



## Model 648 Bipolar Magnet Power Supply



### Model 648 features

- Low noise
- CE mark certification
- $\pm 135\text{ A}/\pm 75\text{ V}$ , 9.1 kW
- Built-in fault protection
- Bipolar, linear, 4-quadrant output
- 1 mA of programmed current resolution
- Analog programming and IEEE-488 and USB interfaces





## Introduction

The Model 648 electromagnet power supply is a robust, fault-tolerant 9 kW supply optimized for powering large 7 or 10 in research electromagnets. It is specifically designed for high precision laboratory use requiring extremely low electrical noise. The linear design removes undesirable higher frequency noise typical of switch mode power supplies. Eliminating the need for external switching or operator intervention to reverse current polarity, the Model 648 uses convenient bipolar, 4-quadrant operation. It is capable of supplying  $\pm 135\text{ A}/\pm 75\text{ V}$  to a nominal 0.5  $\Omega$ , 0.5 H load. The Model 648 is built to last with a rugged design, integrated fault protection, and a simple, clean interior electronic design.

This robust power supply is developed to minimize downtime. It uses worry-free water cooling for quiet efficient operation compared to air-cooled power supplies. The seamless water lines only have external junctions, eliminating internal water leaks. In addition, safety interlocks ensure that cooling water is always flowing to the supply while operating. Magnet water can also be interlocked into the power supply if desired. Internal software controls manage water usage intelligently.

## Output architecture

The low electrical noise design of the Model 648 makes it the ideal power supply for use with large electromagnets in high precision laboratory settings, ensuring greater resolution and finer detail in data taken during highly sensitive measurements. Because low noise is critical to measurement systems, the Model 648 implements both a linear design and bipolar architecture. Linear magnet power supplies have several advantages over switch mode power supplies, primarily smooth field generation that is nearly free from offending electromagnetic signatures. The bipolar, 4-quadrant operation required to safely operate an inductive load provides clean transitions through zero without discontinuities.

## Output programming

The Model 648 output current is programmed internally via the keypad or the computer interface, externally by analog programming input, or by the sum of the external and internal settings. External programming via analog input signal provides analog resolution. The Model 648 generates extremely smooth and continuous ramps — the digitally generated constant current ramp rate is variable between 0.1 mA/s and 50.000 A/s. To ensure a smooth ramp rate, the power supply updates the high-resolution DAC 12.3 times per second.

## Output reading

The Model 648 provides high-resolution output current readings that reflect the actual current in the magnet, and have a resolution of 1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 1 mV. All output readings can be prominently displayed on the front panel and read over the computer interface.

## Protection

The Model 648 provides built-in protection against short circuit, open circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and abrupt change of the external programming input. A proprietary circuit limits the power dissipated in the water-cooled cold plate should low resistance and high line conditions exist. The Model 648 protects itself if operated into resistances outside of nominal limits. By limiting current output, it will safely operate into a shorted load, and operate safely into high resistance loads by limiting voltage output. The Model 648 is also protected against power loss under full operation and nominal magnet load. Both low and high power line conditions are reported on the front panel display.



## Specifications

### Output

**Type:** Bipolar, 4-quadrant, DC voltage/current source  
**Current generation:** Fully linear regulation with digital setting and analog control  
**Current range:**  $\pm 135$  A nominal  
**Compliance voltage (DC):**  $\pm 75$  V  
**Power:** 9.1 kW nominal  
**Nominal load:** 0.5  $\Omega$ , 0.5 H  
**Maximum load resistance:** 0.55  $\Omega$  for  $\pm 135$  A DC operation at +10% to -5% line voltage  
**Minimum load resistance:** 0.41  $\Omega$  for  $\pm 135$  A DC operation at +5% to -10% line voltage  
**Load inductance range:** 0 H to 1 H  
**Current ripple:** 10 mA RMS (0.007%) at 135 A into nominal load  
**Current ripple frequency:** Dominated by the line frequency and its harmonics  
**Temperature coefficient:**  $\pm 50$  ppm of full scale/ $^{\circ}$ C  
**Line regulation:**  $\pm 75$  ppm of full scale/10% line change  
**Stability (1 h):** 2 mA/h (after warm-up, internal setting)  
**Stability (24 h):** 10 mA/24 h (typical, internal setting, dominated by temperature coefficient and line regulation)  
**Isolation:** Differential output is optically isolated from chassis to prevent ground loops  
**Slew rate:** 50 A/s into nominal load (dominated by magnet characteristics), 100 A/s maximum into a resistive load  
**Settling time:**  $< 1$  s for 10% step to within 1 mA of output into nominal load  
**Harmonic distortion:**  $\leq 0.1$  Hz at  $\pm 135$  A sine wave into resistive load,  $< 0.02\%$  THD;  $\leq 10$  Hz at  $\pm 10$  A sine wave into resistive load,  $< 0.30\%$  THD  
**Attenuation:** -0.5 dB at 10 Hz (external programming input)  
**Protection:** Short circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, and over temperature  
**Connector:** Two lugs with 8.64 mm (0.34 in) holes for M8 or 5/16 in bolts

### Output programming

#### Internal current setting

**Resolution:** 1.0 mA (20-bit)  
**Settling time:** 600 ms for 1% step to within 1 mA (of internal setting)  
**Accuracy:**  $\pm 20$  mA  $\pm 0.05\%$  of setting  
**Operation:** Keypad, computer interface  
**Protection:** Programmable current setting limit

#### Internal current ramp

**Ramp rate:** 0.1 mA/s to 50,000 A/s (compliance limited)  
**Update rate:** 12.3 increments/s  
**Ramp segments:** 5  
**Operation:** Keypad, computer interface  
**Protection:** Programmable ramp rate limit

#### External current programming

**Sensitivity:** 10 V/135 A  
**Resolution:** Analog  
**Accuracy:**  $\pm 20$  mA  $\pm 1\%$  of setting  
**Input resistance:** 20 k $\Omega$  differential, 50 k $\Omega$  common-mode  
**Operation:** Voltage program through rear panel, can be summed with internal current setting  
**Limits:** Internally clamped at  $\pm 10.1$  V and bandwidth limited -3 dB at 40 Hz (2 pole, low pass filter)  
**Connector:** Shared 15-pin D-sub

### Readings

#### Output current

**Resolution:** 1.0 mA  
**Accuracy:**  $\pm 20$  mA  $\pm 0.05\%$  of rdg  
**Update rate:** 2.5 rdg/s display, 10 rdg/s interface

#### Output voltage (at supply terminals)

**Resolution:** 1.0 mV  
**Accuracy:**  $\pm 10$  mV  $\pm 0.05\%$  of rdg  
**Update rate:** 2.5 rdg/s display, 5 rdg/s interface

### Front panel

**Display type:** 8-line by 40-character graphic vacuum fluorescent display module  
**Display readings:** Output current, output voltage, and internal water temperature  
**Display settings:** Output current and ramp rate  
**Display annunciators:** Status and errors  
**LED annunciators:** Fault, Compliance, Power Limit, Ramping, Remote  
**Audible annunciator:** Errors and faults  
**Keypad type:** 20 full-travel keys  
**Keypad functions:** Direct access to common operations, menu-driven setup  
**Power:** Green flush ON and red extended OFF push buttons

### Interface

#### IEEE-488.2 interface

**Features:** SH1, AH1, T5, L4, SR1, RL1, PPO, DC1, DT0, C0, E1  
**Reading rate:** To 10 rdg/s  
**Software support:** National Instruments LabVIEW™ driver (consult Lake Shore for availability)

#### USB interface

**Function:** Emulates a standard RS-232 serial port  
**Baud rate:** 57,600  
**Reading rate:** To 10 rdg/s  
**Connector:** Type B USB connector  
**Software support:** National Instruments LabVIEW™ driver (consult Lake Shore for availability)

#### Output current monitor

**Sensitivity:** 7 V/135 A  
**Accuracy:**  $\pm 1.5\%$  of full scale  
**Noise:** 5 mV RMS  
**Source impedance:** 20  $\Omega$   
**Connector:** Shared 15-pin D-sub

#### Output voltage monitor

**Sensitivity:** 7 V/70 V  
**Accuracy:** 1% of full scale  
**Noise:** 2 mV RMS  
**Source impedance:** 20  $\Omega$   
**Connector:** Shared 15-pin D-sub

#### Power supply cooling water

**Remote enable input:** TTL low or contact closure to enable output; used for mandatory 1 gal/min flow switch (included)  
**Connector:** 2-pin detachable terminal block connector  
**Valve power output:** 24 VAC at 1.5 A maximum, automatic or manual control  
**Connector:** 2-pin detachable terminal block connector  
 Water valve optional

#### Magnet cooling water

**Remote enable input:** TTL low or contact closure to enable output; jumper required if unused  
**Valve power output:** 24 VAC at 1.5 A maximum, automatic or manual control

**Connector:** Shared 4-pin detachable terminal block  
 Flow, temperature switch, and water valve not included

#### Auxiliary

**Emergency stop:** Requires 1 A, 24 VAC normally closed (NC) contact to enable power-up; jumper required if unused  
**Fault output:** Relay with normally open (NO) or normally closed (NC) contact, 30 VDC at 1 A  
**Remote enable input:** TTL low or contact closure to enable output; jumper required if unused  
**Connector:** Shared 8-pin detachable terminal block; Emergency stop and inhibit switches not included

### General

#### Line power

**Power:** 15.5 kVA max  
**Voltage and current:** 200 VAC  $\pm 5\%$ , 41 A/phase; 208 VAC  $\pm 5\%$ , 40 A/phase; 220 VAC  $\pm 5\%$ , 38 A/phase; 230 VAC  $\pm 5\%$ , 37 A/phase; 380 VAC  $\pm 5\%$ , 23 A/phase; 400 VAC  $\pm 5\%$ , 21 A/phase; 415 VAC  $\pm 5\%$ , 21 A/phase  
**Protection:** 3-phase thermal relay with adjustable current setting; two class CC 2 A fuses; over-voltage lockout circuit  
**Frequency:** 50 Hz or 60 Hz  
**Configuration:** 3-phase delta  
**Connector:** 4-pin terminal block;  
 Line voltage must be specified at time of order but is field reconfigurable; cable from power supply to facility power not included

#### Cooling water

**Flow rate:** 7.6 L (2.0 gal)/min minimum  
**Maximum pressure:** 552 kPa (80 psi)  
**Pressure drop:** 159 kPa (23 psi) at 7.6 L (2.0 gal)/min minimum for power supply and mandatory flow switch  
**Temperature:** 15  $^{\circ}$ C to 30  $^{\circ}$ C (non-condensing)  
**Connection:** Two 12.7 mm (0.5 in) hose barbs  
**CAUTION:** Internal condensation can cause damage to the power supply  
**Enclosure type:** Custom 19 in rack cabinet  
**Size:** 559 mm W  $\times$  673 mm D  $\times$  1054 mm H (22 in  $\times$  26 in  $\times$  42 in)  
**Weight:** 225 kg (495 lb)  
**Shipping size:** 914 mm W  $\times$  1168 mm D  $\times$  1219 mm H (36 in  $\times$  46 in  $\times$  48 in)  
**Shipping weight:** 281 kg (620 lb)  
**Ambient temperature:** 15  $^{\circ}$ C to 35  $^{\circ}$ C at rated accuracy, 5  $^{\circ}$ C to 40  $^{\circ}$ C at reduced accuracy  
**Humidity:** Non-condensing  
**Warm-up:** 30 min at output current setting  
**Approvals:** CE mark—low voltage compliance to EN61010-1, EMC compliance to EN61326-1

## Ordering information

Part number	Description
648	Model 648—specify 200 VAC, 208 VAC, 220 VAC, 230 VAC, 380 VAC, 400 VAC, or 415 VAC

All specifications are subject to change without notice