SMS SERIES
SUPERCONDUCTING MAGNET
CONTROLLERS

SAMPLE USER'S MANUAL

Controller version SAMPLE ONLY
Keypad
IEEE-488, RS232 and USB interface
Intelligent reverse

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CONTENTS

1 *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.

The voltage sense input, if used, must be securely and correctly connected to the magnet. If the voltage sense input is reversed the power supply can never detect a voltage limit condition and will limit the maximum difference between output and magnet terminal voltage to 1.4V. If this condition is maintained two fusible resistors in the power supply will burn out, making remote voltage sensing ineffective. Damage to these components is NOT covered by the warranty.

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 CRYOGENIC.

Users with the internal or external RS2 Reversing Switch option please read Appendix G first

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.

2 *GENERAL DESCRIPTION*

The CRYOGENIC SMS range of power supplies provide a number of output current and drive voltage options (see Appendix J for details). 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 SMS10C model uses a linear power unit which does not require fan cooling.

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 eight push-button switches. Status indication is via an 80 character alphanumeric vacuum fluorescent display and seven LED indicators on the switches.

Remote control is either via an IEEE-488 interface or a USB interface (with RS232 interfaced versions also available). Remote control commands and output messages consist of English text, passed over the interface as ASCII code strings.

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.

The display of current output can be switched between the direct Amps value or a calculated Tesla value (providing that a Tesla per Amp constant has been entered via the interface).

Two adjustable target current settings are available. The two set-points are mutually limiting, such that the upper point can never be set to less than the lower point. These adjustable settings are in addition to the fixed zero target point and the arbitrary ramp pause facility.

Target currents can be set to a 16-bit resolution (0.0015% of full output). For customers who require a higher resolution, Cryogenic offers a 20-bit current setting using an onboard 20-bit DAC and high-stability current transducer to give overall stability better than 2ppm/K.

A digital ramp generator, under software control, drives high stability sweep control circuitry. Any one of 65 pre-set ramp rates may be selected. The ramp can be halted indefinitely with a temperature related drift no greater than 20 ppm/°C.

An adjustable voltage limit controls both the positive (ramping up) and negative (ramping down) voltages. Voltage limiting overrides the ramp generator if necessary. In the SMS120C and lower output supplies based on this unit the voltage limit applies symmetrically about zero. In other models, the negative voltage limit is slightly less than the positive limit to reduce power dissipation on magnet de-energisation. The voltage limit can be set to a resolution of approximately 0.1V.

The voltage limiting circuit can operate from an optional voltage 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. (Not available on the SMS10C or for units using the RS2 reversing switch).

Automatic quench protection shuts down the power supply immediately an increasing voltage with falling current is detected. A quench can be detected while not ramping and while ramping down, as well as when ramping up. 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. Forced-air cooling is automatically activated, the fan deriving its power from the load under these conditions.

The reference shunt is manufactured from a very low temperature coefficient alloy (10 ppm/°C over the range 15-40°C). For precision monitoring of the output current, the shunt voltage is available at the "DVM" output on the rear panel. The output is unbuffered for the single unit models, buffered for the master-slave models. A calibration for the DVM output to 0.03% accuracy is marked on each individual power supply.

A secondary adjustable output for a switch heater gives an output in the range 0-8V. This output is rated at 100mA and is protected against short term overload. The output current flowing when this output is switched is recorded by the firmware in non-volatile storage, and is used to remind the user that there may be a persistent mode current flowing in the superconducting magnet.

Rear panel connectors are also fitted as standard for; (a) interface to the RS2 reversing switch option, (b) interface to a liquid helium level gauge (analogue input readable via the digital interface, with optional probe pulse control), and (c) external trip input (for connection of a trip switch or relay, or TTL drive).

3 *PREPARING THE UNIT*

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

A mains supply lead is included which has an integral IEC CEE22 connector to fit the power supply power input. The other end of this lead should be fitted with a 3 terminal plug to suit the available AC power line. The colour codes used in this lead are: Brown=Live, Blue=Neutral, Green/Yellow=Earth. Check that the input voltage rating (marked on the back of the unit) matches the supply to which it is to be connected.

A pair of flexible current leads are also supplied. These have 8mm tags at the end to be fitted to the power supply and 6mm tags at the end to be fitted to the cryostat. The recommended torque when fitting the leads to the power supply is 3-5 lbft or 4-7 Nm. This ensures a good electrical contact without overstressing the terminals. Always hold the cable tags when tightening to ensure that the terminals cannot become twisted.

To enable a short circuit test to be performed, bolt the two 6mm tags together. The power supply is designed to drive inductors with low DC resistance. If an attempt is made to run the supply with open circuit terminals, erroneous readings will be obtained.

Before switching on the power supply, ensure that there is a minimum of 150mm clear space behind the unit to allow a free flow of air. When power is applied, check that the sign-on message is written to the display, that the ZERO indicator (only) is on, and that the two cooling fans are delivering a strong flow of air to the back of the unit.

Consult Appendix E for IEEE-488 configuration and connection details.

If an RS2 Reversing Switch has been supplied, read Appendix G before operating with this option.

Additional information about the SMS10C model is given in Appendix H.

4 LOCAL OPERATION

Front Panel Controls and Indicators

The front panel carries an illuminated main on/off switch (with integral 16 Amp circuit breaker), a 2 line by 40 character vacuum fluorescent display, and 22 engraved push-buttons (7 of which have LED status indicators). The push-buttons are designated as follows:

REMOTE (L) - Switches between remote and local control.
SHIFT - Modifies the operation of DOWN, SET and UP.
HEATER (L) - Switches the switch heater output on and off.
TESLA (L) - Switches the output units between Amps and Tesla.
ZERO (L) - Selects zero Amps as the ramping target.
MID (L) - Selects the MID set point as the ramping target.
MAX (L) - Selects the MAX set point as the ramping target.
PAUSE (L) - Suspends and releases ramp generation.

Buttons marked (L) are illuminated when active.

NUMERIC KEYPAD

SELECT - Selects parameters for adjustment.

CANCEL - Cancels unwanted entered value.

ENTER - Writes selected value to memory.

0 - 9 - Numeric numbers

. - Decimal point

Power Up Conditions

Power-up defaults are REMOTE selector off, ZERO selected, PAUSE off, HEATER off and TESLA off.

The upper line of the display shows the model number of the power supply in the centre, with terminal current shown on the left, terminal voltage on the right.

A number of power-up self-checks are performed. If these are all successful, the lower display line will normally show the version number of the controller firmware.

```
  0.0 Amps      SMS120C      0.0 Volts
       Controller Version 6.6
```

Typical Power-Up Display

If a persistent mode condition was recorded when the power supply was last switched off then the power supply will power-up showing the message "Heater switched off at x.x Amps" on the lower display line. See 'The HEATER Button' for details.

If the external trip was enabled when the power supply was last switched off and the back panel input is in the disabling state (open or driven high) then the display will power-up showing the message "External Trip Active" on the lower display line. See ***The External Trip*** and ***The XTRIP Command*** for details.

Any other message on the display at power-up indicates that one of the initialisation checks failed (these messages are shown in Appendix C). If a fault message appears, the unit will be inoperable. If the message is "STORAGE FAULT", see Appendix I for recovery information. Otherwise please contact CRYOGENIC for advice if any of the fault messages are seen.

Quiescent Status

The lower display line normally shows the four most important parameter settings. To change the version message to the message showing parameter settings, press any button. The ZERO selector is convenient to use as it is already active and will have no other effect. Alternatively, for a magnet with a persistent mode switch, it may be useful to get into the habit of using the HEATER button for this purpose. From left to right, the parameters displayed are: the MID setting, the MAX setting, the voltage limit and the ramp rate. The parameter values will be as on the previous power-down.

```
  0.0 Amps       SMS120C       0.0 Volts
    80.0A  120.0A    4.8V   0.012A/s
```

Typical Quiescent Status Display

Note: Only the power-up version message is cancelled as described above. The "External Trip Active" and "Heater switched off at x.x Amps" messages are not cancelled until the respective condition is cancelled.

The TESLA Button

If a field constant has been entered, pressing the TESLA button will convert the terminal current display and the MID and MAX settings to read in Tesla instead of Amps. Note, however, that the ramp rate continues to read in Amps per second. The TESLA button toggles between Amps and Tesla, with the indicator being illuminated when Tesla is selected. If no constant has been entered, pressing the TESLA button will have no effect and the indicator will not illuminate. The field constant may either be entered via the interface (see ***The SET Command***) or using the numeric Keypad (see ***The SELECT, CANCEL, ENTER and SHIFT Buttons***).

```
 0.00 Tesla      SMS120C       0.0 Volts
    6.56T   11.50T    4.8V   0.012A/s
```

Typical Quiescent Status Display With TESLA Active

The SELECT, CANCEL, ENTER and SHIFT Buttons

The four parameters shown in the normal quiescent status message may be changed by simple operation of the SELECT button. The first press of SELECT will enter the 'set mode' and bring the setting message for the last accessed parameter to the lower display line. Further presses of the SELECT button sequentially select the parameters to be change. Next, enter a value of the parameter using the numeric keypad. When the entered value is wrong use the CANCEL button to clear last value. When the ENTER button is pressed the value is memorised.

```
  0.0 Amps      SMS120C      0.0 Volts
      Voltage Limit = 4.8 Volts
```

Typical Set Mode Display

The **Ramp Rate** is entered in a logarithmic fashion at 16 steps per decade. Note that the display of current to 3 decimal places (or field to 4 decimal places) is provided as a guide, but at this level the settings should be regarded as relative rather than absolute.

Pressing buttons SHIFT and SELECT together will bring the setting message for the last accessed alternate 'set mode' parameter to the lower display line access: either the Heater voltage parameter or the TPA (Tesla per amp) field constant.

The persistent mode switch **Heater Output** is usually set to its normal value a single time and memorised . The setting message for this is accessed by pressing SHIFT-SELECT. The step size is just over 0.1 Volt, rounded on the display to the nearest 0.1 (thus, there may be some apparent steps of 0.2V on the display).

The **Tesla/Amp** constant value may be entered in the range 0.01 to 0.5 tpa. If an invalid value is entered then it is ignored. The field constant is set to 0 initially.

Set mode may be entered at any time during operation of the power supply. When SELECT (or SHIFT-SELECT) is pressed, the setting messages replace any other messages on the lower display line. With no activity on the setting buttons (SELECT, SHIFT), 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, MID or MAX) will therefore force restoration of the normal display before the setting time-out with no other effect.

The ZERO, MID and MAX Buttons

A ramp from zero is initiated by pressing the MID or MAX button. The ZERO, MID and MAX 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 display line will show the target current (in Amps or Tesla, as selected) and the ramp rate.

```
 26.2 Amps       SMS120C      3.8 Volts
  Ramping to 80.0 Amps at 0.012 A/s
```

Typical Active Ramp Display

Note: If the external trip is active no ramp can be performed. The external trip condition must be cancelled either by taking the input line to the enabling state (shorted to 0V or driven low) or by disabling the external trip facility via the remote control interface (See ***The External Trip*** in this section and ***The XTRIP Command*** in the ***REMOTE CONTROL*** section).

If the selected ramp rate causes the terminal (or sense) voltage to rise to the set voltage limit, the "..at x.x A/sec" message will change to the "..at voltage limit" message.

Note: If the RS2 reversing switch option is fitted, SHIFT+MID and SHIFT+MAX can be used to initiate a ramp in the negative direction. See Appendix G for full details. 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).

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

The PAUSE Button

A ramp may be halted at any time 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 (ie. 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.

The REMOTE Button

The REMOTE button will not normally be used, as switching between remote and local control modes is performed automatically via IEEE-488 interface signals (pressing this button when the IEEE-488 interface is not being driven will have no effect). The 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 LED will turn off and the other buttons will be operable. A message will be sent to the remote device to signal that this action has been taken. As buttons are pressed, output messages will be generated on the interface to allow the remote device to monitor the activity (any commands from the remote device sent during this time will be accepted but ignored). 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 (this is signalled to the remote device by another interface message). The remote device may issue a command to prevent this use of the REMOTE button (locking ALL buttons, instead of all buttons except REMOTE).

The HEATER Button

If the magnet is fitted with a persistent mode switch, the heater should be switched on (HEATER indicator illuminated) before energising the magnet. Note that the HEATER button can only be operated, to either switch on or switch off, when no ramping is active. The HEATER button will only respond (as shown by the indicator LED) when ramping is inactive. Ramping is inactive when the selected target has been achieved, or if PAUSE is on, or at zero.

Operation of the persistent mode switch may be checked by ramping the power supply to 2 or 3 Amps (use MID or MAX together with PAUSE) with the heater off. An inductive voltage kick should be seen when the heater is then switched on (a similar method may be used to check the minimum voltage required to open the switch by progressively stepping up the heater voltage from zero).

The normal quiescent (non-ramping) status message is, as described above, the four primary parameter values. If the heater is switched off with the power supply delivering current (which the power supply interprets as the switching of a magnet into persistent mode), the status message will change to a record of the current at which the heater was switched off.

```
0.00 Tesla     SMS120C      0.0 Volts
  Heater switched off at 6.76 Tesla
```

Typical 'Persistent Mode' Display

No checks are made to establish whether or not a magnet has actually been put into persistent mode. The message is provided purely as a reminder to the operator. It is valid as a persistent mode indicator only if this is a valid assumption for the system as a whole.

The "Heater switched off at..." message will remain on the display (except while ramping or setting parameters) until the heater is next switched on. If the power supply is powered-down with the magnet in this state, the information is retained in non-volatile memory and the "Heater switched off at..." message will replace the version number message and the standard quiescent state message on the next power-up.

Using the Voltage Sense Input

The power supply can operate in both constant ramp rate and constant voltage control modes. Switching between these modes is performed automatically by the controller. If the set ramp rate does not cause the sensed voltage to rise to the set voltage limit, the controller operates in constant ramp rate mode. If the sense voltage rises to the set voltage limit, the controller switches to constant voltage mode.

Switching of the sense voltage source is also performed automatically. If no connection is made to the voltage sense input, the voltage control circuitry operates from the voltage at the main terminals. If a voltage drive is applied to the voltage sense input, this is used as the control voltage. The terminal voltage will then be allowed to rise above the set voltage limit.

Typically, the sense input is driven from voltage taps connected directly across the magnet windings. Constant voltage control will, in these circumstances, produce a constant rate ramp.

Care should be taken in setting the voltage limit, when operating with the sense input, to allow a sufficient margin for the maximum resistive voltage difference between the sense input and the main terminals. If the main terminal voltage rises to the nominal maximum voltage of the power supply, while the sense input is below the set voltage limit, the controller will switch into a pseudo constant voltage mode (to avoid saturation of the output stage) which is less smooth and stable than the genuine constant voltage mode (the display message is the same as the genuine voltage limiting mode, however).

Reversed voltage sense leads will cause approximately 20 ohms to appear across the load. When operating with large inductance coils this will cause a significant and unexpected time constant to appear. Furthermore, the two 10 ohm protection resistors will be damaged if this condition is prolonged. For these reasons, great care should be taken to connect the voltage sense leads with the correct polarity. *Note:* The voltage sense input should never be used if there is a reversing switch in the system.

Quench Detection

Should the magnet go resistive ('quench') for any reason, the status message will change to a record of the event, including the current flowing in the output terminals at the time of the quench. The power supply instantaneously switches the demand current to zero when it detects an increasingly resistive load. The ZERO ramp target selector will be indicated after a quench, and the message will remain on the display until SET or one of the ramp target selector buttons is pressed. While it is on the display, the units may be switched by use of the TESLA button. No specific action is required to reset the power supply following a magnet quench. The power supply will be inoperable until one second after the terminal current and voltage return to zero.

```
 0.00 Tesla     SMS120C     0.0 Volts
      Quench Trip at 10.44 Tesla
```

Typical 'Quench' Event Display

Note that a quench which occurs in persistent mode will be detected, but the current shown in the message will be the power supply terminal current at the time of the quench detection, NOT the true persistent mode current.

The External Trip

A facility is also provided to trigger an emergency de-energisation of the magnet via an auxiliary input on the back panel (see Appendix D for connection details). This function is only available after it has been enabled via the remote interface (see ***The XTRIP Command*** in the ***REMOTE CONTROL*** section). The action taken by the power supply on detection of an external trip is exactly the same as that taken on the detection of a quench, except that the heater is automatically switched on and the power supply is disabled for as long as the trip condition is active. *An external trip may cause a quench in a small proportion of magnets.*

Note that the external trip input is normally supplied fitted with a shorting link plug. This prevents a trip occurring if the feature is enabled by accident. To use the external trip feature, this plug should be replaced with your own input.

The effect of an external trip is to de-energise the magnet at the fastest possible rate, whatever the existing conditions and parameter settings. This facility may be useful as a 'Panic Button' for attended operation or as simply-implemented automatic system interlock for unattended operation (a trip can also be triggered via the remote interface if the supplied shorting link is removed to further increase the options - see ***The XTRIP Command*** for details). Because the heater is automatically switched on, and remains on until about 1 second after the terminal current falls to zero, an external trip will take a magnet out of persistent mode (subject to correct heater voltage setting and external wiring). The heater is automatically switched off after the magnet has been de-energised whatever the previous on/off state of the heater.

```
 0.00 Tesla     SMS120C      0.0 Volts
    External Trip at 10.44 Tesla
```

Typical 'External Trip' Event Display

Cancellation of the external trip event message is caused by the same button presses as to cancel a quench event message. However, if the external trip condition continues to exist (if the XTRIP function remains enabled and the input line remains in the active condition), the ramp selectors are locked to ZERO. Before the power supply can be used, the trip must be cancelled either by taking the input line to the enabling state (driven low or shorted to 0V, e.g. by fitting the shorting plug) or by disabling the external trip function via the remote interface (see ***The XTRIP Command*** for details). If the trip condition continues to exist after the event message has been cancelled, or if a trip is triggered when there is no output current and no 'persistent mode' record, the message "External Trip Active" will be shown on the display, replacing the normal quiescent status message until the trip condition is cancelled. The external trip enabled/disabled state is held in the non-volatile memory. Therefore, it is possible for an external trip condition to exist at power-up. If this is the case, the "External Trip Active" message will replace both the version message and the normal quiescent message until the trip condition is cancelled.

```
 0.00 Tesla     SMS120C      0.0 Volts
         External Trip Active
```

External Trip Status Display

5 INTERFACE MESSAGES

General Introduction

The interface may be most simply used for direct remote control of the power supply via a computer running a suitable IEEE-488 terminal program, such as that given in Appendix E. Because remote control commands and output messages consist of comprehensible English text passed over the interface using standard ASCII codes, no external software of a specialised nature is required to communicate with the SMS controller.

Frequently, however, a specialised automatic or semi-automatic driver program will be written to monitor the power supply output and to generate commands. The output messages have well defined structures and type prefixes to assist in this mode of use.

Message Structure

Interface messages consist of text lines terminated by a carriage-return, line-feed sequence (ASCII codes 13 and 10 decimal). The text in the line has a three-part structure.

The first 9 characters consist of an 8-character prefix followed by a space. In most cases, this prefix is a timestamp in the format "`HH:MM:SS`". The timestamp may be replaced by other prefixes in special circumstances. The other prefixes are all of the same length as the timestamp so that the information field always starts at character position 10. The next section is of variable length and is terminated by a colon. This specifies the parameter, status or setting information given by the remainder of the line.

Examples of most of the messages appear in the sign-on block shown below. Note that the sign-on header (which gives the identification information) is the only message type which does not include the second section described above (there is no colon in these lines).

The Sign-on Message

The first sequence of messages which will be seen from the power supply after placing it in remote control mode will be the sign-on sequence, similar to that shown below:

```
          SMS120C    Version 6.6 (xxx)
          Superconducting Magnet
          Cryogenic Limited, 1992-2013

........ REMOTE CONTROL: ENABLED
........ EXTERNAL TRIP: DISABLED
........ FIELD CONSTANT: 0.09138 T/A
........ HEATER OUTPUT: 2.2 VOLTS
........ VOLTAGE LIMIT: 4.8 VOLTS
........ RAMP RATE: 0.012 A/SEC
........ MID SETTING: 85.000 AMPS
........ MAX SETTING: 92.700 AMPS
........ HEATER STATUS: OFF
........ PAUSE STATUS: OFF
........ RAMP STATUS: HOLDING ON TARGET AT 0.000 AMPS
........ LEVEL GAUGE: 0 mm
00:00:02 OUTPUT: 0.000 AMPS AT 0.0 VOLTS
```

Hopefully, this is all readily comprehensible and needs little further explanation. In the sign-on block can be seen examples of all the common output messages. The state of all controller parameters are indicated. If the reversing switch and/or multiple heaters options are fitted the sign-on block will contain additional lines to indicate the status of these options (see Appendices G and H for details of the option messages).

If no message is obtained, refer to Appendix E for details of the required IEEE-488 interface connections and settings.

A new sign-on sequence can be generated at any time by dropping the remote enabled state on the interface then re-enabling it after say half a second (see Appendix E).

The status messages generated during normal operations are all to be found in the sign-on message block, with one exception. The additional message, which is generated when the operating units are changed but not included at sign-on because the current units are indicated in several other messages, is:

```
HH:MM:SS UNITS: [AMPS][TESLA]
```

This message line illustrates two of the conventions used in this manual.

First, `HH:MM:SS` is used to indicate the timestamp. This is the time in hours, minutes and seconds since power-up (note that the time returns to zero after 24 hours). Messages generated while under front panel control always carry a timestamp (from the `OUTPUT` message in the sign-on block onwards).

Second, `[ ][ ]` is used to indicate alternative possibilities in a message. The above message description indicates that the message may be either `UNITS: AMPS` or `UNITS: TESLA`.

Ramp Status Messages

Ramp status messages are messages which are output in response to the RAMP STATUS command. These messages are only sent on request from the interface.

```
HH:MM:SS RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.@ A/SEC
HH:MM:SS RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.# VOLTS
HH:MM:SS RAMP STATUS: HOLDING ON [TARGET][PAUSE] AT @.@ [AMPS][TESLA]
HH:MM:SS RAMP STATUS: QUENCH TRIP AT @.@ [AMPS][TESLA]
HH:MM:SS RAMP STATUS: EXTERNAL TRIP AT @.@ [AMPS][TESLA]
```

The `RAMPING..` message will be output when the RAMP STATUS command is used (see The RAMP Command below).

These messages provide examples of the descriptive convention used for numeric values in messages. These are shown using the '`@`' & '`#`' characters. The `@` signifies a variable number of numeric digits, the `#` a single digit.

Where messages are output using either Amps or Tesla values, the number format used in descriptions is `@.@`. Amps are output with 3 decimal places of precision (`@.###`) in models other than the SMS10C (4 decimal places). Tesla are output with 4 decimal places of precision (`@.####`) in models other than the SMS10C (5 decimal places).

Fault Report Messages

```
=======> POWER UNIT FAULT
=======> REVERSING SWITCH FAULT
```

Only faults which do not lock out normal operation are reported over the interface.

6 REMOTE OPERATION

General Introduction

This section provides an outline description of operation via the remote interface. More details, on command formats, output message formats and interface connections, are given in the appendices.

Note that the front panel display and button LED's remain active at all times to locally show status and activity, even when the unit is being controlled over the interface.

Selecting Remote Control

Remote control mode is selected and deselected automatically by interface signals (see Appendix E for details). The LED indicator is illuminated when remote control is selected.

The REMOTE button will have no effect when the interface is not being actively driven (ie. remote control cannot be initially selected by use of the REMOTE button). However, the REMOTE button may be used to return from remote to local control mode, and back again, providing that the button has not been locked by issue of the **LOCK** command over the interface. When in remote control mode, all front panel buttons except REMOTE are locked out if **LOCK** is off - all front panel buttons including REMOTE are locked if **LOCK** is on.

This topic is also covered in ***The REMOTE Button*** in the ***LOCAL OPERATION*** section and in Appendix E.

When the REMOTE button changes the source of control, a status update message in the following form is transmitted over the interface.

```
HH:MM:SS REMOTE CONTROL: [EN][DIS]ABLED
```

Command Structure

Most commands consist of a primary command word and a secondary or qualifier word (one command, **`UPDATE`**, requires no qualifier, and one command, **`SET`**, requires a numerical value in addition to a qualifier).

If an unrecognised primary command word is issued (e.g. a question mark), a message giving a list of all the valid commands will be returned:

```
-------> Commands: G(ET),R(AMP),P(AUSE),H(EATER),T(ESLA),S(ET)
,X(TRIP),U(PDATE),L(OCK)
```

(Note that this message is output as a single line. The line break shown above is due to width restrictions in this manual).

While the command words may be given in full, the list indicates by the use of brackets that the commands may be abbreviated to the initial letter (the brackets are not part of the command). Other general rules about commands are:

1. A list of recognised qualifiers for any command may be obtained by issuing the command followed by **`?`** or any other invalid qualifier. Such messages have a "`------->`" prefix (as shown above) and are described as **command information** messages.

2. The present status of the command function may be obtained by issuing the command with no qualifier. Such messages have a "`. . . . . .`" prefix and are described as **status confirmation** messages.

3. A valid command with valid qualifier (and, in the case of **`SET`**, with a valid numerical value) will generate a **status update** message in response. These messages are prefixed by a timestamp in the form `HH:MM:SS`.

4. Alphabetic case is not significant, and a space between command and qualifier (also between qualifier and value in the case of **`SET`**) is optional.

The commands are individually described in the following sections. Alternative qualifiers are shown separated by a comma in these descriptions. While many qualifiers may be abbreviated to an initial letter, as for the primary command words, some have special abbreviated forms (where the initial letter does not uniquely identify the qualifier). The first form of abbreviation is shown by enclosing the optional part within parentheses (as above). The special alternatives for a qualifier are shown within square brackets, e.g. **`[0][OFF]`** signifies that either **`0`** or **`OFF`** may be used to switch the function off. The commas, parentheses and brackets are merely descriptive devices and are not part of the command.

See Appendix G for details of the additional DIRECTION command when the reversing switch option is fitted (also applies to the SMS10C model with integral RS2).

See Appendix F for additional parameters on the HEATER command when the multiple heater outputs option is fitted.

The UPDATE Command

Syntax: **`U(PDATE)`**

The **`UPDATE`** command is used to obtain an updated version of the sign-on status block (minus the identification header which is transmitted at sign-on only). **`UPDATE`** requires no qualifiers. Any given will be ignored.

The GET Command

Syntax: **G(ET) O(UTPUT)**
G(ET) L(EVEL)
G(ET) [MID][%]
G(ET) [MAX][!]
G(ET) R(ATE)
G(ET) (T)PA,
G(ET) H(V)
G(ET) V(L)
G(ET) S(IGN)
G(ET) P(ER)

The **GET OUTPUT** command returns the present output current and voltage values by a status update message of the following form:

```
HH:MM:SS OUTPUT: @.@ [AMPS][TESLA] AT @.# VOLTS
```

The **GET LEVEL** command returns a value determined from the present voltage at the auxiliary analogue input connector. The assumption is made that this input is connected to the analogue output of a liquid helium level gauge with an output of 2mV per millimetre. A status update message of the following form is output:

```
HH:MM:SS LEVEL GAUGE: @ mm
```

The range of the analogue input is 0 to 2.55V with a resolution of 10mV. Thus the level resolution is 5mm with a full scale of 1275mm. If it is desired to use the analogue input for some other purpose, the value returned by the **GET LEVEL** command may be converted in this manner. This command also produces an 80ms positive-going pulse at the 'level gauge pulse' output on the AUX IN/OUT connector (see Appendix D).

Both messages may be obtained on one command by use of the **GET** command with no qualifier.

```
HH:MM:SS OUTPUT: @.@ [AMPS][TESLA] AT @.# VOLTS
HH:MM:SS LEVEL GAUGE: @ mm
```

The following commands are an alternative to the **UPDATE** command reading parameters. The major advantage is the single line response in contrast to the answer delivered with **UPDATE**. They also save time and minimises the traffic over the interface.

The **GET MID,MAX,%,!** Commands retrieve the various target fields available using the same abbreviations as the **SET** command. The reponse will contains the set unit in order to distinguish between current and field values.

The current ramp rate can be querried with the **R(ATE)** qualifier, the currently used heater voltage is requested with **H(V),** and the current Field constant can be viewed with **T(PA)**. The set voltage limit can be read with **V(L).**

If the current of the power supply is reversible the set direction is retrieved with the **S(IGN)** qualifier. If the unit is unipolar an empty string is returned.

If a coil has been put into persistent mode, which in terms of the power supply means the heater has been switched off having current flowing, the preserved field or current can be read with the **P(ER)** option.

If an unrecognisable qualifier is given (e.g. **GET ?**), the following command information message will be output:

```
-------> Qualifiers to GET: O(UTPUT),L(EVEL),[%][MID],[!][MAX], ….
….(R)ATE,(T)PA,(H)V,(v)L,(S)IGN,(P)ER
```

(Note that this message is output as a single line. The line break shown above is due to width restrictions in this manual).

The RAMP Command

Syntax: **R(AMP) [0][ZERO]**
R(AMP) [%][MID]
R(AMP) [!][MAX]
R(AMP) S(TATUS)

This command performs the function of the **ZERO**, **MID** or **MAX** buttons on the front panel in selecting a new active ramp target. No response is output to the interface. If required the **STATUS** qualifier can be used to interrogate the present ramping status. The response is a ramp status message (see below).

If the **STATUS** qualifier is given (ie. **RAMP STATUS**), a ramp status confirmation message will be output, in one of the following forms:

```
........ RAMP STATUS: HOLDING ON [TARGET][PAUSE] AT @.@ [AMPS][TESLA]
........ RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.@ A/SEC
........ RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.# VOLTS
........ RAMP STATUS: QUENCH TRIP AT @.@ [AMPS][TESLA]
........ RAMP STATUS: EXTERNAL TRIP AT @.@ [AMPS][TESLA]
```

See the 'Ramp Status Messages' section for further descriptions of the **RAMP STATUS** messages.

If the **RAMP** command re-selects the existing target, or an unknown qualifier is supplied or if no qualifier is given (ie. if the command is simply **RAMP**), the command is ignored.

If an attempt is made to perform a ramp when an external trip condition is active, the following command information message will be output:

```
-------> Ramp disabled by active external trip
```

See the 'External Trip' section for a description of the external trip function and the **XTRIP** command for details of how this function is enabled, disabled and triggered.

The PAUSE Command

Syntax: **P(AUSE) [0][OFF]**
P(AUSE) [1][ON]

This command performs the function of the PAUSE button on the front panel in disabling and enabling ramp generator activity.

If the command changes the pause on/off status, this is immediately acknowledged by a status update message in the following form:

```
HH:MM:SS PAUSE STATUS: [OFF][ON]
```

If the **PAUSE** command re-selects the present state, or if no qualifier is given (ie. if the command is simply **PAUSE**) the timestamp will be missing and no ramp status message will follow:

```
........ PAUSE STATUS: [OFF][ON]
```

If an unrecognisable qualifier is given (e.g. **PAUSE ?**), the following command information message will be output:

```
-------> Qualifiers to PAUSE: [0][OFF],[1][ON]
```

The HEATER Command

Syntax: **H(EATER) [0][OFF]**
H(EATER) [1][ON]

This command performs the function of the HEATER button on the front panel in switching the persistent mode heater output on or off.

If the command changes the heater on/off status, this is immediately acknowledged by a status update message in the following form:

```
HH:MM:SS HEATER STATUS: [ON][OFF][SWITCHED OFF AT @.@ [AMPS][TESLA]]
```

Switching the heater on always generates the simple `HEATER STATUS: ON` message.

Switching the heater off generates the simple `HEATER STATUS: OFF` message if there is no current flowing. If there is current flowing at the power supply output at the time that heater is switched off, the `SWITCHED OFF AT..` form is output.

The latter form indicates a status condition which continues to exist (even through a power-down) until the heater is next switched on.

If the command re-selects the existing state, or if no qualifier is given (ie. if the command is simply **HEATER**) the status confirmation form of the message will be output.

If an unrecognisable qualifier is given (e.g. **HEATER ?**), the following command information message will be output:

```
-------> Qualifiers to HEATER: [0][OFF],[1][ON]
```

Changing the state of the heater output during a ramp is not permitted. If an attempt is made to change the heater state during a ramp (not if the present state is reselected) the following command information message will be output:

```
-------> Cannot switch heater during a ramp
```

The TESLA Command

Syntax: **T(ESLA) [0][OFF]**
T(ESLA) [1][ON]

This command performs the function of the TESLA button on the front panel in switching the active units to be used for power supply output readings between Amps and Tesla.

If the command changes the selected units, this is acknowledged by a status update message in the following form:

```
HH:MM:SS UNITS: [TESLA][AMPS]
```

Thereafter, all messages which include an output current value will use the selected units (except ramp rates).

If the command re-selects the units already being used, or if no qualifier is given (ie. if the command is simply **TESLA**) the status confirmation form of the message will be output.

If an unrecognisable qualifier is given (e.g. **TESLA ?**), the following command information message will be output:

```
-------> Qualifiers to TESLA: [0][OFF],[1][ON]
```

Switching to Tesla without a valid field constant entered into the power supply is not permitted. If an attempt is made to switch to Tesla without a valid constant, (not if Amps are reselected) the following command information message will be output:

```
-------> No field constant has been entered
```

The XTRIP Command

Syntax: **X(TRIP) [0][OFF]**
X(TRIP) [1][ON]

This command enables or disables the external trip facility. If the command changes the status of the external trip function, this is immediately acknowledged by a status update message in the following form:

```
HH:MM:SS EXTERNAL TRIP: [DISABLED][ENABLED][ACTIVE]
```

If the command re-selects the existing state, or if no qualifier is given (ie. if the command is simply **XTRIP**) the status confirmation version of the message will be output.

XTRIP can be used in two ways. Firstly, if the auxiliary digital input assigned to this function (see Appendix D) is connected to 0V or driven low, the command **XTRIP ON** has no immediate effect but enables the input to act as an external trip trigger line (in this case the **XTRIP ON** command is acknowledged with the message `EXTERNAL TRIP: ENABLED`). Secondly, if the input line is already open circuit or driven high, the **XTRIP ON** command itself will trip the power supply (the message will be `EXTERNAL TRIP: ACTIVE` in this case, and it will be immediately followed by a `RAMP STATUS` message, as shown below). Note that for operation in the latter mode, the supplied shorting plug must be removed from the input connector.

The action taken by the power supply on detection of an external trip is similar to that taken on the detection of a quench. That is, the demand current is instantaneously switched to zero. In addition, the heater is first switched on then switched off about 1 second after the current and voltage at the terminals return to zero. The ZERO ramp target will be selected. An external trip also disables the **RAMP** command until the trip condition is cancelled. The effect of an external trip is to de-energise the magnet at the fastest possible rate, whatever the existing conditions and parameter settings

The activation of an external trip is signalled by the following message:

```
HH:MM:SS RAMP STATUS: EXTERNAL TRIP AT @.@ [AMPS][TESLA]
```

This message will always appear immediately after an `EXTERNAL TRIP: ACTIVE` message. This may be in response to the **`XTRIP`** command (if the input line is already open circuit or driven high) or in response to the input line going high (if the external trip was previously enabled). Cancellation of the external trip condition may be either by issuing the **`XTRIP OFF`** command, or by returning the input line to the inactive (low) state.

In the former case, an `EXTERNAL TRIP: DISABLED` message will be output. In the latter case, an `EXTERNAL TRIP: ENABLED` message will be output.

Note that an external trip may cause a quench in a small proportion of magnets.

The LOCK Command

Syntax: **`L(OCK) [0][OFF]`**
`L(OCK) [1][ON]`

The **`LOCK ON`** command prevents use of the front panel REMOTE button to revert to local control. The **`LOCK OFF`** command cancels this action. The lock is also cancelled if remote control mode is dropped by interface signals.

If the command changes the lock status, this is immediately acknowledged by a status update message in the following form:

```
HH:MM:SS LOCK: [OFF][ON]
```

If the command re-selects the current state, or if no qualifier is given (ie. if the command is simply **`LOCK`**) a status confirmation message will be output:

```
........ LOCK: [OFF][ON]
```

If an unrecognisable qualifier is given (e.g. **`LOCK ?`**), the following command information message will be output:

```
-------> Qualifiers to LOCK: [0][OFF],[1][ON]
```

The SET Command

Syntax: **S(ET) [%][MID] n**
S(ET) [!][MAX] n
S(ET) R(AMP) n
S(ET) L(IMIT) n
S(ET) H(EATER) n
S(ET) T(PA) n

The **"n"** indicates that the parameter specifier should be followed by a value for the parameter given as a decimal number in any of the generally recognised forms.

Examples: **SET MID 78.6** **SET LIMIT 4**
SET RAMP 2E-2 **SET TPA 0.0987**

No unit specifiers are recognised. If they are given they will be ignored. **LIMIT** and **HEATER** values are interpreted as Volts, **RAMP** values as Amps per second and **TPA** values as Tesla per Amp. **MID** and **MAX** values are interpreted as Amps or Tesla, according to the currently selected working unit.

All settable numeric parameters are positive. Any sign character will be ignored. Thus, for example, entering **SET HEATER -3** will result in the heater output voltage being set to 3.0 Volts.

One of the following status update messages is returned if the **SET** command sets a new value for a parameter:

```
HH:MM:SS MAX SETTING: @.@ [AMPS][TESLA]
HH:MM:SS MID SETTING: @.@ [AMPS][TESLA]
HH:MM:SS RAMP RATE: @.@ A/SEC
HH:MM:SS VOLTAGE LIMIT: @.# VOLTS
HH:MM:SS HEATER OUTPUT: #.# VOLTS
HH:MM:SS FIELD CONSTANT: 0.@ T/A
```

If a qualifier but no value is given, a status confirmation message showing the present value of the specified parameter will be output. If no parameter is specified (ie. if the command is simply **SET**) the present values of all the settable parameters will be output in a sequence of status confirmation messages.

If an unrecognisable qualifier is given (e.g. **SET ?**), the following command information message will be output:

```
-------> Qualifiers to SET: [%][MID],[!][MAX],R(AMP),L(IMIT),
H(EATER),T(PA)
```

(Note that this message is output as a single line. The line break shown above is due to width restrictions in this manual).

Command information messages will also be output if the supplied value cannot be accepted (ie. is out of range). These messages are:

```
-------> Maximum MAX setting: @.@ [Amps][Tesla]
-------> Less than MID setting: @.@ [Amps][Tesla]
-------> Greater than MAX setting: @.@ [Amps][Tesla]
-------> Maximum LIMIT setting: @.# Volts
-------> Maximum HEATER setting: #.# Volts
-------> Valid T/A range: 0.01 to 0.5 or zero
```

There is no out-of-range message for ramp rate. As there are only 65 possible ramp rates, **SET RAMP** always rounds to the nearest available rate. This also applies to out of range values, so that an under-range value gives the minimum ramp rate, an over-range value the maximum ramp rate.

APPENDICES

A INTERFACE COMMANDS

Command input and message output consist of sequences of code values in the range 0 to 127 inclusive (7-bit binary). Using the American Standard Code for Information Interchange (ASCII), each value translates either to a printable character (codes greater than 31) or to a standard teletype control function (codes less than 32 and code 127). Command input should be terminated by a carriage-return code (CR, code 13) or a line-feed code (LF, code 10) or a CR,LF pair. Message output is always terminated by a CR,LF pair.

Command Summary

```
U(PDATE)
R(AMP)        [0][ZERO],[%][MID],[!][MAX],S(TATUS)

G(ET)         O(UTPUT),L(EVEL),[%][MID],[!][MAX],(R)ATE,
              (T)PA,(H)V,(v)L,(S)IGN,(P)ER

S(ET)         [%][MID],[!][MAX],R(AMP),L(IMIT),
              H(EATER),T(PA) n

P(AUSE)       [0][OFF],[1][ON]
H(EATER)      [0][OFF],[1][ON]
T(ESLA)       [0][OFF],[1][ON]
X(TRIP)       [0][OFF],[1][ON]
L(OCK)        [0][OFF],[1][ON]        (see Appendix E)

S(ET) H(EATER) AU(X) [A,B,C,D,E,F,G,H][] n
                                      (see Appendix F)
H(EATER)      AU(X) [A,B,C,D,E,F,G,H][] [0][OFF],[1][ON]
                                      (see Appendix F)
D(IRECTION)   [-][+]                  (see Appendix G,M)
D(IRECTION)   [-][0][+]               (see Appendix N)
```

B *INTERFACE OUTPUT MESSAGES*

Message Types

There are 5 message types, identified by the prefix characters appearing in positions 1 to 8 of the message line (position 9 is always a space and position 10 is the start of the actual message).

Firstly, the **controller identification** messages (3 lines) are prefixed by a string of spaces.

The primary message type is the **status update**, which is prefixed by a timestamp. This indicates that the message contains some new information (the value or status described by the line has been changed by a command or by an event). The time indicated is that since the last power-up of the power supply (if this was less than 24 hours previously). As an example, the time 4 hours, 17 minutes and 10 seconds is output as "`04:17:10`". The time string is shown in the descriptions of messages in general form as follows:

```
HH:MM:SS
```

The **status confirmation** messages may be output in response to a status enquiry or an existing status re-selection. The messages themselves are the same as the status update messages. However, in these cases the messages do not convey new information. (The only case in which status confirmation messages may be considered to contain new information is when they are transmitted as part of the general status block following the sign-on). The status confirmation prefix is shown literally in the message descriptions, as follows:

```
. . . . . .
```

The next message type is the **fault report** message, the prefix for which is shown literally in message descriptions, as follows:

```
=======>
```

The final message type is the **command information** message, the prefix for which is shown literally in message descriptions, as follows:

```
------->
```

One of these message header types precedes every line of output from the power supply. When operating in a teletype mode, they help to separate the important from the unimportant messages at a glance. When operating in automatic or semi-automatic remote control mode, they provide the first message filtering level for the driver program.

Descriptive Devices

In the message descriptions, the characters `[` and `]` are used to indicate possible alternative sections within the message. The sequence of alternatives is started by a single `[` character, the alternatives are divided by `][` combinations, and the sequence is terminated by a single `]` character. The `[` and `]` characters do not form part of the message.

Variable numerical values are shown by combinations of special characters. The period (`.`) is literally a decimal point. The hash (`#`) represents one decimal digit. The 'at' sign (`@`) represents any number of decimal digits (from a minimum of one to a maximum of eight), as required to represent the value. A literal digit may be given if the value of the digit is invariable (for example, values that are always less than 1.0 may be written as "`0.@`").

Where part of a value (either before or after the decimal point) is output in a fixed format, the `#` character is usually used. The exception is in the many instances where Amps and Tesla values are alternative units. To include the fixed format for these values on each occasion would over-complicate the description of these messages. Where "`@.@ [AMPS][TESLA]`" is seen in message descriptions, the partially fixed format "`@.### AMPS`" or "`@.#### TESLA`" can be substituted ("`@.#### AMPS`" and "`@.##### TESLA`" for the SMS10C).

The character `«` is used to represent the end-of-line CR,LF sequence. The `«` character appearing alone on a line signifies a blank line.

The Controller Identification Block

These message lines are placed in the output buffer in response to remote control being selected. In the first line, the model identification and version number are variables. Examples are shown.
Each line of the controller identification block is prefixed with a string of nine spaces. Two empty lines precede the block, one empty line follows.

```
SMS120C    Version 6.6 (xxx)
Superconducting Magnet
Cryogenic Limited, 1992-2013
```

Status Update and Status Confirmation Messages

These messages may be prefixed by a timestamp (in the form `HH:MM:SS`, indicating a status update) or with the "........" prefix (indicating a status confirmation).

The status update forms, generally show the changes caused by command input. They also report the occurrence of 'events'. The status confirmation forms are used in responses to status interrogation commands and when existing states are reselected. Status confirmation forms are also used within the sign-on sequence, except for the `OUTPUT` message.

```
RAMP TARGET: [ZERO][MID][MAX]«
PAUSE STATUS: [OFF][ON]«
HEATER STATUS: [ON][OFF][SWITCHED OFF AT @.@ [AMPS][TESLA]]«
MAX SETTING: @.@ [AMPS][TESLA]«»MID SETTING: @.@ [AMPS][TESLA]«
RAMP RATE: @.@ A/SEC«
VOLTAGE LIMIT: @.# VOLTS«
HEATER OUTPUT: #.# VOLTS«
UNITS: [TESLA][AMPS]«
RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.@ A/SEC«
RAMP STATUS: RAMPING FROM @.@ TO @.@ [AMPS][TESLA] AT @.# VOLTS«
RAMP STATUS: HOLDING ON [TARGET][PAUSE] AT @.@ [AMPS][TESLA]«
RAMP STATUS: [QUENCH][EXTERNAL] TRIP AT @.@ [AMPS][TESLA]«
REMOTE CONTROL: [DISABLED][ENABLED]«
LOCK: [ON][OFF]«
OUTPUT: @.@ [AMPS][TESLA] AT @.# VOLTS«
LEVEL GAUGE: @ mm
FIELD CONSTANT: 0.@ T/A«
EXTERNAL TRIP: [DISABLED][ENABLED][ACTIVE]«
```

The status confirmation form of the UNITS message is not included in the status report block. It is transmitted only in response to a **TESLA** command.

The status update form of the REMOTE CONTROL message is transmitted at the transition between local and remote control originating from manual operation of the REMOTE button. The status confirmation form is transmitted only as part of the status report block.

Command Information Messages

Command information messages have a "-------->" prefix and are output only when operating in remote control mode. In local control mode, it is not possible to generate unrecognised commands, or to specify out of range values for a parameter (the UP and DOWN buttons stop responding at the limits). In the cases of the operations which are interlocked with other conditions, the buttons fail to respond.

```
Commands:(G)ET,(R)AMP,(P)AUSE,(H)EATER,(T)ESLA,(S)ET
,X(TRIP),U(PDATE),L(OCK)«
Qualifiers to GET: O(UTPUT),L(EVEL)«
Qualifiers to RAMP: S(TATUS),[0][ZERO],[%][MID],[!][MAX]«
Qualifiers to PAUSE: [0][OFF],[1][ON]«
Qualifiers to HEATER: [0][OFF],[1][ON]«
Qualifiers to TESLA: [0][OFF],[1][ON]«
Qualifiers to XTRIP: [0][OFF],[1][ON]«
Qualifiers to LOCK: [0][OFF],[1][ON]«
Qualifiers to DIRECTION: +,-«
Qualifiers to SET: [%][MID],[!][MAX],R(AMP),L(IMIT)
,H(EATER),T(PA)«
Maximum MAX setting: @.@ [Amps][Tesla]«
Less than MID setting: @.@ [Amps][Tesla]«
Greater than MAX setting: @.@ [Amps][Tesla]«
Maximum LIMIT setting: @.# Volts«
Maximum HEATER setting: #.# Volts«
Valid T/A range: 0.01 to 0.5 or zero«
Cannot switch heater during a ramp«
Ramp disabled by external trip«
No field constant has been entered«
Option not fitted«
Reversing switch fault«
Reversing relays not switching«
Cannot change current direction with current flowing«
```

Event Messages

Event messages are status update or fault report messages which are generated automatically by the controller, rather than in direct response to command input. The messages which are output in this way are as follows:

```
HH:MM:SS EXTERNAL TRIP: [ENABLED][ACTIVE]«
=======> POWER UNIT FAULT«
=======> CONTROLLER FAULT«
```

The `EXTERNAL TRIP` messages are treated as events because the enabled/active condition of this function is controlled by the auxiliary input as well as by the **`XTRIP`** command (the `EXTERNAL TRIP: DISABLED` condition can be created only by the **`XTRIP`** command, so this message is not generated as an event).

Message suffix

Each message sent to the terminal is terminated by CR, LF. A message block consists in one or more messages. A suffix is added automatically at the end of every message block to mark the end of the transmission block. This is especially useful for long message groups which can last up to 3 secs in some cases (SIGNON/UPDATE). The suffix is a single non-printable control character (currently 19 or 13H, DC3). Any software driver for the power supply should accept the suffix character to mark the end of transmission. Empty lines or empty transmission blocks should be discarded by the driver.

Message format:
<Message>< CR>< LF>
<suffix>

Message block format:
<Message1>< CR>< LF>
<Message2>< CR>< LF>
<Message3>< CR>< LF>
<Message4>< CR>< LF>
<suffix>

C DISPLAY MESSAGES

Normal Power-up

```
###.# Amps      SMS###C      ##.# Volts
        Controller Version 6.6
```

Faults detected at power-up (all lock out normal operation)

```
        ANALOGUE INTERRUPT FAULT
        Controller Version 6.6
```

```
            CPU RAM FAULT
        Controller Version 6.6
```

```
     GENERAL AUXILIARY MEMORY FAULT
        Controller Version 6.6
```

```
            AUX RAM FAULT
        Controller Version 6.6
```

```
            NOV RAM FAULT
        Controller Version 6.6
```

```
        NOV RAM + STORAGE FAULT
        Controller Version 6.6
```

```
        AUX RAM + STORAGE FAULT
        Controller Version 6.6
```

```
            STORAGE FAULT
        Controller Version 6.6
```

Operating faults which lock out further operation

```
        CONTROLLER FAULT
    Controller Version 6.6
```

```
      POWER FAIL INTERRUPT FAULT
    Controller Version 6.6
```

Operating faults which do not lock out further operation

```
••••••••••••••••••••••••••••••••••••••••
          POWER UNIT FAULT
```

```
••••••••••••••••••••••••••••••••••••••••
        REVERSING SWITCH FAULT
```

Normal Upper Line

Amps selected:

```
###.# Amps      SMS###C      ##.# Volts
••••••••••••••••••••••••••••••••••••••••
```

Tesla selected:

```
##.## Tesla      SMS###C     ##.# Volts
••••••••••••••••••••••••••••••••••••••••
```

Lower Line - Normal Quiescent State

Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
      @.#A   @.#A   @.#V   @.@A/s
```

Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
     @.##T   @.##T   @.#V   @.@A/s
```

Lower Line - 'Persistent Mode Recorded' Quiescent State

Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
    Heater switched off at @.# Amps
```

Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
   Heater switched off at @.## Tesla
```

Lower Line - Quiescent State Following a Quench Trip

Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
        Quench Trip at @.# Amps
```

Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
        Quench Trip at @.## Tesla
```

Lower Line - Quiescent State Following an External Trip

Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
        External Trip at @.# Amps
```

Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
       External Trip at @.## Tesla
```

Lower Line - Quiescent State with External Trip Active

```
••••••••••••••••••••••••••••••••••••••••
          External Trip Active
```

Lower Line - Active Ramp

Constant rate, Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
    Ramping to @.# Amps at @.@ A/sec
```

Constant rate, Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
   Ramping to @.## Tesla at @.@ A/sec
```

Constant voltage, Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
Ramping to @.# Amps at Voltage Limit
```

Constant voltage, Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
 Ramping to @.## Tesla at Voltage Limit
```

Lower Line - Parameter Setting Mode

The MID setting display is the same as the MAX setting display, except that the word "MID" is substituted.

MAX setting, standard resolution, Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
        MAX Set Point = @.# Amps
```

MAX setting, standard resolution, Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
       MAX Set Point = @.## Tesla
```

MAX setting, extended resolution, Amps selected:

```
••••••••••••••••••••••••••••••••••••••••
      MAX Set Point = @.### Amps
```

MAX setting, extended resolution, Tesla selected:

```
••••••••••••••••••••••••••••••••••••••••
     MAX Set Point = @.#### Tesla
```

Ramp rate setting:

```
••••••••••••••••••••••••••••••••••••••••
          Ramp Rate = @.@ A/sec
```

Voltage limit setting:

```
••••••••••••••••••••••••••••••••••••••••
        Voltage Limit = @.# Volts
```

Heater voltage setting:

```
••••••••••••••••••••••••••••••••••••••••
        Heater Output = @.# Volts
```

Field constant setting:

```
••••••••••••••••••••••••••••••••••••••••
        Tesla/Amp = @.##### T/A
```

D *REAR PANEL CONNECTIONS*

MAINS INPUT

IEC CEE22 socket for connection to mains supply. Supply requirements are shown on a plate on the rear panel, as follows:

190-255 Volt 50/60 Hz, 8 Amp max. or 95-130 Volt 50/60 Hz, 10 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 16 Amps. In addition, the main power unit, electronics power supply and the fan drive are protected by individual fuses.

OUTPUT+, OUTPUT-

M8 terminals for connection to load. 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 overstressing the terminal studs. Always hold the cable tags when tightening to ensure that the terminal blocks do not twist.

DVM+, DVM-

4mm jack sockets for connection to external DVM. Provides direct reading of shunt voltage at 600 ohm source impedance (buffered for high output master-slave models). A calibration for this output is marked on the rear panel.

IEEE-488 INTERFACE

A standard IEEE-488 connector for GPIB remote control. IEEE-488 operation is described in Appendix E. The interface is optically isolated from the power supply output to allow multiple power supply configurations to be used without the risk of earth loop burn-outs.

HTR & SENSE

5-way 240° DIN connector for optional connections to cryostat.
Pin 1 - Heater -
Pin 2 - Sense -
Pin 3 - Screen (see below)
Pin 4 - Sense +
Pin 5 - Heater +

Pin 3 (screen) is common 0V referenced to power supply internal 0V. This is not isolated from the output and should not be used as a through connection.

Pin 1 is at the bottom left corner of the accessory plug.

EXTERNAL TRIP INPUT

2-pin Molex connector for an optional external trip switch or TTL drive.

Looking from the back of the unit: **0V IN**

The housing around the IN pin has slightly rounded corners and is nearer the locking mechanism.

The external trip feature may be implemented and enabled by the user. The input can either be driven by an open collector TTL gate capable of sinking 12mA, or a switch connected between the two pins may be used to change the input state.

If the command **XTRIP ON** is issued over the remote interface, the pins on this connector must be short-circuited or the IN pin driven low for the power supply to operate. If these pins are then open circuited (or if the IN pin is driven high) while the power supply is delivering current, the output will be immediately shut down (and the heater output will be switched on temporarily to ensure that a magnet in persistent mode is de-energised). The action is similar to that taken on detection of a 'quench', except that the report reads EXTERNAL TRIP instead of QUENCH TRIP. The external trip may be disabled by the command **XTRIP OFF**.

LEVEL GAUGE INTERFACE

5-way 180° DIN connector for optional input from a liquid helium level gauge (with optional pulse control).

Pin 1 - Analogue Input +
Pin 2 - Screen (see below)
Pin 3 - Analogue Input gnd
Pin 4 - Pulse 0V
Pin 5 - Pulse output

This connector is intended for use with liquid helium level gauges. The **GET LEVEL** command returns a reading from the analogue input in millimetres. See 'The GET Command' for details.

Pins 1 and 3 are a 0 to 2.55V differential input which is read by an 8-bit analogue to digital converter (ie. the resolution is 10mv, which corresponds to 5mm LHe level). Input impedance is 20K.

Pin 2 (screen) is common 0V referenced to power supply internal 0V. This is not isolated from the output and should not be used as a through connection.

Great care should be taken when using this input to avoid creating earth loops as it is NOT isolated from the power supply output terminals. The maximum common mode voltage that can be tolerated on these terminals is around 20V with respect to the output terminals of the power supply.

The level gauge pulse output is normally held at a low level while the power supply is operating. Every **GET LEVEL** command received over the interface produces a TTL high level pulse of 80ms length. If no **GET LEVEL** command is issued within a period of 17 minutes, such a pulse is automatically generated by the controller. This output is intended for connection to liquid helium level gauges with the required control input (identified by a 5-way DIN connector on the rear panel). The normal low level suppresses pulsing of the level gauge probe, the high level pulse causes the level gauge to generate a probe pulse. Thus, level gauge activity can be placed under software control.

While pulsing is suppressed, the level gauge display is maintained by an analogue sample-and-hold circuit. This slowly drifts with time, so the automatic pulsing after 17 minutes of inactivity is used to update the reading. If the power supply is switched off, or the line to the level gauge is disconnected, the level gauge pulses the probe at the specified MIN or MAX rate (set by a switch on the front panel). Note that, when the level gauge pulse line is used, **`GET LEVEL`** commands return the level gauge reading BEFORE the pulse is generated.

REVERSING SWITCH CONTROL

Female DB9 for connection to optional RS2 reversing switch unit.

Pin 1 - FWD output
Pin 2 - REV output
Pin 3 - no connection
Pin 4 - no connection
Pin 5 - no connection
Pin 6 - no connection
Pin 7 - ID input
Pin 8 - STATUS input
Pin 9 - Common 0V

The input on pin 7 reads high if no RS2 is connected. When connected, a RS2 pulls this line low.

The input on pin 8 reads high if no RS2 is connected or if the RS2 is short-circuiting the output (by being instructed by the control outputs, by being un-powered or by a fault condition). It reads low when the RS2 is correctly set to either the forward or the reverse direction.

The RS2 is set into the forward direction when the pin 1 output is high and the pin 2 output is low. It is set into the reverse direction when the pin 1 output is low and the pin 2 output is high. The RS2 short circuits the output current if both outputs are low or if both outputs are high.

E *THE IEEE-488 INTERFACE*

Capabilities

The IEEE-488 interface can be switch configured for operation on any device address from 0 to 30 inclusive. As supplied, the device address is set to 4.

The interface has the following capabilities in accordance with the ANSI standard:

SH1, AH1, T4, L2, TE0, LE0, SR0, RL2, PP0, DC0, DT0, C0, E1.

SH1: Source handshake capability.
AH1: Acceptor handshake capability.
T4: Basic talker.
L2: Basic listener.
TE0: No extended talker functions.
LE0: No extended listener functions.
SR0: No service request capability.
RL2: Remote-local with no local lockout.
PP0: No parallel poll capability.
DC0: No device clear capability.
DT0: No device trigger capability.
C0: No controller capability.
E1: Open collector drivers.

Remote-Local Switching

The remote-local facilities operate in the following manner:

1. If the interface has not been placed in the remote enabled state (by putting the interface into the listen addressed state with the REN line asserted) remote control cannot be selected via the front panel REMOTE button.

2. When the interface is placed in the remote enabled state remote control is automatically selected (the LED on the REMOTE button illuminates). The sign-on message is also placed into the output message queue for transmission when the device is requested to talk. All front panel buttons are inoperative except the REMOTE button.

3. Unless the **LOCK ON** command has been issued over the interface (see below), if the remote button is pressed while in the remote enabled state, the remote-enabled state will be cancelled. However, the output queue will not be cancelled and messages reflecting the local operations will continue to be loaded into the output queue (including a message which reads `REMOTE CONTROL: DISABLED`). These output messages can be monitored but any commands sent to the power supply will be ignored. When remote control has been disabled by this method, it may be reselected with another press of the REMOTE button. A message reading `REMOTE CONTROL: ENABLED` will be loaded into the output buffer.

4. If the REN line is released at any time, the device will immediately return to the local control mode. Any pending messages in the output queue will be cancelled and state (1) will be re-entered. If the device is subsequently placed in the remote enabled state, a new sign-on message sequence will be generated.

The **LOCK ON** command disables the REMOTE button so that local control cannot be seized from the front panel. This action can be cancelled by issue of the **LOCK OFF** command or by releasing the GPIB REN line (which re-enables all front panel buttons).

Interface Clear

After asserting the IFC line, allow about 250ms before addressing the device to talk or listen. Until this period has elapsed, the interface may not respond.

Talk Mode

Data from the power supply is collected in an output queue. When the interface is addressed to talk the contents of the queue are output to the GPIB until an untalk command is received.

The only way to determine if there is data in the output queue is to regularly address the device to talk. If there are no messages waiting, a single LF code is returned. Messages are terminated by CR,LF. In the current version of the hardware the EOI line is disabled. The listener must therefore be configured to recognise LF as the terminating character.

Listen Mode

When the interface is addressed to listen, all data received on the GPIB is passed directly to the main controller via the internal serial link. The controller will recognise CR or LF or CR,LF as a command terminator. It does not recognise EOI as input.

Changing the GPIB Device Address

The GPIB device address is set via a bank of DIP switches located near the IEEE-488 connector on the back panel (through an aperture in the panel). The 5 poles furthest from the connector set the GPIB address (the 6th pole nearest the connector is unused). The pole furthest from the connector corresponds to bit 0 of the address in binary, with subsequent poles corresponding to bits 1, 2, 3 and 4. This notation (which may not agree with the numbers printed on the switch) is used in the following table.

Address	***Bit 4***	***Bit 3***	***Bit 2***	***Bit 1***	***Bit 0***	
0	OFF	OFF	OFF	OFF	OFF	
1	OFF	OFF	OFF	OFF	ON	
2	OFF	OFF	OFF	ON	OFF	
3	OFF	OFF	OFF	ON	ON	
4	OFF	OFF	ON	OFF	OFF	DEFAULT
5	OFF	OFF	ON	OFF	ON	
6	OFF	OFF	ON	ON	OFF	
7	OFF	OFF	ON	ON	ON	
8	OFF	ON	OFF	OFF	OFF	
9	OFF	ON	OFF	OFF	ON	
10	OFF	ON	OFF	ON	OFF	
11	OFF	ON	OFF	ON	ON	
12	OFF	ON	ON	OFF	OFF	
13	OFF	ON	ON	OFF	ON	
14	OFF	ON	ON	ON	OFF	
15	OFF	ON	ON	ON	ON	
16	ON	OFF	OFF	OFF	OFF	
17	ON	OFF	OFF	OFF	ON	
18	ON	OFF	OFF	ON	OFF	
19	ON	OFF	OFF	ON	ON	
20	ON	OFF	ON	OFF	OFF	
21	ON	OFF	ON	OFF	ON	
22	ON	OFF	ON	ON	OFF	
23	ON	OFF	ON	ON	ON	
24	ON	ON	OFF	OFF	OFF	
25	ON	ON	OFF	OFF	ON	
26	ON	ON	OFF	ON	OFF	
27	ON	ON	OFF	ON	ON	
28	ON	ON	ON	OFF	OFF	
29	ON	ON	ON	OFF	ON	
30	ON	ON	ON	ON	OFF	
	ON	ON	ON	ON	ON	ILLEGAL

Sample Terminal Program

The following program provides a basic keyboard-screen interface to a single device on the GPIB. It may be modified for other hardware types.

```
1000 '============================================================
1010 '
1020 '    A SIMPLE GPIB TERMINAL FOR IEEE-488 VERSIONS OF
1030 '              SMS SERIES POWER SUPPLIES
1040 '
1050 ' This program is for IBM PC/XT/AT fitted with the Capital
1060 ' Equipment Corp. PC<>488 interface card, or equivalent.
1090 ' It is designed to simulate as closely as possible the
1100 ' appearance of the equivalent RS232-interfaced instrument
1110 ' on a simple 'dumb' terminal with command echo enabled.
1115 '
1120 ' If the program is to be compiled, the following changes
1125 ' must be made:
1130 ' Change SEND%=9 to SEND%=36.
1135 ' Change ENTER%=21 to ENTER%=39.
1140 ' Change CALL INITIALIZE%, CALL ENTER% and CALL SEND%
1145 ' statements to CALL ABSOLUTE statements with the routine
1150 ' offset address as an additional argument, as in the
1160 ' following example:
1170 '
1180 ' CALL INITIALIZE% (MY.ADDR%,LEVEL%)
1190 '   is changed to
1200 ' CALL ABSOLUTE (MY.ADDR%,LEVEL%,INITIALIZE%)
1210 '
1220 ' If compiling with Microsoft QuickBASIC, specify the
1230 ' QB.LIB library to the linker for CALL ABSOLUTE support.
1235 ' Some versions of QB.LIB do not work correctly with the
1236 ' PC<>488 card. CEC supply a replacement on their disks.
1240 '
1245 ' If this program fails to work, check the PC<>488 address
1246 ' setting. Address C400 hex is assumed in the DEF SEG
1247 ' statement at line 1340. This may need changing.
1248 '
1250 '============================================================
1260 '
```

```
1270 '
1280 '--- SET UP -------------------------------------------
1290 '
1300 PROMPT$="}"          'Define the local input prompt string
1310 '
1320 MSG$=SPACE$(100)        'Define the ENTER line buffer size
1330 '
1340 DEF SEG=&HC400         'Segment address of the PC<>488 ROM
1350 '
1360 INITIALIZE%=0         'Entry offset for INITIALIZE routine
1370 SEND%=9                 'Entry offset for the SEND routine
1380 ENTER%=21              'Entry offset for the ENTER routine
1390 '
1400 DEVICE%=4              'Define the external device address
1410 MY.ADDR%=21             'Define the PC<>488 device address
1420 LEVEL%=0         'Specify the PC<>488 as system controller
1430 '
1440 CALL INITIALIZE% (MY.ADDR%,LEVEL%)    'Initialize PC<>488
1450 '
1460 ' The interface requires at least 200ms to become ready
1465 ' following the IFC performed by the INITIALIZE routine.
1470 ' Until this time has elapsed no request to talk or
1480 ' listen will be recognised.
1490 '
1500 START=TIMER
1510 WHILE TIMER-START<.25: WEND
1520 '
1530 ' An initial call to the SEND routine tests for the
1535 ' presence of the device on the bus (SEND times out if
1540 ' there is no response) and asserts the GPIB REN line to
1550 ' enable the device on the bus. The only data transferred
1560 ' is the LF code added by the SEND routine (this will be
1570 ' ignored by the magnet controller).
1580 '
1590 COMLINE$=""                  'Clear the command line string
1600 CALL SEND% (DEVICE%,COMLINE$,STATUS%)   'Send nothing (LF)
1610 IF STATUS%>0 THEN 2780         'Terminate on timeout error
1620 '
1630 '
1640 '--- PREPARE TERMINAL SCREEN ----------------------------
1650 '
1660 CLS: KEY OFF
1670 LOCATE 25,1: PRINT STRING$(80,"-");
1680 LOCATE 25,4: PRINT "GPIB Terminal"
1690 LOCATE 25,20: PRINT "Device";STR$(DEVICE%)
1700 LOCATE 25,63: PRINT"<Ctrl+End>=Exit";
1710 LOCATE 1,1,1
1720 '
```

```
1730 '
1740 '--- COMMUNICATIONS LOOP ---------------------------------
1750 '
1760 ' The following block gets keyboard input. If REMOTE% is
1765 ' true, printable characters are accumulated in COMLINE$
1770 ' and echoed to the screen. Most non-printable keyboard
1780 ' input is ignored, with the following exceptions:
1785 '
1790 ' <Ctrl-End>
1795 ' Terminates the program (exits the communications loop).
1800 ' <Esc>
1805 ' Deletes line in COMLINE$ and erases it from the screen.
1810 ' <backspace>
1815 ' Deletes the last character in COMLINE$ and erases it
1820 ' from the screen.
1830 ' <Del>
1835 ' Same as <backspace>.
1840 '
1845 ' The length of COMLINE$ cannot exceed 40 characters. Any
1850 ' attempt to enter more than 40 characters on a line will
1855 ' get a warning bleep. One keypress is fetched on each
1860 ' pass. If the keypress translates to an ASCII code
1870 ' (printable or non-printable) this is passed on in IN$.
1880 ' If there was no keypress to be fetched, or if the
1885 ' keypress was an extended code, IN$ is passed on as an
1890 ' empty string.
1900 '
1910 'Get keyboard input.
1920 IN$=INKEY$
1930 'Check for extended code. Only Ctrl-End is significant.
1940 IF LEN(IN$)<2 THEN 1990
1950 IN$=RIGHT$(IN$,1)
1960 IF IN$=CHR$(117) THEN 2780
1970 IN$=""
1980 'Jump to end of block if no input.
1990 IF IN$="" THEN 2200
2000 'Check for printable code or control code.
2010 IF ASC(IN$)>31 AND ASC(IN$)<127 THEN 2160
2020 'Backspace or Delete code, erase last character.
2030 IF ASC(IN$)<>8 AND ASC(IN$)<>127 THEN 2090
2040 IF LEN(COMLINE$)=0 THEN GOTO 2200
2050 PRINT CHR$(29);" ";CHR$(29);
2060 COMLINE$=LEFT$(COMLINE$,LEN(COMLINE$)-1)
2070 GOTO 2200
```

```
2080 'Escape code, erase whole line.
2090 IF ASC(IN$)<>27 THEN 2200
2100 FOR N%=1 TO LEN(COMLINE$)
2110 PRINT CHR$(29);" ";CHR$(29);
2120 NEXT N%
2130 COMLINE$=""
2140 GOTO 2200
2150 'Printable character code.
2160 IF REMOTE%=0 THEN GOTO 2200
2170 IF LEN(COMLINE$)=40 THEN BEEP: GOTO 2200
2180 PRINT IN$;
2190 COMLINE$=COMLINE$+IN$
2200 '
2210 ' If REMOTE% is true, the following block transmits
2215 ' COMLINE$ when <Enter> is pressed (IN$ received holding
2220 ' the ASCII CR code). The SEND routine automatically adds
2230 ' the LF terminator.
2240 '
2250 IF IN$<>CHR$(13) OR REMOTE%=0 THEN 2310
2260 PRINT                      'Terminate present command line
2270 PRINT PROMPT$;                          'and start a new one
2280 CALL SEND% (DEVICE%,COMLINE$,STATUS%)    'Transmit command
2290 IF STATUS%>0 THEN 2780          'Terminate on timeout error
2300 COMLINE$=""             'Cancel command after transmission
2310 '
2320 ' Between each examination of the keyboard, the interface
2330 ' is checked for incoming messages. If no message is
2335 ' received (LENGTH%=0) the remainder of the loop is not
2340 ' executed.
2350 '
2360 TALK%=1                                  'Set the TALK flag
2370 CALL ENTER% (MSG$,LENGTH%,DEVICE%,STATUS%)'Check for input
2380 IF STATUS%>0 THEN 2780          'Terminate on timeout error
2390 TALK%=0                                 'Clear the TALK flag
2400 IF LENGTH%=0 THEN 1920           'Restart loop if no input
2410 '
2420 ' The incoming message is checked to see whether
2430 ' it is a SMS remote control status report.
2435 ' This is used to modify the state of the REMOTE%
2440 ' flag which controls whether the local input prompt is
2450 ' printed and whether keyboard input is passed to the
2460 ' device. This function is included to complete the
2470 ' simulation of RS232 control with command echo enabled.
2480 ' If it is not required, the relevant lines may be deleted
2485 ' to make this program less device-specific (other action
2490 ' to make REMOTE% true will then be required, or all
2500 ' references to REMOTE% must be deleted).
```

```
2510 '
2530 IF MID$(MSG$,10,14)<>"REMOTE CONTROL" THEN 2650
2540 IF MID$(MSG$,26,7)="ENABLED" THEN REMOTE%=-1: GOTO 2650
2550 REMOTE%=0: COMLINE$=""
2570 '
2580 ' The present cursor line is first erased, then the
2585 ' received message is printed on the present line. If
2590 ' REMOTE% is true, the command prompt and any partially
2600 ' entered command line is then reprinted on the next line
2610 ' (this prevents incoming messages breaking up incomplete
2620 ' command lines on the screen, simulating the action of
2630 ' the RS232 interface with command echo enabled).
2640 '
2650 LOCATE,1                'Move to beginning of present line
2660 PRINT STRING$(LEN(PROMPT$)," "); 'Erase the command prompt
2670 PRINT STRING$(LEN(COMLINE$)," ");   'and any partial entry
2680 LOCATE,1                'Move to beginning of present line
2690 PRINT LEFT$(MSG$,LENGTH%)    'Print the input message line
2700 IF REMOTE%=0 THEN 1920        'If in remote control mode:
2710 PRINT PROMPT$;                      'Reprint the prompt
2720 PRINT COMLINE$;         'and any partially entered command
2730 '
2740 GOTO 1920                                'End of loop
2750 '
2760 '
2770 '--- TERMINATE ----------------------------------------
2780 '
2790 IF STATUS%=0 THEN 2840    'Normal termination if STATUS%=0
2800 PRINT: PRINT               'Otherwise, its a timeout error
2810 PRINT"*** Error: GPIB device";DEVICE%;"is not ";
2820 IF TALK% THEN PRINT"Talking" ELSE PRINT"Listening"
2830 '
2840 CALL INITIALIZE% (MY.ADDR%,LEVEL%)  'Send IFC, release REN
2850 '
2860 SYSTEM
```

F THE MULTIPLE HEATERS OPTION

With the optional multiple heater output (standard in the SMS10C) is a female DB25 connector on the back panel (near the main output terminals) and additional settings are available on the **HEATER** and **SET HEATER** commands.

Connections

Pins 14 - 21 are common 0V. Pins 9 - 13 and pins 22 - 25, no connection. Heater outputs are on pins 1 - 8, as follows:
Pin 1 - Auxiliary Heater H
Pin 2 - Auxiliary Heater G
Pin 3 - Auxiliary Heater F
Pin 4 - Auxiliary Heater E
Pin 5 - Auxiliary Heater D
Pin 6 - Auxiliary Heater C
Pin 7 - Auxiliary Heater B
Pin 8 - Auxiliary Heater A

Auxiliary Heaters Command Options

The auxiliary heater outputs can only be controlled via the remote interface. At power-up, all outputs are switched off. The output voltage for all of the auxiliary outputs may be set as follows:

```
SET HEATER AUX n
```

This command will set all auxiliary outputs to the requested voltage (the valid range is 0 to 6.3 Volts). This command may be abbreviated as follows:

SHXn (Example: **SHX5.3** sets all outputs to 5.3 Volts)

Auxiliary heater voltages may also be set individually by inclusion of a specifier A to H, as shown in the following example:
SHXB2.6 - sets auxiliary heater B to 2.6 Volts, leaves others unaltered.

When auxiliary heater output settings are changed they take immediate effect for all heaters which are switched on. The following message is output:

```
HH:MM:SS HTRAUX OUTPUTS: #.#, #.#, #.#, #.#, #.#, #.# VOLTS
```

The first value in the message is for auxiliary heater A, the last is for auxiliary heater H. This message is output even if only one output value is changed. The present settings may be obtained by issue of the **SHX** command with no value. The confirmation form of this message is included in the general status update block if the presence of the option is detected at power-up. The auxiliary heater outputs may be switched on or off by use of the additional **AUX** (or **X**) qualifier to the **HEATER** command, as shown in the following examples.

HEATER AUX ON or HX1 - Switches all auxiliary heaters on
HEATER AUX OFF or HX0 - Switches all auxiliary heaters off
HEATER AUX G ON or HXG1 - Switches auxiliary heater G on
HEATER AUX F OFF or HXF0 - Switches auxiliary heater F off

The responsive message to switching the auxiliary heaters (individually or globally) is as follows:

```
HH:MM:SS HTRAUX STATUS: [OFF][ON], [OFF][ON], [OFF][ON], [OFF][ON]
, [OFF][ON], [OFF][ON]
```

The first status is auxiliary heater A, the last auxiliary heater H. The form of this message confirmation may be obtained by issuing the **HX** command without an **ON** or **OFF** qualifier. This message will also be included in the general status update block if the presence of the option is detected at power-up. The following confirmation message example shows heaters B and D on, with all others off:

```
........ HTRAUX STATUS: OFF, ON, OFF, ON, OFF, OFF, OFF, OFF
```

If the **AUX** or **X** qualifier is omitted from the **HEATER** or **SET HEATER** commands, the command will access the main heater output, as described in 'The HEATER Command' and 'The SET Command'. If any of the auxiliary heater commands are issued to a unit which does not have the option fitted, the following message will be output:

```
-------> Option not fitted
```

G THE REVERSING SWITCH OPTION

Bipolar operation of the SMS superconducting magnet controllers is possible via the integral reversing switch fitted with SMS10C - SMS150C models or via the external RS2 option for other models. Support for the reversing switch is fully integrated into the main controller.

At the heart of both the SMS10C reversing switch and the RS2 are solid state FET switches which are arranged to give a closed transition during current reversal. The output terminals are therefore either always connected to the supply, in forward or reverse mode, or short-circuited. In the event of a mains power failure the load is short-circuited.

A bi-directional thyristor protection circuit, with a trigger voltage of 12V, is included across the output terminals to prevent damage to the power supply which would be caused by reverse current flow. Such a condition may arise if a magnet is taken out of persistent mode with the reversing switch in the inappropriate direction.

The external reversing switch is controlled via a 9-way interface cable to a connector on the main controller unit. The RS2 should only be operated under the control of the SMS controller which incorporates important checks and safeguards, as outlined in the control section below.

Do not use the voltage sense input when the reversing switch is in use. If the voltage sense polarity is reversed the controller can never detect a voltage limit condition and will limit the maximum difference between output and magnet terminal voltage to 1.4V. Eventually, fusible resistors will burn out, making remote voltage sensing ineffective.

WARNING

It is potentially lethal to attempt to disconnect the leads between the magnet and reversing switch or reversing switch and power supply while current is flowing.

RS2 Installation

If your system has been supplied with an external reversing switch as an integrated rack-mounted unit, you should still read through these installation instructions and check that all cables are correctly installed.

The RS2 is supplied with the following items:

1) IEC mains power extension lead
2) Short current leads (2)
3) 9-way control cable

The mains input lead should be connected to the RS2 and the main controller unit powered from the RS2 "POWER OUT" socket, using the supplied extension lead. In operation, the mains switch on the SMS unit should be left ON and the power to both units controlled using the front panel switch on the RS2.

Using the short current leads supplied, connect the SMS +OP terminal to the RS2 IN+ terminal and the SMS -OP terminal to the RS2 IN- terminal. The terminals should be tightened to a torque of 3-5 lbft (4-7 Nm).

Connect the supplied control cable between the "RS2" connector on the SMS unit and the 9-way connector on the rear of the RS2. Fasten the fixing screws to ensure that the cable does not become accidentally disconnected.

General Considerations

When the polarity is switched to negative, all Amps and Tesla values (except for the MID and MAX set points) are shown with a leading minus sign, both on the front panel display and in the interface messages.

If the heater is switched off with current flowing in the negative direction, this is indicated by a leading minus sign in the persistent mode record messages ("Heater switched off at..") shown on the display and sent over the interface.

At power-up the current direction is usually positive. However, if a negative persistent mode record exists, the reversing switch is initialised to the negative direction. The output polarity may only be switched when no current is being delivered by the power supply.

Front Panel Reversing Switch Control

When operating from the front panel, a current ramp in the negative direction can be initiated by pressing the button combination SHIFT+MID or SHIFT+MAX. However, this will only work if; (a) a reversing switch exists in the system, and (b) the output current and voltage are zero. At all other times, pressing SHIFT+MID or SHIFT+MAX has exactly the same effect as pressing MID or MAX alone.

If current is being driven in the negative direction, you may switch between the MID and MAX targets either by pressing the appropriate button alone or in combination with SHIFT. In either case, the direction will not be switched.

Return to zero current by pressing the ZERO button as usual (SHIFT-ZERO is not an active combination). When the current reaches zero the display will show -0.0, indicating that the reversing switch remains set to the negative direction. Subsequently, if MID or MAX is pressed without SHIFT the RS2 will switch to the positive direction before commencing the ramp. If SHIFT+MID or SHIFT+MAX is the next ramp command, the switch will remain set in the negative direction.

When the presence of a reversing switch is detected at power up, it is regularly monitored during operation. Should the reversing switch become disconnected from the power supply, a display message similar to the following will be shown:

```
 0.00 Tesla     SMS120C      0.0 Volts
        REVERSING SWITCH FAULT
```

This fault does not actually lock operation of the power supply. However, when the reversing switch is disconnected from the power supply the contactors become de-energised and the output terminals are short-circuited. The control outputs are also set to this state on detection of the fault so that reconnection of the reversing switch does not cause the contactors to re-energise. The power supply must be switched off to cancel this condition.

Interface Reversing Switch Control

When the reversing switch option is fitted, an additional interface command is available:

```
D(IRECTION) [-][+]
```

When the current polarity is changed, the following message is output:

```
HH:MM:SS CURRENT DIRECTION: [NEGATIVE][POSITIVE]
```

The present status may be interrogated by issuing the **DIRECTION** command without a qualifier. If the option is detected at power-up, the confirmation form of this message is included in the general status update block. The output polarity may only be switched when no current is being delivered by the power supply. Use of the **DIRECTION** command at any other time will return the following message:

```
-------> Cannot change current direction with current flowing
```

If the **DIRECTION** command is issued to a unit which does not have the option fitted, the following message will be output:

```
-------> Option not fitted
```

If an invalid qualifier is given to the **DIRECTION** command, the following message will be output:

```
-------> Qualifiers to DIRECTION: +,-
```

If the "REVERSING SWITCH FAULT" message is shown on the display (see the previous section) the following message will also be sent over the interface:

```
=======> REVERSING SWITCH FAULT
```

If an attempt is made to issue a **DIRECTION** command while such a fault condition exists, the following message will be output:

```
-------> Reversing switch fault
```

If no reversing switch disconnection fault has been detected but the contactors fail to properly respond to a **DIRECTION** command, the following message will be output:

```
-------> Reversing relays not switching
```

This message indicates that the **DIRECTION** command was not executed. The contactors remain in their previous state.

Please note that whilst switching off the mains supply to the power supply the '`------> Reversing switch fault`' may be seen momentarily on the front panel. This is NOT a fault but is due to the reversing switch operating mode changing before power has fully dissipated from the control circuits.

H *THE SMS10C MODEL*

The SMS10C is a low output, high resolution controller which is fitted with a linear power unit. Its main application is for the energization of shim coils.

All Amps and Tesla values displayed and output by the SMS10C model have one more decimal place than other models (Amps to 4 decimal places, Tesla to 5 decimal places).

Both the reversing switch and multiple heaters options are fitted as standard in the SMS10C (see Appendices G and H). The reversing switch components are internally fitted in the SMS10C.

Because a reversing switch is fitted, the voltage sense terminals are not available on the SMS10C (disconnected).

I NON-VOLATILE STORAGE INITIALISATION

It may happen that the message "STORAGE FAULT" appears on the display at power up. This indicates that some corruption of the non-volatile storage has occurred. In the longer term, the 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 "STORAGE ERROR" message is on the display, or as power is switched on subsequently, press the SHIFT and REMOTE buttons. This should result in the following display:

```
     Initialise non-volatile memory
Switch off to cancel, else press any key
```

Pressing any key will change the display to:

```
Press Select to initialise for SMS120C
- select correct model with SHIFT
```

The SMS controller uses a single firmware version for all models. The differences between models are stored along with user-configured parameters within the non-volatile RAM store. Therefore, be sure to select the correct model, including any "-H" suffix. If your SMS model is a SMS120C, press the SELECT button. Otherwise, press SHIFT until the correct model is shown on the upper line, then press SELECT. The display will change to:

```
Memory initialised
Now switch off
```

At this point there is no option but to switch off the unit to complete the initialisation. The next switch-on should be clear of "STORAGE FAULT". If it is not, the non-volatile RAM module has failed and you should contact CRYOGENIC for advice.

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

Note that if a "STORAGE FAULT" occurs, the only options are to switch off and press the SHIFT and REMOTE buttons on power up to re-initialise memory. If you switch the unit off, the "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 non-volatile RAM which could lead to erroneous operation.

J ALTERNATIVE OUTPUT RATINGS

Model		Output Rating	Input Power	115V	230V
SMS10C		10A,+5V,-5V	200 W	YES	YES
SMS60C		60A,+5V,-5V	600 W	YES	YES
SMS60C-H		60A,+15V,-12V	1300 W	YES	YES
SMS80C		80A,+5V,-5V	1000 W	YES	YES
SMS80C-H		80A,+15V,-12V	1500 W	NO	YES
SMS120C		120A,+5V,-5V	1000 W	YES	YES
SMS120C-H		120A,+10V,-8V	1500 W	NO	YES
SMS130C-H		130A,+9V,-8V	1500 W	NO	YES
SMS150C		150A,+4.5,-4V	1000 W	YES	YES
SMS160C-H		160A,+15V,-12V	1500 W	NO	YES
SMS240C	*	240A,+5V,-5V	2000 W	YES	YES
SMS240C-H	*	240A,+10V,-8V	3000 W	NO	YES
SMS300C	*	300A,+4.5,-4V	2000 W	YES	YES
SMS450C	*	450A,+4.5,-4V	3000 W	YES	YES
SMS600C	**	600A,+5V,-4.5V	5250 W	NO	NO

* Master-Slave configuration (see Appendix K)
**Integrated - Master-Slave with single "Brick" (3Ph + Neutral 380-415V AC)
** See Appendix L

K *HIGH OUTPUT MULTIPLE UNITS*

To achieve output currents larger than the standard 80, 120 or 150 Amps, CRYOGENIC offer a modular system of multiple units based on a single main (master) unit and up to 3 slave units., giving a maximum possible output capability of 600A. See Appendix J for standard configurations.

The master unit is identical to a standard power supply apart from the inclusion of an additional 9-way 'D' type connector on the rear of the unit which carries the necessary control signals to the slave(s). Each slave unit has a male and a female 9-way 'D' type connector which are used to connect the master and subsequent slaves in "daisy-chain" fashion.

Multiple power supplies are normally supplied complete with output bus-bar and interconnecting wiring, mounted in a 19" rack. Each slave unit takes the drive signal to the output amplifier of the master unit and uses it to drive its own output amplifier producing an identical output current.

The current from each slave is measured by individual shunts within each slave.
The master unit sums the shunt voltages from itself and each slave and uses them to produce an accurately controlled output.

There is only one adjustment within the slave unit and that is current balance (RV1). This potentiometer is factory set at full output to give a current balance between master and slave(s) of better than 5A.

It should be noted that the master unit DVM output for multiple units represents the buffered shunt voltages from the master and all the slaves and is scaled to give between 3 and 7.5V at full output.

Each mains input to the power supply can draw up to 10A from the mains supply and suitable arrangements must be made to provide an adequately rated fused supply to the complete rack.
The mains supply to each slave is switched by a double pole relay within the slave, energised by a control voltage from the master.

L 600A UNIT - DESCRIPTION

The 600A power supply is an integrated master-slave system with one master, three slave units and a switch-mode power unit (brick).

The unit consists of two 4U boxes fitted with the master + 1 slave and a second 4U box containing two slaves. A third (6U) box at the base of the rack holds the "brick" unit.

This system is operated from an AC mains **three-phase neutral earth only.** The output DC current is supplied from the two bus bars at the back of the unit via 3 x 35mm² cables.

The master, slave and brick units are integrated via a D-type connection cable which carries all necessary signals.

The DVM output terminals are provided for precise analogue measurement of the output current.

The brick has fitted a 3 phase mains switch, two LCD displays, 3 LED’s and two potentiometers. The potentiometers are protected by locking nuts.

The brick is operating in an external voltage control mode, what is normally indicated by lighting of the LED nearest to the Voltage LCD display.

The foldback current is set to the maximum value and should not be adjusted. In this condition the LED nearest the LCD current display will remain permanently off.

The third LED (nearest to the right handle) indicates the mains phase condition. When that LED is ON this indicates one of the mains phases is missing or the phase connection order is incorrect.

M *Intelligent reverse option*

The Intelligent Reverse of the current output is possible if the reversing switch is fitted together with the special version of internal software.

The manual command for reversing the current direction will be issued when SHIFT+MAX or SHIFT+MID buttons are pressed.

When only positive current direction is required then depressing either the MID or MAX button will make the power supply ramp to the positive SET current.

If the opposing current direction is required then depressing either the MID or MAX button together with the SHIFT button will make the power supply ramp to the SET current in the opposite sense.

When the power supply is holding the current at the positive target, issuing the command SHIFT+MID or (MAX) will make the power supply ramp the current to ZERO and then when the Voltage on the output terminals is detected '0' the power supply will automatically reverse the current direction by operating the reversing switch and start ramping to the negative target. Pressing SHIFT+(MID) or (MAX) again will reverse the process.

The same effect of the function under remote control operation is available by issuing the command:

D(IRECTION)[+] or **[-]**
Zero target will be obtained as normal by the remote command: **R(AMP) [0]** or in manual operation by pressing the ZERO button.

During the process of crossing through "0" Amps a voltage rise on the power supply terminals occurs which is dependant on the coil inductance. The current ramp rate is constant during the voltage excursion.. The voltage rise is caused by a 5 millisecond short of the terminals as the current direction is changed. This effect is more noticeable on power supplies fitted with solid state reversing switch units.

N *Low Field Option*

The low field option is a special precision bipolar current source with a maximum current of 300mA fitted in the power supply with the FET reversing switch.

The low field option current source is accessible only under remote control operation.

The Low Field Option is activated using the following command:

D(IRECTION) [0]

Note:
Access to the low field option is only possible when the current and voltage from the main power supply is '0' and the magnet is not in persistent mode.

When the Low field option is selected the main power supply will be disconnected from the output terminals and the Low Field Option current source will be connected instead.

The switch heater can operate as normally used with the main power supply unit.

WARNING: If the magnet is in persistent mode after having been energised with the main power supply, the low field option should not be selected until the magnet is fully discharged (using the main power supply). If the switch heater is activated without first discharging the magnet the low field option electronics will suffer severe damage.

The low field option current source is controlled by a 20-bit bipolar D-A converter optically isolated from the control signals. The control signals are generated by the LabView software VI's and the wire connections to the parallel port of the control computer. The special cable is provided with power supplies fitted with the Low field Option.

The connection cable also includes a twisted pair of wires directly connected to a shunt resistor for the precise current readout of the Low Field Option's current source.

For remote operation:

D(IRECTION) [0] for Low field option activation.

When the low field option is selected the main "switch mode" power supply and the heatsink fan are turned off and the Low Field Option current source is activated.
The value of the current can only be controlled by Labview VI panel. There is no ramp generator for the Low Field Option.

The return to the main power supply is obtained by using one of the commands:

D(IRECTION) [+] or
D(IRECTION) [-]

O *Mains Input Voltage Options*

Input Voltage:	EWS1500 BRICK SET:	Linear Power Supply SET:
100V	LINK A-B ON	J1 1-2-3 linked and 4-5-8 linked
115V	LINK A-B ON	J1 1-2-3 linked and 6-7-8 linked
200V	LINK A-B OFF	J1 1-2 linked and 3-4 linked and 5-8 linked
215V	LINK A-B OFF	J1 1-2 linked and 3-6 linked and 5-8 linked
230V	LINK A-B OFF	J1 1-2 linked and 3-6 linked and 7-8 linked

Note:

BRICKS HWS series
Mains Voltage setting is automatic

P *USB Interface*

Currently the standard SMS series power supplies are installed with a USB interface as standard.

The procedure for the installation of the USB driver on a host computer requires that the driver software is loaded prior to connecting the USB cable between the power supply interface and the control computer. The driver can be found on the companion disk supplied with the power supply. Alternatively, if the computer is connected to the Internet, Windows XP operating system will find the relevant driver.

Once the software CD with the driver is in the CD drive, connecting the USB cable between the computer and the power supply will automatically start the installation process. The mains supply not need to be connected to the power supply at this stage.
The driver installation has two stages; first, the software installs the support for USB controller, and secondly the software installs a virtual COM port. If the host computer hardware already has two COM ports installed, (which are handled by BIOS and labelled as COM1 and COM2), the emulation port will take the next available label as COM3.

Once the port is installed the power supply can be turned ON and communication should be established. To test the communication the user can try the Windows Hyper terminal (with standard settings) for serial communication.

Labview applications are normally using VISA drivers, so Visa should be installed prior to using the LabView VI's. The VISA drivers are also included on the CD supplied with the power supply. The VISA drivers can also be downloaded from the National Instruments web site.

All instructions for communications to the power supply are used as for the standard serial port.