

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

Mr. SQUID® is a complete Superconducting QUantum Interference Device (SQUID) magnetometer 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 signals. The Mr. SQUID® system consists of an HTS thin-film SQUID chip mounted on a probe with removable magnetic shield, a battery-operated 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 x-y chart recorder. 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 an x-y chart recorder.

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 ($Y_1Ba_2Cu_3O_7$, usually referred to as YBCO) with two active devices called Josephson junctions, the basic building block of all superconducting electronics. Two YBCO 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 to input external signals. 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 signals if they are properly coupled to the SQUID. The limiting performance of Mr. SQUID® is set by its economical electronics package and the sensitivity of the feedback 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.

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

Introduction
Setting up Mr. SQUID®
Getting Started with Mr. SQUID® (New Users)
Getting Started with Mr. SQUID® (Advanced Users)
An Introduction to Superconductivity and SQUIDs
Troubleshooting and Getting Help
Advanced Experiments (see below)
About STAR Cryoelectronics
Technical Specifications and Schematics
References

ADVANCED EXPERIMENTS FOR MR. SQUID®

Resistance vs. temperature of the YBCO SQUID
Building a 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
Building an 8-bit or 12-bit Digital Flux-Locked Loop

Mr. SQUID® SPECIFICATIONS

(Effective 9/20/04 and subject to change without prior notice)

ELECTRONICS BOX:

- Box: Steel construction, with internal battery compartment
Size (W×H×D): 6 × 2.6 × 7.5 (inch) (153 × 66 × 190 (mm))
Weight: 2.65 lb (1200g)
- Power: ±9 VDC, 48 mA supplied by two 9 V alkaline transistor batteries.
- Outputs: X (current): 1 V corresponds to 100 μA through SQUID or mod. coil
Y (voltage): 1 V corresponds to 100 μV across SQUID
- Sweep: Oscilloscope (high speed) setting: 15 Hz
X-Y recorder (low-speed) setting: 0.07 Hz
- Amplifier: Voltage gain: ×10,000
Frequency response: 0 to 2.8 kHz
Voltage noise floor: <1.8 nV/Hz^{1/2} for f > 10 Hz
Total output noise voltage: <1mV

SQUID PROBE VER. 8 SPECIFICATIONS:

- Probe Length: 17.5 inch (445 mm)
- Connector: DB-9 receptacle with integral pi-filter
- SQUID type: Bicrystal grain-boundary Josephson junction dc SQUID
- SQUID inductance: nom. 100 pH
- Internal coil 2 (external coil 1)
- Mutual inductance: nom. 28 (41) pH
- SQUID critical current: >5 μA
- Voltage swing: >2 μV
- SQUID field sensitivity: 0.5 μT/Φ₀

