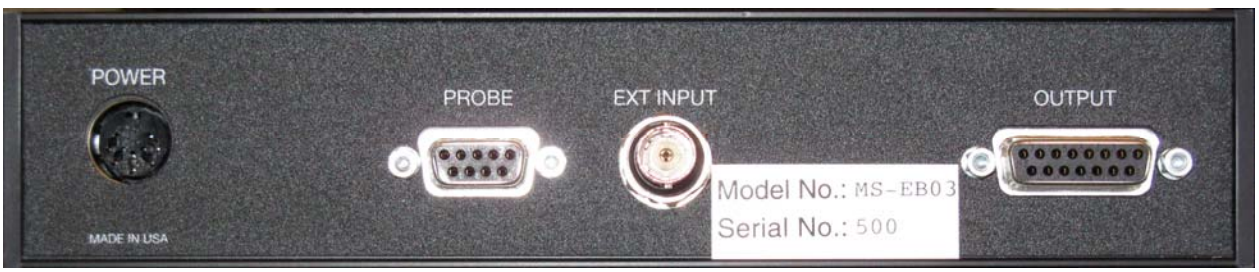
1 DESCRIPTION

The Model MS-EB03 Mr. SQUID Electronics Box from STAR Cryoelectronics provides a simple and convenient way to display SQUID and Josephson junction current-voltage (*V*-*I*) and voltage-flux (*V*-Φ) characteristics on an oscilloscope. The low-noise electronics can be powered using an external power pack or batteries. Three selectable voltage amplification ranges (100×, 1,000×, and 10,000×) enable characterization of shunted and unshunted junctions. The electronics employ a true four-terminal technique with differential bias current source. A direct measurement of the bias current using a precision series resistor enables accurate characterization of unshunted Josephson junctions below the energy gap.

Buffered outputs are available for easy interfacing to an optional data acquisition accessory in order to digitize, display, and capture the *I*-*V* and *V*-Φ characteristics on a Windows-based PC via a USB 2.0 interface. The digitizers are bus powered and based on National Instruments' 14-bit (48 kS/s maximum sampling rate) or 16-bit (250 kS/s maximum sampling rate) data acquisition devices.

Adapter cables are available to simplify connections to STAR Cryoelectronics' standard 10-pin and 14-pin cryocables and general-purpose test probes.

The MS-EB03 electronics box is compatible with all STAR Cryoelectronics' Mr. SQUID probes, and may be used to characterize LTS and HTS SQUIDs and shunted or unshunted Josephson junctions.



2 SPECIFICATIONS

2.1 General

Size:	(W×H×D): 8.38 × 1.94 × 7.25 (in) (213 × 49.3 × 184 (mm))	
Weight:	1.7 lb (772 g)	
Power:	±12 VDC, ±100 mA supplied by external DC power supply	
Temperature:	0 to 40 °C non-condensing	
Outputs:	Current:	1 V corresponds to 100 µA through SQUID or feedback coil
	Voltage:	1 V corresponds to 100 µV across SQUID (using default ×10,000 gain setting)
Sweep:	800 $\mu A_{p\text{-}p}$, 20 Hz, adjustable from 10 to 50 Hz	
Offsets:	Current:	±450 µA
	Flux:	±1 mA
Amplifier Gain:	100, 1,000 or 10,000 (user configurable via internal switch)	
Frequency response:	0 to 4 kHz	
Voltage noise floor:	<2 $nV/Hz^{½}$ for f > 10 Hz	
External Input:	Direct coupling to Mr. SQUID® external coil (fused for 1 mA) or buffered (true differential, 100 µA/V), user configurable via internal switch.	

2.2 Front Panel Controls

POWER Switch: A two-position toggle switch that selects power ON (up) or power OFF (down) to the system.

MODE Switch: A two-position toggle switch that selects between the *V*–*I* (up) and *V*–Φ (down) modes.

- In *V*–*I* mode, the triangle wave test signal is applied across the SQUID bias terminals.
- In *V*–Φ mode, the triangle wave test signal is applied across the internal feedback terminals.

VOLTAGE Output: A BNC connector providing the amplified voltage across the SQUID. The amplifier circuit can be configured for a gain of 100, 1,000 or 10,000 using an internal switch. The default factory-configured gain setting is 10,000.

CURRENT Output: A BNC connector providing a voltage signal proportional to the current output of the Mr. SQUID® electronics box. The CURRENT output signal is the voltage output of an operational amplifier that measures the voltage drop across a precision (0.1%) 10 Ω series resistor through which the current flows. The operational

amplifier is configured with a gain of 1,000 so a voltage of 1 V at the CURRENT monitor output corresponds to a current of 100 µA.

- In the *V–I* mode, the CURRENT output is the bias current through the SQUID (the sum of the triangle wave plus the DC bias offset current set by the CURRENT OFFSET control).
- In the *V*–Φ mode, the CURRENT output is the current through the feedback coil (the sum of the triangle wave plus the DC flux offset current set by the Flux Bias control).

SWEEP OUTPUT control: Sets the amplitude of the triangle wave test signal in either the *V–I* or *V*–Φ mode.

In either mode, use the SWEEP OUTPUT control to set the width of the test signal sweep. In *V-I* mode, the triangle wave is applied to the bias (*I*) terminals of the SQUID; in *V*-Φ mode, the triangle wave is applied to the internal feedback terminals.

CURRENT OFFSET control: Applies a positive or negative DC bias current to the SQUID. In the 12 o'clock position, this current is approximately zero.

This control is used to apply a DC bias current offset to the SQUID.

FLUX OFFSET control: Applies a positive or negative DC current to the internal feedback coil terminals. In the 12 o'clock position, this current is approximately zero.

This control is used to modulate the critical current of the SQUID manually by the application of a magnetic flux produced by the current in the feedback coil coupled to the SQUID.

2.3 Rear Panel I/O Specifications

POWER: A five-pin DIN socket for the external ±12 VDC power supply (or optional battery pack).

Pin	Description
1	Analog ground
2	Integrator balance offset signal (for use with optional MS-FLL Flux-Locked Loop accessory)
3	
4	-12 VDC
5	+12 VDC

PROBE: DB-9 socket for connections to the SQUID or Josephson junction under test.

Pin	Description
1	+V
2	-V
3	+I
4	-I
5	$+I_{int}$ (internal feedback)
6	$-I_{int}$ (internal feedback)
7	$+I_{ext}$ (externalfeedback)
8	$-I_{ext}$ (external feedback)
9	Analog ground

EXT INPUT: BNC connector to couple a voltage signal to an external feedback coil. A MODE switch inside the Mr. SQUID® electronics box (accessible by removing the top cover) selects whether this signal is routed directly through a 100 mA fuse at location F1 inside the box to the external feedback coil (switch position DIR) or is converted to true differential using a buffer amplifier and then routed to the feedback coil (switch position BUF). The current output from the buffer amplifier (*i.e.*, the current applied to the external feedback coil) is 100 µA/V. The buffered configuration is the default set at the factory.

OUTPUT: Buffered single-ended outputs of all SQUID signals (SQUID bias current (I), SQUID output voltage (V), internal feedback coil current (I_{int}), and external feedback coil current (I_{ext})). The pinouts and scaling are summarized in the table below.

The signals at the OUTPUT connector can be connected to the optional MS-DAQ14 or MS-DAQ16 USB Mr. SQUID® Digitizer to display the SQUID V-I and V-Φ characteristics on a computer. The Mr. SQUID® Digitizer software simplifies measurements of the SQUID parameters (I_c, R_N, ΔV, ΔI_m) and transfer function ($dV/d\Phi$).

Pin	Description	Scaling
1	SQUID output voltage, *V*	10,000 (default)[1]
2	Internal feedback coil current, I_{int}	100 µA/V
3	SQUID bias current, *I*	100 µA/V
4	External feedback coil current, I_{ext}	100 µA/V
5		
6		
7		
8	Analog ground	
9	Analog ground	
10	Analog ground	
11	Analog ground	
12	Analog ground	
13		
14		
15	Analog ground	

[1]May be configured for a scaling factor of 100, 1,000 or 10,000 using a gain switch inside the Mr. SQUID® electronics box accessible by removing the top cover.