Model 625 Superconducting Magnet Power Supply

Model 625 features

- 60 A/5 V, bipolar, true 4-quadrant output
- 0.1 mA output setting resolution
- Linear regulation minimizes noise
- Ripple ≤ 0.007% of maximum current (into a 1 mΩ load)
- 1 mA per hour stability
- Parallel operation to ±120 A
- Full 3 year standard warranty

Introduction

The Model 625 superconducting magnet power supply is the ideal supply for small to medium sized superconducting magnets used in high sensitivity materials research applications. The Model 625 is a practical alternative to both the larger, one size fits all, superconducting magnet supplies and the endless adaptations of generic power supplies. By limiting output power, Lake Shore was able to concentrate on the performance requirements of the most demanding magnet users. The resulting Model 625 provides high precision, low noise, safety, and convenience.

Precision in magnetic measurements is typically defined as smooth continuous operation with high setting resolution and low drift. Achieving these goals while driving a challenging load, such as a superconducting magnet, requires a unique solution. The Model 625 delivers up to 60 A at a nominal compliance voltage of 5 V, with the supply acting as either a source or a sink in true 4-quadrant operation. Its current source output architecture with analog control enables both smooth operation and low drift. A careful blending of analog and digital circuits provides high setting resolution of 0.1 mA and flexible output programming.

Lake Shore chose linear input and output power stages for the moderate 300 W output of the Model 625. Linear operation eliminates the radiated radio frequency (RF) noise associated with switching power supplies, allowing the Model 625 to reduce the overall noise in its output and the noise radiated into surrounding electronics.

Safety should never be an afterthought when combining stored energy and liquid cryogens in a superconducting magnet system. The Model 625 incorporates a variety of hardware and firmware protection features to ensure the safety of the magnet and supply.

Instrument users have come to rely on Lake Shore for convenience and ease of use. The Model 625 includes the features necessary to conveniently manage a superconducting magnet, such as a persistent switch heater output, calculated field reading, current ramping, and quench detection. Computer interfaces are also integrated for automation of the magnet system. The Model 625 is truly an excellent one-box solution for controlling a superconducting magnet.

Output architecture

True 4-quadrant output capability of the Model 625 is ideal for the charge and discharge cycling of superconducting magnets for both positive and negative fields. Tightly integrated analog control of the 4-quadrant output provides smooth current change with very low overshoot on output change. The Model 625 has the ability to charge and discharge magnets up to a 5 V rate.

True 4-quadrant operation eliminates the need for external switching or operator intervention to reverse the current polarity, significantly simplifying system design. The transition through zero current is smooth and continuous, allowing the user to readily control the magnetic field as polarity changes.

At static fields, output current drift is also kept low by careful attention in the analog control circuits and layout. The high stability and low noise of the Model 625 make it possible in many situations to run experiments without going into persistent mode. This can help to reduce the time necessary to gather data.

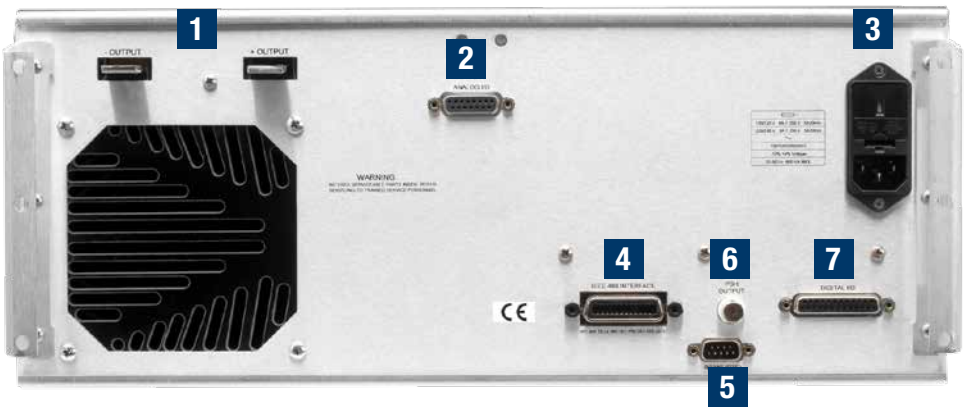
The Model 625 output architecture relies on low noise, linear input and output stages. The linear circuitry of the Model 625 permits operation with less electrical noise than switch-mode superconducting magnet power supplies. One key benefit of this architecture is CE compliance to the electromagnetic compatibility (EMC) directive, including the radiated emissions requirement.

Output programming

The Model 625 output current is programmed internally via the keypad or the computer interface, externally by the analog programming input, or by the sum of the external and internal settings. For the more popular internal programming, the Model 625 incorporates a proprietary digital-to-analog converter (DAC) that is monotonic over the entire output range and provides a resolution of 0.1 mA.

Model 625 rear panel

1 Positive and negative outputs
2 Analog I/O
3 Line input assembly
4 IEEE-488 interface
5 Serial (RS-232C) I/O (DTE)
6 PSH output
7 Digital I/O



The Model 625 generates extremely smooth and continuous ramps with virtually no overshoot. The digitally generated constant current ramp rate is variable between 0.1 mA/s and 99.999 A/s. To assure a smooth ramp rate, the power supply updates the high-resolution DAC 27 times per second. A low-pass filter on the output DAC smooths the transitions at step changes during ramping. Ramping can also be initiated by the trigger input.

The output compliance voltage of the Model 625 is settable to a value between 0.1 V and 5 V, with a 100 µV resolution. The voltage setting is an absolute setting, so a 2 V setting will limit the output to greater than –2.0 V and less than +2.0 V.

Output readings

The Model 625 provides high-resolution output readings. The output current reading reflects the actual current in the magnet, and has a resolution of 0.1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 100 µV. A remote voltage reading is also available to more accurately represent the magnet voltage by bypassing voltage drops in the leads connecting the power supply to the magnet. All output readings can be prominently displayed on the front panel and read over the computer interface.

Protection

Managing the stored energy in superconducting magnets necessitates several different types of protection. The Model 625 continuously monitors the load, line voltage, and internal circuits for signs of trouble. Any change outside of the expected operating limits triggers the supply to bring the output to zero in a fail-safe mode. When line power is lost, the output crowbar (SCR) will activate and maintain control of the magnet, discharging at a rate of 1 V until it reaches zero.

Quench detection is necessary to alert the user and to protect the magnet system. The Model 625 uses a basic and reliable method for detecting a quench. If the current changes at a rate greater than the current step limit set by the operator, a quench is detected and the output current is safely set to zero.

The remote inhibit input allows an external device to immediately set the output current to zero in case of a failure. This input is normally tied to an external quench detection circuit, the fault output of a second power supply, or an emergency shutdown button. The fault output is a relay contact that closes when a fault condition occurs. The contact closure alerts other system components of the fault.

Parallel operation

If an application requires more output current than a single Model 625 can provide, two supplies can be connected in parallel for 120 A/5 V operation. Each unit is programmed for half of the total output current, operates independently, and retains 0.1 mA resolution at 60 A operation. When the units are properly configured, either unit can detect a fault, protect itself, and issue a fault output signaling the other unit to automatically enter the proper protection mode.

Persistent switch heater output

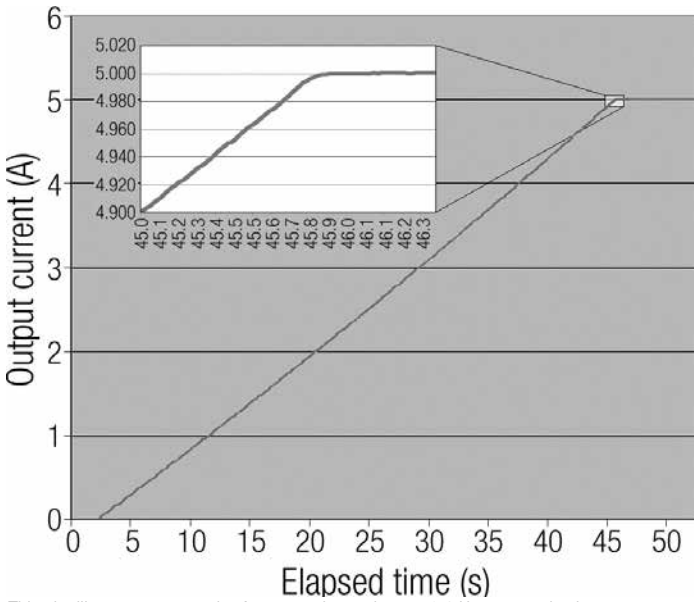
The integrated persistent switch heater output is a controlled DC current source capable of driving most switch heaters. It sources from 10 mA to 125 mA with a setting resolution of 1 mA and selectable compliance voltage of 12 V or 21 V. The minimum load that the persistent switch heater can drive is 10 Ω. Persistent mode operation is integrated into the instrument firmware to prevent mis-operation of the magnet.

Interfaces

The Model 625 includes IEEE-488 and RS-232C computer interfaces that provide access to operating data, stored parameters, and remote control of all front panel operating functions. In addition, the Model 625 includes a trigger function that is used to start an output current ramp. When the trigger is activated, either by an external trigger or by computer interface command, the power supply will begin ramping to the new setpoint.

The Model 625 provides two analog outputs to monitor the output current and voltage. Each output is a buffered, differential, analog voltage representation of the signal being monitored. The current monitor has a sensitivity of 1 V = 10 A, while the voltage monitor has a sensitivity of 1 V = 1 V.

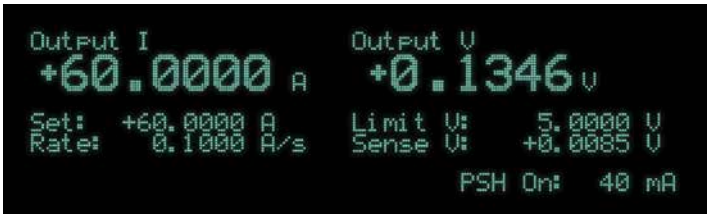
Current change using internal programming



This plot illustrates an actual 5 A current change into an 8.6 H superconducting magnet. A smooth, 95 mA/s ramp is shown with minimal overshoot highlighted in the detail area. (Output current monitor measured at 58.88 Hz rate with a HP 34401 – data multiplied by 10× to obtain output current results.)

Display and keypad

The Model 625 incorporates a large 8-line by 40-character vacuum fluorescent display. Output current, calculated field in tesla or gauss, output voltage, and remote voltage sense readings can be displayed simultaneously. Five LEDs on the front panel provide quick verification of instrument status, including ramping, compliance, fault, PSH status, and computer interface mode. Error conditions are indicated on the main display along with an audible beeper. Extended error descriptions are available under the Status key.



Current and voltage settings, current and voltage readings, ramp rate, voltage sense, and persistent switch heater status and instrument status displayed simultaneously

The instrument can be set up to show calculated field along with output field setting, current ramp rate, the output current reading, the output current setting, the output voltage setting, the voltage compliance setting, and the remote voltage sense reading

The keypad is arranged logically to separate the different functions of the instrument. The most common functions of the power supply are accessed using a single button press. The keypad can be locked to either lock out all changes or to lock out just the instrument setup parameters allowing the output of the power supply to be changed.

Specifications

Output

Type Bipolar, 4-quadrant, DC current source
Current generation Linear regulation with digital setting and analog control
Current range ±60 A
Compliance voltage ±5 V maximum (nominal, both source and sink)
Maximum power 300 W
Load reactance 0 H to 100 H
Current ripple (max) 4 mA RMS at 60 A, (0.007%) into 1 mΩ load (significantly reduced into a reactive load or at lower current)
Current ripple frequency Dominated by line frequency and its harmonics
Temperature coefficient ±15 ppm of full scale/°C
Line regulation 15 ppm/6% line change
Source impedance 25 Ω
Stability (1 h) 1 mA/h (after warm-up)
Stability (24 h) 10 mA/24 h (typical, dominated by temperature coefficient and line regulation)
Isolation Output optically isolated from chassis to prevent ground loops
Parallel operation 2 units can be paralleled for ±120 A, ±5 V operation
Protection Quench, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and remote inhibit (on critical error conditions, magnet discharges at 1 V nominal)

Output programming

Internal current setting	
Resolution	0.1 mA (20-bit)
Settling time	600 ms for 1% step to within 0.1 mA into a resistive load
Accuracy	±10 mA ±0.05% of setting
Operation	Keypad, computer interface
Protection	Current setting limit
Internal current ramp	
Ramp rate	0.1 mA/s to 99.999 A/s (compliance limited)
Update rate	27.7 increments/s
Ramp segments	5
Operation	Keypad, computer interface, and trigger input
Protection	Ramp rate limit
External current programming	
Sensitivity	6 V = 60 A
Resolution	Analog
Accuracy	±10 mA ±1% of setting
Bandwidth (3 dB)	40 Hz, 2-pole, low-pass filter (10 Hz pass band, compliance limited)
Input resistance	>50 kΩ
Operation	Voltage program through rear panel
Connector	Shared 15-pin D-sub
Limits	Internally clamped at 6.1 V
Compliance voltage setting	
Range	0.1 V to 5.0 V
Resolution	100 µV
Accuracy	±10 mV ±1% of reading

Readings

Output current	
Resolution	0.1 mA
Accuracy	±1 mA ±0.05% of reading
Update rate	2.5 readings/s display, 10 readings/s interface
Compensation	Compensated for lead resistance and 25 Ω source resistance
Output voltage (at supply terminals)	
Resolution	100 µV
Accuracy	±1 mV ±0.05% of reading
Update rate	2.5 readings/s display, 5 readings/s interface

Remote voltage (at magnet leads)

Resolution	100 µV
Accuracy	±1 mV ±0.05% of reading
Update rate	1.25 readings/s
Input resistance	>50 kΩ
Connector	Shared 15-pin D-sub

Persistent switch heater output (PSHO)

Current range 10 mA to 125 mA
Compliance voltage (minimum) 12 V or 21 V selectable
Heater resistance (minimum) 10 Ω
Setting resolution 1 mA
Accuracy ±1 mA
Operation On/Off with lockout delay of 5 s to 100 s
Protection Open or shorted heater detection, error message if off and on output currents differ
Connector BNC

Front panel

Display type 8-line by 40-character, graphic vacuum fluorescent display module
Display readings Output current, calculated field (T or G), output voltage, and remote voltage sense
Display settings Output current, calculated field, compliance voltage, and ramp rate
Display annunciators Status and errors
LED annunciators PSHO on, remote, compliance limit, fault, and ramping
Keypad type 26 full travel keys
Keypad functions Direct access to common operations, menu driven setup

Interface

IEEE-488.2 interface

Features	SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT1, C0, E1
Reading rate	To 10 readings/s
Software support	National Instruments LabVIEW™ driver (see www.lakeshore.com)

Serial interface

Electrical format	RS-232C
Baud rates	9600, 19200, 38400, 57600
Reading rate	To 10 readings/s
Connector	9-pin D-sub

Output current monitor

Sensitivity	60 A = 6 V
Accuracy	±1% of full scale
Noise	1 mV
Source impedance	20 Ω
Connector	Shared 15-pin D-sub

Output voltage monitor

Sensitivity	1 V = 1 V
Accuracy	±1% of full scale
Noise	1 mV
Source impedance	20 Ω
Connector	Shared 15-pin D-sub

Fault output

Type	Relay (closed on fault)
Relay contact	30 VDC at 1 A
Connector	Shared 25-pin D-sub

Remote inhibit input

Type	TTL or contact closure
Connector	Shared 25-pin D-sub

Trigger input

Type	TTL or contact closure
Connector	Shared 25-pin D-sub

General

Ambient temperature 15 °C to 35 °C
Cooling Air cooled with internal 2-speed fan
Warm-up 30 minutes at output current setting
Line power 100, 120, 220, 240 VAC +6% -10%, single phase, 50 or 60 Hz, 850 VA
Size 483 mm W × 178 mm H × 520 mm D (19 in × 7 in × 20.5 in), rack mount (integrated rack mount ears)
Weight 27.2 kg (60 lb)
Calibration schedule 1 year

Ordering information

Part number	Description
625	Superconducting magnet power supply—includes two front handles (6241), two rear handles/protectors (6242), one output shorting bar and terminal fasteners (6243), one 25-pin D-sub digital I/O mating connector (6251), one 15-pin D-sub analog I/O mating connector (6252), a calibration certificate and a user's manual
625-DUAL	Two Model 625s and one 6263 dual supply interconnect cable kit

Please indicate your power/cord configuration:

1 100 V—U.S. heavy duty cord (NEMA 5-15)
2 120 V—U.S. heavy duty cord (NEMA 5-15)
3 220 V—Euro cord (CEE 7/7)
4 240 V—Euro cord (CEE 7/7)
5 240 V—U.K. cord (BS 1363)
6 240 V—Swiss cord (SEV 1011)
7 220 V—China cord (GB 1002)

Accessories

6201	1 m (3.3 ft) long IEEE-488 (GPIB) computer interface cable assembly
6261	10 ft magnet cable kit, AWG 4
6262	20 ft magnet cable kit, AWG 4
6263	Dual supply interconnect cable kit including magnet cables and safety interlock cable
CAL-625-CERT	Instrument recalibration with certificate
CAL-625-DATA	Instrument recalibration with certificate and data
119-037	Model 625 user manual

All specifications are subject to change without notice