

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 $\leq 0.007\%$ of maximum current (into a 1 m Ω load)
- 1 mA per hour stability
- Parallel operation to ± 120 A

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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 cryogenics 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.

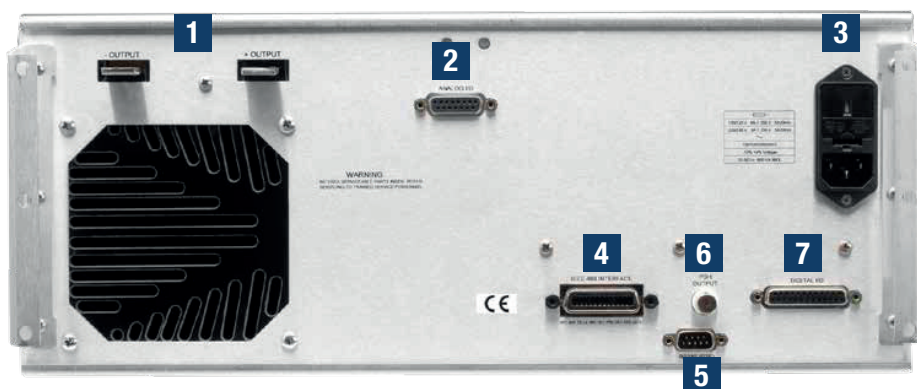
The Model 625 output architecture relies on low noise, linear input and output stages. The linear circuitry of the Model 625 permits operation with less electrical noise than switch-mode superconducting magnet power supplies. One key benefit of this architecture is CE compliance to the electromagnetic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



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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 μ V 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 μ V. 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

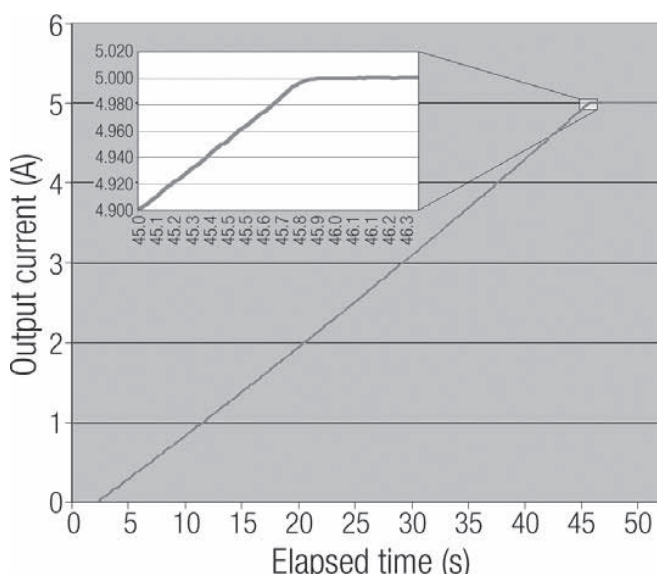
The integrated persistent switch heater output is a controlled DC current source capable of driving most switch heaters. It sources from 10 mA to 125 mA with a setting resolution of 1 mA and selectable compliance voltage of 12 V or 21 V. The minimum load that the persistent switch heater can drive is 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



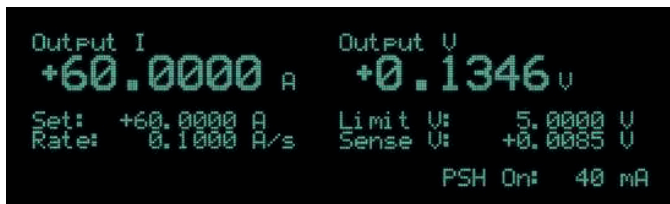
This plot illustrates an actual 5 A current change into an 8.6 H superconducting magnet. A smooth, 95 mA/s ramp is shown with minimal overshoot highlighted in the detail area. (Output current monitor measured at 58.88 Hz rate with a HP 34401 – data multiplied by 10 \times to obtain output current results.)

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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 m Ω 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/ $^{\circ}$ 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)
Setting time 600 ms for 1% step to within 0.1 mA into a resistive load
Accuracy ± 10 mA $\pm 0.05\%$ 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 $\pm 1\%$ of setting
Bandwidth (3 dB) 40 Hz, 2-pole, low-pass filter (10 Hz pass band, compliance limited)
Input resistance > 50 k Ω
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 μ V
Accuracy ± 10 mV $\pm 1\%$ of reading

Readings

Output current

Resolution 0.1 mA
Accuracy ± 1 mA $\pm 0.05\%$ 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 μ V
Accuracy ± 1 mV $\pm 0.05\%$ of reading
Update rate 2.5 readings/s display, 5 readings/s interface

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Remote voltage (at magnet leads)

| | |
|-------------------------|------------------------------------|
| Resolution | 100 μ V |
| Accuracy | ± 1 mV $\pm 0.05\%$ of reading |
| Update rate | 1.25 readings/s |
| Input resistance | >50 k Ω |
| 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 | $\pm 1\%$ 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 | $\pm 1\%$ 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 $^{\circ}$ C to 35 $^{\circ}$ C |
| Cooling | Air cooled with internal 2-speed fan |
| Warm-up | 30 minutes at output current setting |
| Line power | 100, 120, 220, 240 VAC $\pm 6\%$ -10%, single phase, 50 or 60 Hz, 850 VA |
| Size | 483 mm W \times 178 mm H \times 520 mm D (19 in \times 7 in \times 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