Mr. SQUID®

Mr. SQUID® - A High-T_c Superconductor SQUID System for Undergraduate Laboratories!

Mr. SQUID® is a complete Superconducting QUantum Interference Device (SQUID) system based on high-temperature superconductor (HTS) technology. Owing to the quantum properties of superconductivity, a SQUID may be used to measure extremely small magnetic fields. The Mr. SQUID® system consists of an HTS thin-film SQUID chip mounted on a probe with removable magnetic shield, an advanced electronics control box, and a vacuum dewar flask. The Mr. SQUID® probe is immersed in a liquid nitrogen bath in the vacuum dewar flask, and the electronics control box is used to display the SQUID characteristics on an oscilloscope or data acquisition device. An extensive 100-page User's Guide is provided that details the operation of Mr. SQUID® and includes many experiments suitable for laboratory experiment courses. Mr. SQUID® demonstrates the principles of superconductive electronics with the addition of only liquid nitrogen and either an oscilloscope or data acquisition device.

WHAT IS INSIDE THE PROBE?

The heart of Mr. SQUID® is a small integrated circuit chip containing a dc SQUID and two feedback coils. The SQUID itself is a superconducting ring made of yttrium barium copper oxide ($YBa_2Cu_3O_7$, usually referred to as YBCO) with two active devices called Josephson junctions, the basic building block of all superconducting electronics. Two feedback coils are concentric with the SQUID ring. One feedback coil is used to modulate the SQUID using the Mr. SQUID® electronics box, the other feedback coil is available for an external input signal. Mr. SQUID® is designed to operate in a liquid nitrogen bath at 77 K (-169 °C).

WHAT DOES MR. SQUID® DO?

Mr. SQUID® is a sensitive superconducting magnetometer and can therefore be used to detect small magnetic fields if they are properly coupled to the SQUID. The limiting performance of Mr. SQUID® is set by the small effective area of the SQUID and the sensitivity of the input coil coupling to the SQUID. As a result, Mr. SQUID® does not have the sensitivity of high-performance laboratory SQUIDs and thus cannot be used to detect truly minute signals such as those generated by the human brain. On the other hand, Mr. SQUID® is designed to demonstrate the principles behind all SQUID applications and is ideal as a teaching tool for undergraduate laboratory experimental courses.

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THE BASIC FUNCTIONS

The Mr. SQUID® electronics box contains all the necessary amplifiers, current drivers, and switches to allow the observation and investigation of the basic phenomena of SQUIDs and Josephson junctions. The two standard outputs are the voltage-current (V-I) characteristics and the voltage-flux (V-Φ) characteristics of the SQUID. These characteristics exemplify the dc Josephson effect and magnetic flux quantization, two hallmarks of the quantum nature of superconductivity. Mr. SQUID® is therefore a particularly effective system for demonstrating quantum mechanical phenomena in the undergraduate laboratory or lecture environment.

THE USER'S GUIDE

Mr. SQUID® comes with a comprehensive User's Guide that explains the operation of the system in step-by-step fashion and provides introductory material on superconductivity, SQUID magnetometers, and other SQUID applications. It also includes an annotated bibliography of useful references on SQUIDs and superconductive electronics. A large section of the manual is devoted to a set of six detailed, advanced experiments (listed below) that use the Mr. SQUID® system in conjunction with additional easily-obtained parts and equipment.

MR. SQUID® USER'S GUIDE CONTENTS

ADVANCED EXPERIMENTS FOR MR. SQUID®

Resistance vs. temperature of the YBCO SQUID Building an Analog Flux-Locked Loop

Building an Analog Flux-Locked Loop

Using a Flux-Locked Loop as a Sensitive Voltmeter

Microwave-induced (Shapiro) steps at 77K and h/e

Inductive Measurement of the T_c of an HTS Film

SQUID Properties in Pumped Liquid Nitrogen

STAR CRYOELECTRONICS

Mr. SQUID®

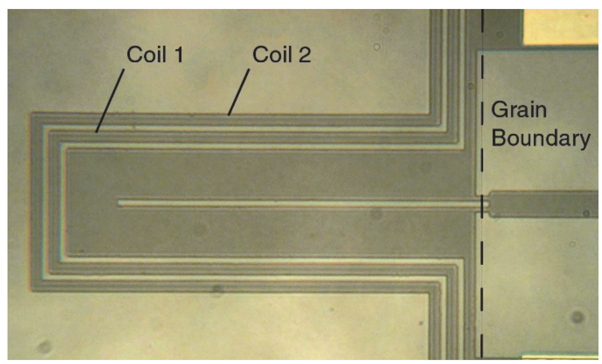
Mr. SQUID® SPECIFICATIONS

ELECTRONICS BOX

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 μA_{p-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: $<2\ nV/\sqrt{Hz}$ 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.

PROBE

Length: 17.5 inch (445 mm)
Connector: DB-9 receptacle with integral pi-filter 0.8 MHz, 4,000 pF low-pass
SQUID type: Bicrystal grain-boundary Josephson junction DC SQUID
SQUID inductance: nom. 73 pH
Mutual inductance, internal coil 2 (external coil 1): nom. 23 (35) pH
SQUID critical current: >5 μA
Voltage swing: >2 μV
SQUID field sensitivity 0.5 $\mu T/\Phi_0$



MAGNETIC SHIELD

Conetic alloy tube, 0.625 in (15.9 mm) diameter, 3.5 in (88.9 mm) long, black baked enamel finish, textured outside, smooth inside, 7500 Gauss saturation induction, initial permeability 30,000 at 295 K, approx. 4,500 at 77 K.

VACUUM DEWAR FLASK

Aluminum-encased silvered glass vacuum flask, 1000 mL, 2.75 in (70 mm) ID, 13.3 in (337 mm) height.

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Mr. SQUID® ACCESSORIES

MS-DAQ14, Mr. SQUID® Digitizer

The Model MS-DAQ14 Mr. SQUID® Digitizer accessory enables students to digitize, display, and capture Mr. SQUID current-voltage (V-I) and voltage-flux (V-Φ) characteristics on a Windows-based PC via a USB 2.0 interface. The digitizer is bus powered and based on a National Instruments 14-bit data acquisition device with 48 kS/s maximum sampling rate.

The Mr. SQUID® Digitizer control software can be used to display, capture, and save V-I characteristics for variable values of flux. Cursor pairs simplify measurement of the critical current and resistance. Similarly, V-Φ characteristics (using internal or external flux signals) for variable values of bias current can be displayed, captured, and saved, and the cursor pairs can be used to measure the current per Φ_0 and flux-to-voltage transfer coefficient. Multiple plots can be recorded per graph, with user-configurable labels.

MS-OSC, Mr. SQUID® Oscillator

The Model MS-OSC Mr. SQUID® Oscillator accessory is a 44 GHz microwave oscillator for the Mr. SQUID® Shapiro step experiment. The Mr. SQUID® Oscillator is powered using the DC power source provided with the Mr. SQUID® control electronics box. A 5-pin DIN cable included with the Oscillator accessory is used to power the Mr. SQUID® electronics box through the Oscillator box. A coaxial cable with 1/4-wave antenna is included to couple the 44 GHz microwave signal to Mr. SQUID®.

To set up the Shapiro step experiment, the Mr. SQUID® voltage-current (V-I) characteristic is displayed using an oscilloscope or data acquisition unit, then the microwave power can be turned on using a switch on the front panel of the Oscillator box. The step positions on the V-I characteristic can then be recorded. To revert back to the original V-I characteristic, simply switch off the power to the Oscillator box.

MS-FLL, Mr. SQUID® Flux-Locked Loop

The Model MS-FLL Mr. SQUID® Flux-Locked Loop accessory enables students to operate Mr. SQUID in flux-locked loop mode, learn how feedback electronics work, and use Mr. SQUID for more advanced measurement applications.

The Mr. SQUID Flux-Locked Loop accessory is powered using the DC power source provided with the Mr. SQUID® control electronics box. A 5-pin DIN cable included with the Flux-Locked Loop accessory is used to power the Mr. SQUID® electronics box through the Flux-Locked Loop box. The voltage output from the Mr. SQUID® electronics box is connected to the voltage input on the front panel of the Flux-Locked Loop box, and the feedback signal from the rear panel of the Flux-Locked Loop box is connected to the external feedback port on the rear panel of the Mr. SQUID® electronics box. After adjusting Mr. SQUID® for maximum V-Φ output, the balance adjustment potentiometer on the front panel of the Flux-Locked Loop box is used to center the V-Φ characteristic about zero Volts, then the toggle switch on the front panel of the Flux-Locked Loop box is used to lock the feedback loop and to reset the feedback loop as necessary. The flux-locked loop output signal is available at the front panel of the Flux-Locked Loop box and may be connected to an oscilloscope or data acquisition unit.

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