

## LOW- $T_c$ SQUID SENSORS

STAR Cryoelectronics offers an extensive line of dc SQUIDs and integrated SQUID sensors for a broad range of measurement applications. STARCryo LTS dc SQUIDs are simple to operate using pcSQUID™, STAR Cryoelectronics' advanced PC-based SQUID control and readout electronics. SQUIDs encapsulated in STARCryo's miniature package assemblies may be operated without any cooled matching circuitry by selecting the single-transformer option in the pcSQUID™ feedback loop electronics. This greatly simplifies installation for many applications. Alternately, SQUIDs packaged with STARCryo's removable niobium shield assembly with cooled matching transformer and connector interface may be operated using conventional 2-transformer coupling. The smooth dc characteristics of the SQUIDs also ensure easy operation using any compatible feedback electronics.



## INSTRUMENTATION SQUIDS

STARCryo low- $T_c$  dc SQUIDs for instrumentation applications are available with input inductances ranging from 100 nH to 1.16  $\mu$ H. Two feedback modes are supported: the modulation and feedback signals may be combined and connected to a coil that is transformer-coupled to the SQUID inductance for conventional flux-lock operation, or the feedback may be separately connected to a coil that is transformer-coupled to the SQUID input circuit for input current-lock operation (requires a superconducting load, e.g., a pickup loop made using superconducting wire). In this latter mode, the feedback signal opposes any change of the current in the pickup loop and SQUID input circuit.

Six contact pads are available for normal-metal wire bond connections to the SQUID: one pair for current bias/voltage out, one pair for the modulation/feedback coil, and one pair for the input circuit feedback coil. Two large pads are available for superconducting wire bond connections to the SQUID input.

The SQUID chips are available mounted and encapsulated in a miniature cryogenic package with superconducting screw terminals to the SQUID input, integral heater resistor to de-flux the SQUID if necessary, and a detachable niobium shield assembly with a reliable multi-pin connector interface. The package is easy to install and compatible with operation in liquid cryogen or vacuum. Mating cryocables are available separately. Alternately, the miniature SQUID package may be mounted inside a compact connectorless niobium shield assembly with through-holes for wiring to the SQUID.

## FEATURES

- Small 2 mm × 3 mm (nom.) chip size
- Compatibility with a wide range of load inductances
- Feedback may be coupled to the input circuit to enable input current-lock operation using standard closed-loop feedback electronics (desirable for magnetic field measurements using superconducting pickup coils)
- Cooled matching circuitry is not required using pcSQUID™ electronics
- May be operated with as few as four wires (plus two for heater) using pcSQUID™
- Fabricated using a robust and reliable Nb/Al-AlO<sub>x</sub>/Nb trilayer Josephson junction technology

Six instrumentation SQUID models are currently in production. The nominal specifications are summarized in the table below.

*Instrumentation SQUID Specifications (typical, with matched load attached)*

	<a href="#">SQ100</a>	<a href="#">SQ180</a>	<a href="#">SQ300</a>	<a href="#">SQ600</a>	<a href="#">SQ680</a>	<a href="#">SQ1200</a>	Unit
Screened SQUID Ind. $L_{dc}$	39	183	91	102	134	104	pH
Input Inductance $L_i$	105	178	299	596	683	1162	nH
Max. Load Inductance	Infinite	200	300	Infinite	700	1200	nH
Input Coupling $1/M_i$	1	0.35	0.44	0.20	0.20	0.13	$\mu A/\Phi_0$
Feedback Coupling <sup>1</sup> :							
Current-Lock	28	50	51	48	44	48	$\mu A/\Phi_0$
Flux-Lock	48	13	8	10	7.2	8.3	$\mu A/\Phi_0$
Energy Resolution	4.7	0.8	2.5	1.1	1.2	0.9	$\times 10^{-31}$ J/Hz
Flux Noise $S_\Phi^{1/2}$	3	3	3	3	3	3	$\mu\Phi_0/\text{Hz}^{1/2}$
Input Current Noise $S_I^{1/2}$	3	1	1.3	0.6	0.6	0.4	pA/Hz <sup>1/2</sup>

<sup>1</sup>With matched load installed. Specifications are subject to change without prior notice

## SERIES SQUID ARRAYS AND INTEGRATED SQUID AMPLIFIERS

The Model [SA1xx/SA6xx](#) series low-Tc dc SQUID amplifiers from STAR Cryoelectronics are designed to read out cryogenic detectors such as transition edge sensor (TES) microcalorimeters used for X-ray spectroscopy. The [SA1xx/SA6xx](#) series amplifiers are integrated, two-stage devices with a low-noise, voltage-biased SQUID input stage that coherently modulates a series SQUID array output stage. The SA1xx series amplifiers have 100 nH input inductance, while the SA6xx amplifiers have 600 nH input inductance. The amplifiers are available with either 32-SQUID or 48-SQUID output arrays. Series SQUID array chips (AR32 and AR48) are available as well to assemble two-stage amplifiers where the input SQUID (e.g., SQ100 or SQ600) is located at a different temperature. See the table below for available design configurations.

Eight contact pads are provided for normal-metal wire bond connections to the SQUID amplifier: one pair for array current bias/voltage out, one pair for array feedback, one pair for input SQUID bias, and one pair for input SQUID feedback. Two large pads are provided for superconducting wire bond connections to the SQUID amplifier input.

The SQUID amplifier is available mounted in a miniature cryogenic package with screw terminals and solder pads for all electrical connections to the amplifier. The miniature package includes an efficient heater resistor to de-flux the SQUID amplifier if necessary. The SQUID amplifier package is compatible with operation in liquid cryogen or vacuum, and is available mounted in a niobium shield assembly with connector interface, or in a small, connectorless niobium shield assembly for applications requiring a more compact sensor size. Optional mating cryocables are available.

*Series SQUID Array and Two-Stage SQUID Amplifier Designs.*

Device	AR32	AR48	SA132	SA148	SA632	SA648
Input Inductance (open input),nH	38	57	111	111	650	650
Input Sensitivity, $\mu A/\Phi_0$	7.8	7.8	1	1	0.2	0.2
Array Size	32	48	32	48	32	48

Specifications are subject to change without prior notice

**INTEGRATED MONOLITHIC MAGNETOMETERS**

The STARCryo integrated low- $T_c$  dc SQUID magnetometers are monolithic thin-film sensors specifically designed for ultra low-noise magnetic field measurements. An integral modulation and feedback coil coupled to the pickup loop enables current-lock feedback operation using standard locked-loop feedback electronics. In this mode, the feedback signal opposes any change of the current in the superconducting pickup loop and SQUID input circuit. This feedback technique offers the advantages that screening currents in the pickup loop do not distort the local magnetic field to be measured, and cross-talk between neighboring channels is minimized. These features are particularly important when precise magnetic field measurements are required (e.g., applications in biomagnetism).

The standard magnetometer package is a rugged, two-piece fiberglass assembly that simplifies handling and installation. The magnetometers require only four connections to room temperature: one pair for current bias/voltage out and one pair for modulation/feedback. Two additional wires are used to power a heater resistor installed in the package to de-flux the magnetometer if necessary. The compact package design and six-wire pin-out simplify magnetometer installation in a wide range of user applications.

*LTS Magnetometer Specifications (typical values)*

	<u>M050</u>	<u>M200</u>	<u>M600</u>	<u>M800</u>	Unit
Pickup Loop OD	0.55	1.8x2.35	5.75	7.75	mm
Screened SQUID Ind. $L_{dc}$	87	63	103	103	pH
Feedback Coupling: Current-Lock	7	3	50	50	$\mu A/\Phi_0$
Field Sensitivity $B_\Phi$	43	7	1.2	0.83	nT/ $\Phi_0$
Field Noise $S_B^{1/2}$ , $f > 10$ Hz	130	21	4	2.5	fT/Hz <sup>1/2</sup>
Energy Resolution $\epsilon_c$	0.5	1.1	1	1.6	$\times 10^{-31}$ J/Hz

Specifications are subject to change without prior notice

**ALSO AVAILABLE FROM STAR CRYOELECTRONICS:**

- Model GA1165 LTS First-Order Axial Gradiometer
- Model G140 LTS First-Order Long Baseline Planar Gradiometer
- Model QS2020 LTS Q-Spoiler Series SQUID Array
- Model SS50 LTS Miniature SQUID Susceptometer

**HIGH- $T_c$  SQUID MAGNETOMETERS**

The Model M1000 and Model M2700 High- $T_c$  dc SQUID magnetometers are fabricated from a single layer of  $YBa_2Cu_3O_{7-x}$  (YBCO) using a bicrystal grain-boundary Josephson junction technology. The magnetometer designs consist of a large-area pickup loop connected in parallel with the SQUID inductance. An external magnetic field sensed by the pickup loop is coupled to the SQUID by direct injection. Excellent low-noise performance is achieved with this singlelayer design, even at low frequencies (<1 Hz) using AC current bias.

The magnetometer die are mounted on a standard FR-4 button-shaped printed circuit board using cryogenic epoxy. Integral heater resistors allow the magnetometer to be heated above  $T_c$  to deflux the SQUID if necessary. Embedded in the pc board button of the Model M1000 magnetometer is a wire-wound copper feedback coil for closed-loop operation using standard feedback electronics, while the M2700 magnetometer has an integral thin-film feedback coil deposited on top of the pickup loop.

The magnetometer button is encapsulated and hermetically sealed using a glass-epoxy (G-10) cover and attached to a G-10 sensor package that houses an impedance matching circuit for conventional room temperature readout electronics. The package also includes a mounting flange that is fitted with a 10-pin LEMO connector to simplify electrical connections to the magnetometer. Optional mating cryogenic cables are available from STAR Cryoelectronics. For applications requiring a small form factor, two different magnetometer button-only configurations are available.

**FEATURES**

- Compact, hermetically-sealed magnetometer package design.
- Standard sensor assembly includes cooled matching circuitry and LEMO connector interface; optional right-angle mounting is available for transverse field measurements.
- Optional magnetometer button-only package may be installed without any cooled matching circuit for applications requiring small foot print.

*HTS Magnetometer Specifications*

	<a href="#">M2700</a>	<a href="#">M1000</a>	Unit
Pickup Loop OD	2.7x2.7	9.3x8.5	mm
Feedback Coupling: Current-Lock	45	7	$\mu A/\Phi_0$
Field Sensitivity $B_\Phi$	25	10	nT/ $\Phi_0$
Field Noise $S_B^{1/2}, f > 10$ Hz	<300	<100	fT/Hz <sup>1/2</sup>

Specifications are subject to change without prior notice