injury resulting from the misuse of this equipment.

Display Messages.

Normal Power-up

SMC##+##-## ROM Version M#.#

Faults which lock out further operation:

HALT-SMC FATAL ERROR POWER FAIL INT FAULT

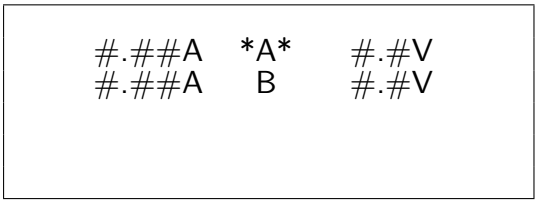
Should the appropriate error occur, the follow messages will appear on the third line instead of the error given above:

ANALOGUE INT FAULT
CONTROLLER FAULT
CONT"LER & ANL FAULT
MULTIPLE ERROR
I2C INTERFACE FAULT
I2C & ANL INT FAULT
I2C & CONT"LER FAULT
GEN SUBSYSTEM FAULT
GEN AUX MEMORY FAULT
AUXILIARY RAM FAULT
AUX RAM & STOR FAULT
NOVRAM FAULT
NOVRAM & STORE FAULT

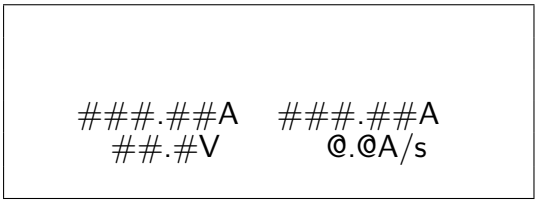
If two four digit numbers appear at the bottom right hand corner of the display, please note these down and include them in the report to Twickenham, as this gives an internal error code to help identify the nature of the fault.

This error is recoverable by following the instructions:

Normal upper two lines

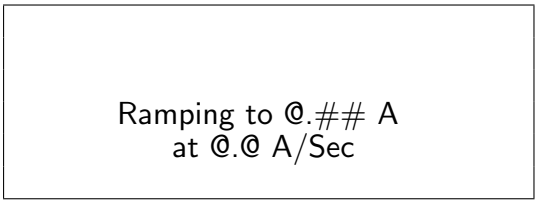


Lower two lines - Normal Quiescent State

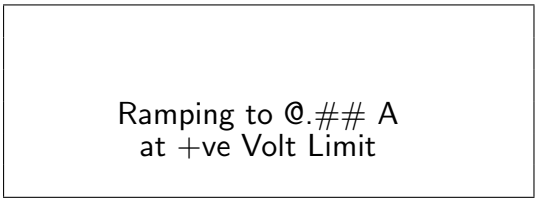


Lower two lines - Active Ramp

Constant rate



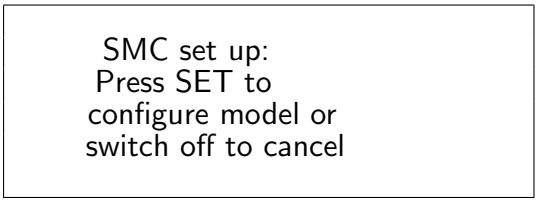
Constant Voltage:



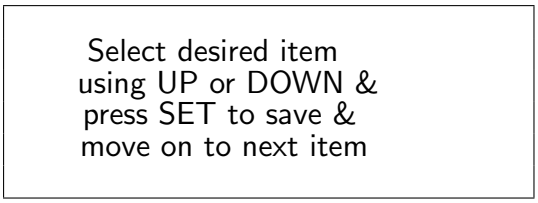
Reinitialisation of Non-volatile Storage (NOVRAM)

It may happen that the message NOVRAM STORAGE FAULT appears on the display at power up. This indicates that some corruption of the non-volatile RAM (NOVRAM) storage has occurred. In the longer term, this battery-backed RAM module may need replacement, especially if this error occurs regularly. However, the stored parameters may be restored to a valid default state by following the procedure below.

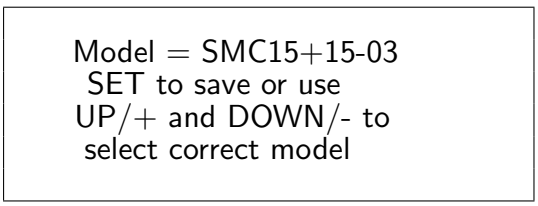
When the NOVRAM STORAGE ERROR message is on the display, or as power is switched on subsequently, press the *Set* and *Up* buttons simultaneously. If power has just been applied, the SMC - POWER ON TEST message appears first. Then following display:



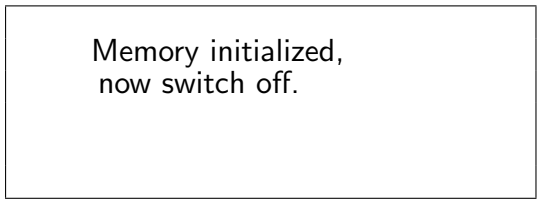
Pressing the *Set* key will change the display to:



Pressing *Set* to move on:



The SMC uses a single firmware version for all models, including the EMC range. The differences between models are stored along with user-configured parameters within the NOVRAM store. Therefore, be sure to select the correct model, including any `-nn` suffix. If the SMC model is a SMC15+15-03, press the *Set* button. Otherwise, press *Up* or *Down* until the correct model is shown on the upper line, then press *Set*. The display will change to:



At this point switching off the unit will complete the initialisation. The next switch-on should be clear of NOVRAM STORAGE FAULT. If it is not, the NOVRAM module has failed and you should contact the staff at Twickenham for advice.

Unfortunately, the reinitialisation of necessity resets all user-configured parameters to default values so these will need to be re-entered.

Note that if a NOVRAM STORAGE FAULT occurs, the only options are to switch off or press *Set* and *Up* to re-initialise memory. If you switch the unit off, the NOVRAM STORAGE FAULT will not be repeated at the next power up unless there is a serious problem with the stored data. The unit will attempt to operate with the data stored in the NOVRAM which could lead to erroneous operation.