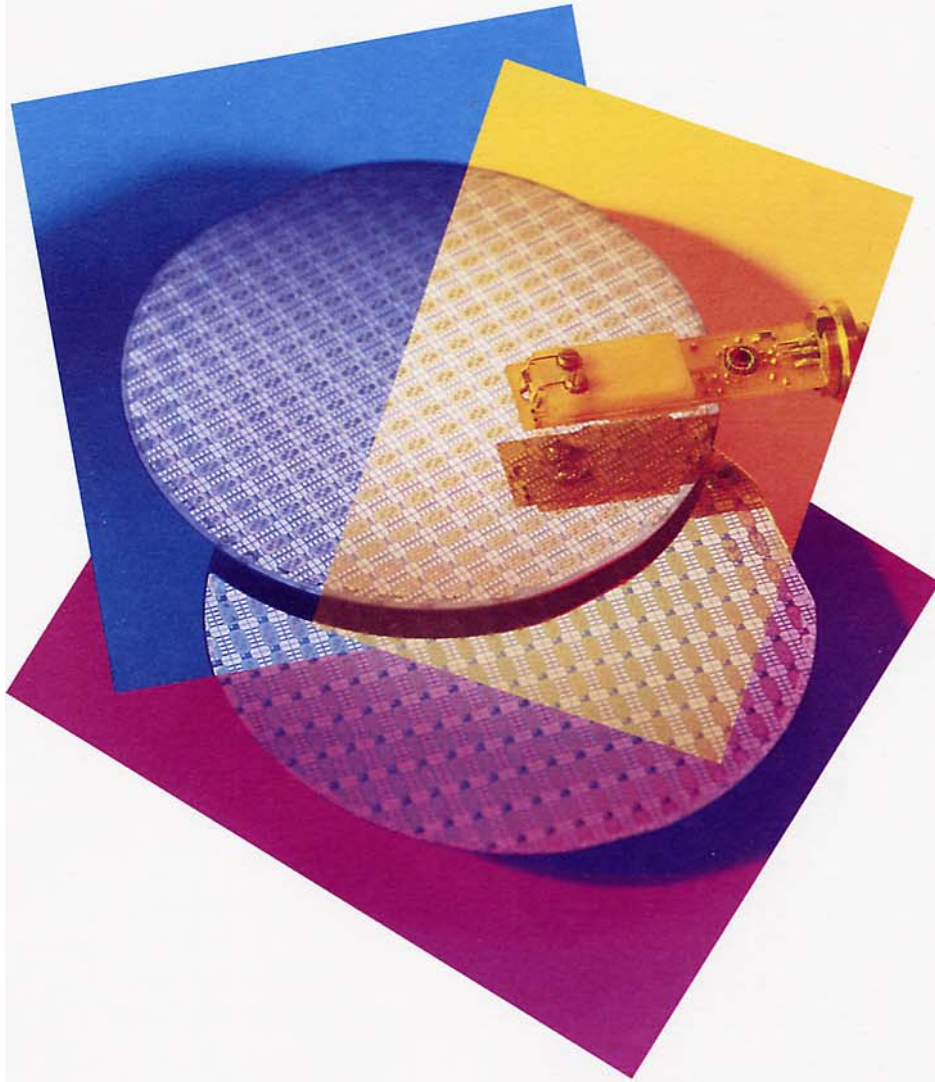


Electronics & Sensors

# DC SQUID + RF SQUID Systems



*"It's all in their design. Quantum Design was the first company to offer all-thin-film SQUIDs that combine durability with the highest level of measurement sensitivity."*



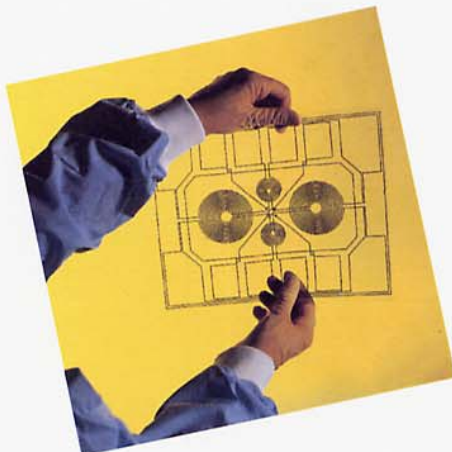
 **QUANTUM  
DESIGN**

# Quantum Physics, Superconductors and SQUIDS

*Quantum Design's SQUID systems are complete. They have everything you need to configure flexible, powerful systems.™*



Path-breaking research requires the proper equipment. For many applications, that means using ultra-sensitive measuring systems that employ superconducting technology. Quantum Design SQUID Systems (Superconducting QUantum Interference Devices) use the most rugged and sensitive all-thin-film sensors commercially available.



What further distinguishes Quantum Design SQUIDS is their combination of reliability and easy-to-use flexibility. In application after application, they have proven themselves to match or exceed performance requirements—easily withstanding the rigors of repeated temperature cycling. This robust performance rests firmly on their design, which is directly responsible, in turn, for the adaptability they have shown in a variety of measurement situations. Quantum Design's patented high-symmetry dc SQUID is the first of its kind to be configured specifically for ultra-sensitive measurement applications.

*Our unique, patented SQUID design sets our systems apart from the rest. With the modulation coils located directly on the SQUID, and the highly symmetric design, performance is improved in even the most difficult applications.*

## Complete Systems

Quantum Design provides all of the elements needed to configure flexible and powerful systems. A DC SQUID system can include the following components:

- ▶ Model 50 All-niobium Thin Film DC SQUID Sensor
- ▶ Model 5000 DC SQUID\*\* Controller (one to eight channels)
- ▶ Model 550 DC SQUID Controller (single channel)
- ▶ DC SQUID Micropreamp
- ▶ Model DFP-1 Flexible SQUID Probe
- ▶ Multicard

\*\* Model 5000 DC SQUID Controller is not CE certified

# DC SQUID Systems

## Astrophysicist Tests Theory of Relativity

Dr. Warren Johnson of Louisiana State University is conducting an experiment designed to test Einstein's general theory of relativity. According to Einstein, an exploding supernova should generate gravity waves, and Johnson is attempting to make the first observation of this phenomenon by using an aluminum gravity-wave antenna that vibrates in response to the presence of a gravity wave.

To amplify the antenna's vibrations, Johnson uses a superconducting transducer (a niobium diaphragm) that moves back and forth whenever the antenna vibrates. The superconducting sensor coil of a DC SQUID responds to changes in the position of the moving diaphragm by generating more current whenever the diaphragm moves closer to it, allowing the researchers to measure vibrations in the antenna.

Describing its ability to operate at ultra-low cryogenic temperatures, Johnson says, "The energy resolution of this SQUID is better by at least a factor of five than the commercial SQUID from a different manufacturer. As far as we know, this is the first and only commercial SQUID that's useful in this temperature range (50 mK). We are also using Quantum Design's controller for these measurements. The total package of the Quantum Design SQUID and controller gives lower noise than anything else we've tested."

## Model 50 DC Thin Film SQUID Sensor

Quantum Design was the first company to offer all thin film SQUIDs, and this state-of-the-art sensor combines durability with the highest level of measurement sensitivity commercially available. The performance of Model 50 is based on the following features:

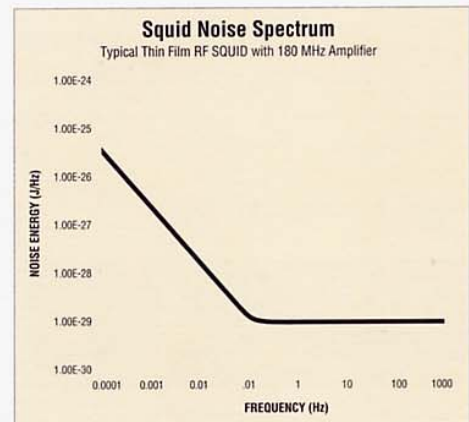
- ▶ A patented thin film design with integral signal and modulation coils.
- ▶ Use of a niobium/aluminum tri-layer process with no lead or other fragile materials.
- ▶ Modulation coils on the thin film sensor arranged with a symmetry that eliminates stray coupling due to mutual inductance and sensitivity to uniform magnetic fields (gradiometer configuration).
- ▶ Introduction of the bias current into the Josephson Junctions such that there is no coupling between this current and the SQUID loop.
- ▶ Attachment of low-inductance superconducting leads between pads on the chip and external bulk terminals—using a proprietary process that creates a true metallurgical bond to the pads on the chip (superconducting up to 9 Kelvin).

## A Word About DC SQUID Controllers

Quantum Design has created powerful and flexible systems of controllers and accessories designed to optimize the SQUID and its use. While the Model 5000 Controller offers multi-channel capabilities, the Model 550 Controller offers single-channel capabilities. Both systems, however, utilize the Micropreamp, the Model 50 SQUID, and the Model DFP-1 Probe, and both systems offer the following features:

- ▶ Individual fine tuning for each channel's offset, output voltage reset points, 1/f noise suppression (YAMS), and more.
- ▶ Analog view displaying voltage output for each sensor.

- ▶ Ability to ramp channel bias levels, read output levels, and set peak response levels from front panel.
- ▶ Heater activation to allow junctions to be heated above the  $T_c$  to release trapped magnetic flux—especially helpful with large, multi-channel systems and those working in non-shielded environments.
- ▶ Choice of front-panel or remote interface.
- ▶ YAMS: Quantum Design's low frequency noise reduction scheme.
- ▶ Auto-reset when output exceeds user-defined limits.



"The sensor's energy sensitivity and low noise level make it ideal for a variety of measurements."



# DC SQUID Systems

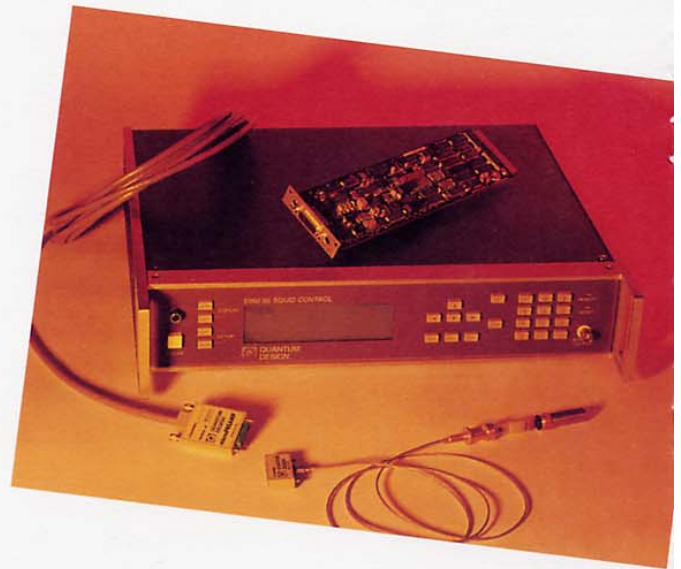
## Model 5000 DC SQUID Controller

This flexible solution is for researchers who need a high-performance DC SQUID controller for multiple channels. It has eight expansion slots available for plug-in Model 5000 multicards, permitting from one to eight channels of operation. It also provides three methods of operational control:

1. Front-panel LCD display and key pad.
2. Remote computer and GPIB port (IEEE-488 Protocol), supporting the full bandwidth of the A/D converter, up to 16KHz for digitized single-channel SQUID output.
3. Remote computer and RS-232 port for lower data transfer rates.

The Model 5000 also possesses the following high-performance capabilities in addition to the previously listed features that it shares with the Model 550 Controller:

- ▶ 16-bit A/D converter capable of multiplexing all eight channels of SQUID output.
- ▶ 68020 microprocessor, EPROMs, and battery backup RAM for program control.
- ▶ Floating point unit (or math coprocessor) and real-time clock.
- ▶ Instant-access configuration menus to allow control of all functions directly from the front panel display.
- ▶ Quick selection of the range, gain, bandwidth, filter settings, and other operating parameters for all channels.
- ▶ Simultaneous overall display of one to eight channels on front-panel LCD to show independent values for range, gain, bandwidth, status, and filter states.



## Model 550 DC SQUID Controller

This low-cost controller is the latest product offering from Quantum Design. In addition to its small size, it provides an affordable alternative for users who need only one channel. It also features many output options. Since it permits so many configuration alternatives and outputs, it can be easily integrated

into a wide range of experiments. In addition to the previously listed capabilities that it shares with the Model 5000 Controller, it offers the following features:

- ▶ Low power, low noise electronics in a compact package.
- ▶ Open architecture to adapt to a variety of applications.
- ▶ High-performance packaging and I/O buffering providing EMI/RFI protection and ground loop isolation.
- ▶ Enhanced tuning capabilities to ease optimization for low-noise operation.
- ▶ Compensation for zero temperature coefficient.

CHANNEL	1	2	3	4	▶5	6	7	8
RANGE	50	50	50	500	5s	5s	50	50
GAIN	2k	5x	1x	1k	10x	10x	5x	1x
BANDWT	50K	16K	2K	2K	16K	2K	2K	2K
STATUS	DGN	RUN	RS	RUN	RUN	RUN	RUN	RUN
TEST	@	@	@	@	@	@	@	ON
Post Filter: 500Hz Line Notch: ON								

CH 8 Voltage : 2.099			
RANGE▶	5s	SELECT:	2K
GAIN :	1x	GRP-RS:	DISABLE
RESET :	OFF	OFFSET:	81.14%
BIAS :	43%	SKEW :	50%
DISC :	4.9	NULL :	MAN
		TEST :	OFF
		HTR :	OFF
		YAMS :	OFF



*"Some people prefer to use a remote computer to perform the functions listed, but the front-panel LCD display offers much of the same flexibility for monitoring and controlling your experiments. The Model 5000 Multiple Channel and Single Channel Displays are shown here."*

## DC SQUID Systems



*"With its expansion slots for mult cards, the Model 5000 can provide up to eight channels of operation."*

### Model 500 DC SQUID Multicard

Multicards enable users to select range, gain, bandwidth, null, bias, three-pole low-pass filters, and an auto-zero function for each channel.

*"As a single-channel system, the Model 550 offers many of the same features as the Model 5000 in a compact package."*



### DC SQUID Micropreamp

Suitable for use with either Model 550 or Model 5000, this small, backshell-style unit meets the demands of single- and multi-channel systems. It provides a standard interface to the DC SQUID sensor and provides a balanced drive level to controllers and mult cards. Featuring impressive low-noise performance, it can be used with either internal or external feedback—with up to 10 meters of cable for the Model 5000 and up to 12 meters of cable for the Model 550. The micropreamp's built-in RF shielding and filtering improve the system's immunity to RF interference.

### Model DFP-1 DC SQUID Probe

This probe—used with either the Model 550 or Model 5000—provides a flexible transmission line and the appropriate operating environment for the sensor. Installation is easy as the sensor fits into the simple plug-in connector without the restrictions of a rigid probe. The sensor quickly cools to superconducting temperatures—taking advantage of its low thermal heat load design. The probe is wired for internal or external feedback applications, and it provides both RF immunity and magnetic shielding for the sensor—all characteristics that contribute to accurate, trouble-free measurements.



### Stanford Researcher Requires Nanoradian Resolution

*At Stanford University, Dr. Jim Lockhart is testing another aspect of Einstein's general theory of relativity with a Quantum Design SQUID. Einstein's theory says the Earth distorts the space-time continuum in a way that would interfere with the motion of a rotating sphere (or satellite) placed in space. Lockhart's test places a rotating, niobium-coated, quartz sphere inside the superconducting pickup loop of a SQUID sensor. When the spin axis of the sphere changes, the currents in the pickup loop change. As Lockhart explains, these changes are infinitesimally small: "In the case of the smaller effect we'll be looking for a gradual 200-nanoradian change in the angle of the spin axis occurring over a period of one year, with a desired resolution of one nanoradian. What's a nanoradian? If you have a beam 50 miles long and lift one end by a hair's width, you change the angle by one nanoradian. That's the kind of resolution available with Quantum Design's SQUID."*

# Specifications

## DC SQUID Products

### MODEL 50 DC SQUID SENSOR

Energy Sensitivity  
 $5 \times 10^{-31}$  J/Hz

Flux Noise  
 $< 5 \times 10^{-6} \phi_0 / \sqrt{\text{Hz}}$

1/f Noise Onset  
<0.5 Hz

Input Coil  
Inductance 2.0  $\mu\text{H}$   
Coupling 0.2  $\mu\text{A}/\phi_0$

Modulation Coil  
Inductance 0.3  $\mu\text{H}$   
Coupling 1.5  $\mu\text{A}/\phi_0$

Operating Temperature  
Typical 4.2K  
Range 0-7K

### MODEL 5000 CONTROLLER \*\*

Communications  
GPIB port  
(IEEE-488.2 protocol)  
Bi-directional RS232 on  
9-pin D-shell  
300 to 19.2K baud rates  
Front-panel key pad

CPU  
Motorola 68020  
microprocessor, 16MHz  
clock speed  
Motorola 68882 floating  
point unit  
Real-time clock  
16-bit analog-to-digital  
converter with 6KHz-48KHz  
selectable digitizing rate

Digital Signal Processing  
IIR filtering  
Digitizing bandwidth  
6-48 KHz

Display  
8-line, 40-character graphic  
LCD display  
Adjustable contrast

Filter  
1, 10, 100 Hz Lowpass,  
60 Hz notch & 16, 4, 2  
& 1KHz 3-pole Butterworth

Power  
AC line operation  
100 to 125 and 200 to  
240 VAC, 50 or 60 Hz, 60 W

Range  
See Model 500 Multicard

Size  
3.5"(h) x 17.0"(w) x 15.0"(d)  
(8.9cm x 43.2cm x 38.0cm)

Weight  
10 Kg (22 lbs)

### MODEL 550 CONTROLLER

Detector Output  
Connector  
Wideband output from  
phase detector

Frequency Response  
0-50 KHz (nominal)

Interface  
Analog display: bar graph  
Analog output: BNC & DB-  
25 $\pm$ 10V

Ranges  
Four ranges provided, 5S,  
5, 50, & 500U yielding  $\sim$ 5  
to 500  $\phi_0$  full scale.  
5S is nominal  $\pm 5 \phi_0$  full  
scale, slow range providing  
stable low frequency  
operation.  
500U range is user  
configurable.

Sensitivity  
 $< 5 \times 10^{-6} \phi_0 / \sqrt{\text{Hz}}$  with  
Quantum Design's standard  
DC SQUID Preamp, Flex-  
Cable (Model DFP-1), and  
Sensor (Model 50).

Signal Conditioning  
Output signals are DET,  
RMS, OUT, and FTR.  
DET provides output of  
phase detector.  
RMS provides RMS or  
logRMS of output signal.  
OUT yields output of  
feedback loop and FTR  
provides output of feedback  
loop through user  
configurable active filter for  
one-, two-, and three-pole  
high-pass and low-pass  
filters, plus notch filter and  
gain options.

Size  
2.25"(h) x 5.12"(w) x  
7.50"(d)  
(5.7cm x 13.0cm x 19.0cm)

### MODEL 500 MULTICARD

Bandwidth  
(Intrinsic loop bandwidth)  
50KHz Normal mode  
1KHz Ultra-stable mode

Bias  
DC bias levels set via  
8-bit D/A converter

Filter  
16, 4, 2 & 1 KHz 3-pole,  
low-pass Butterworth  
Null/Offset adjustment  
 $\pm 1 \phi_0$  range, 12-bit  
resolution

Gain  
1X, 2X, 5X, & 10X

Ranges  
1, 10, & 100  $\phi_0$  /volt  
1  $\phi_0$  /volt Ultra-stable mode  
( $\pm 5\text{V}$  full scale)

### MICROPREAMP

Cable Length  
4 or 12 meters (Model 550)  
4 or 10 meters (Model 500)

Power Consumption  
0.3W

Size  
2.13"(h) x 1.50"(w) x 0.38"(d)  
(54mm x 38mm x 10mm)

### DFP-1 FLEXIBLE PROBE

Flexible Length  
48"(122cm)  $\pm$  .25"( $\pm$ 65cm)  
custom lengths available

Niobium SQUID Shield\*  
Standard length 1.8"  
(4.6cm)  $\pm$  0.05"(.13cm)  
Long version 3.0"  
(7.6cm)  $\pm$  0.05"(.13cm)

\* Note: Shield length does not affect  
the magnetic shielding of the SQUID  
sensor, it allows additional room  
inside for user circuitry.

\*\*The Model 5000 Controller  
is not CE certified

*"Quantum Design's SQUIDs are now at work in some of the world's most advanced sensor applications, including the detection of corrosion and defects in aircraft wings and studies of gravitational radiation in Gravity Probe B."*



### **About Quantum Design**

In the decade since it was founded, Quantum Design has become the leader in developing and delivering superior SQUID-based instruments and systems. We provide a full spectrum of scientific and engineering support for customers internationally. Our scientists keep in constant touch with leading scientists around the world who

furnish unique insights into new and existing product and performance requirements. Quantum Design's charter is to create, engineer, market, and support leading-edge systems and instruments based on a solid foundation of advanced technology.

Quantum Design's family of SQUID sensors, electronics, and systems brings high performance

and ease of use to your laboratory. This product line represents a new generation of instruments and components that will form the heart of future SQUID measurement systems for military, commercial, and research applications. Quantum Design is committed to providing its customers with the most advanced measurement systems, instruments, and components possible.



## Quantum Design



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