



QUANTUM COMPUTER

Low noise signal processing solution

Providing the optimal systems for controlling multi-qubits

Multi-channel low noise arbitrary waveform generation system

Multi-channel precision low noise DC voltage source

Multi-channel low noise amplification system

Customized products

NF Corporation

QUANTUM COMPUTER

Low noise signal processing solution

Low noise&High stability

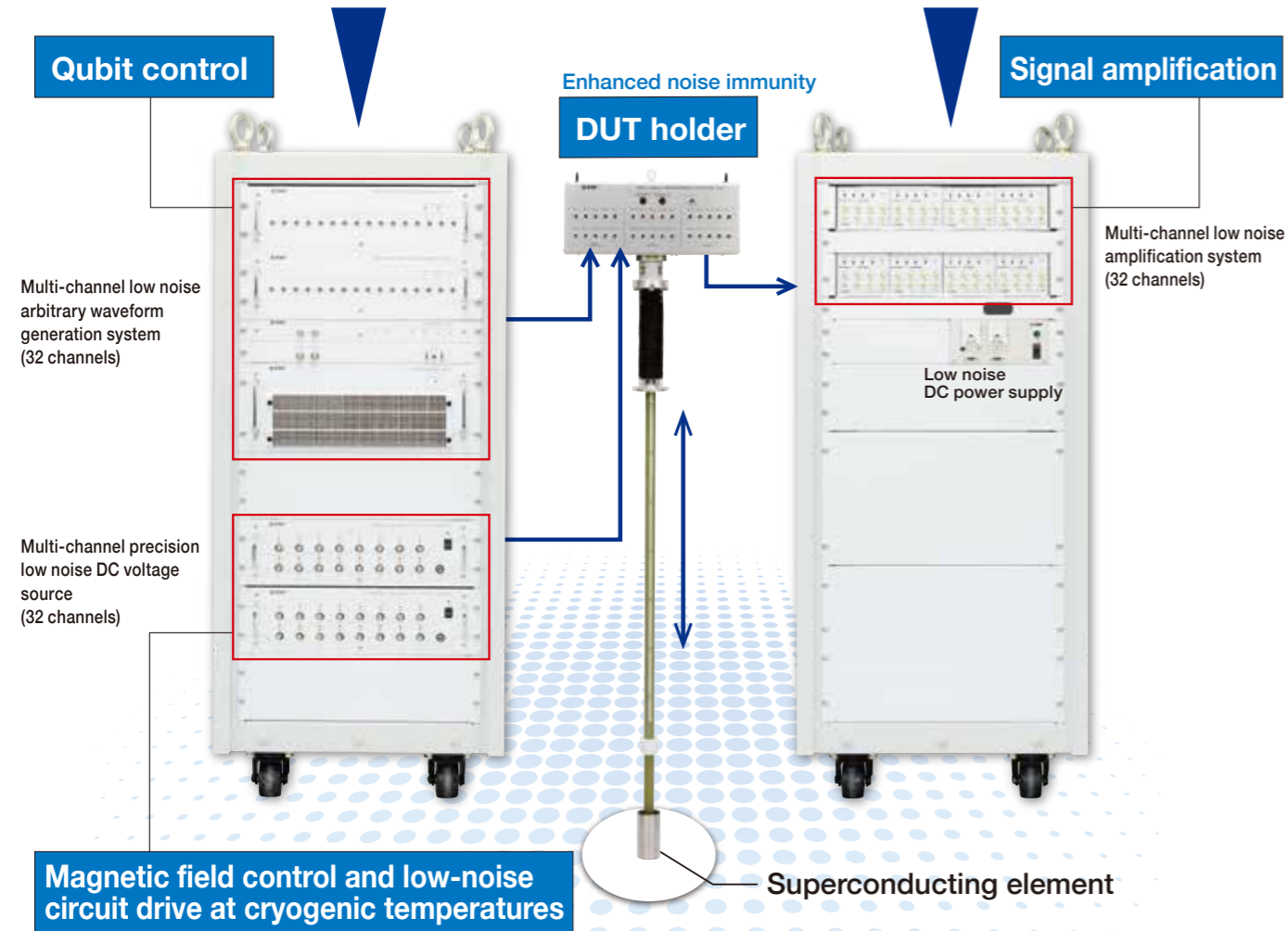
A low-noise system required for control of superconducting elements and high-precision signal detection in quantum annealing computer equipment.

Multiple qubits

Multi-channel systems are suitable for evaluating multiple qubits.

Driving and controlling superconducting elements

Signal detection of superconducting elements



Signal source for qubit control

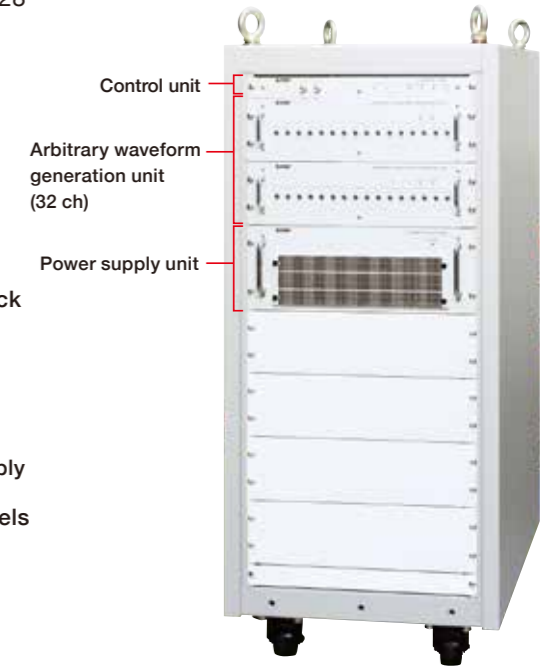
Multi-channel low noise arbitrary waveform generation system

Up to 128 channels

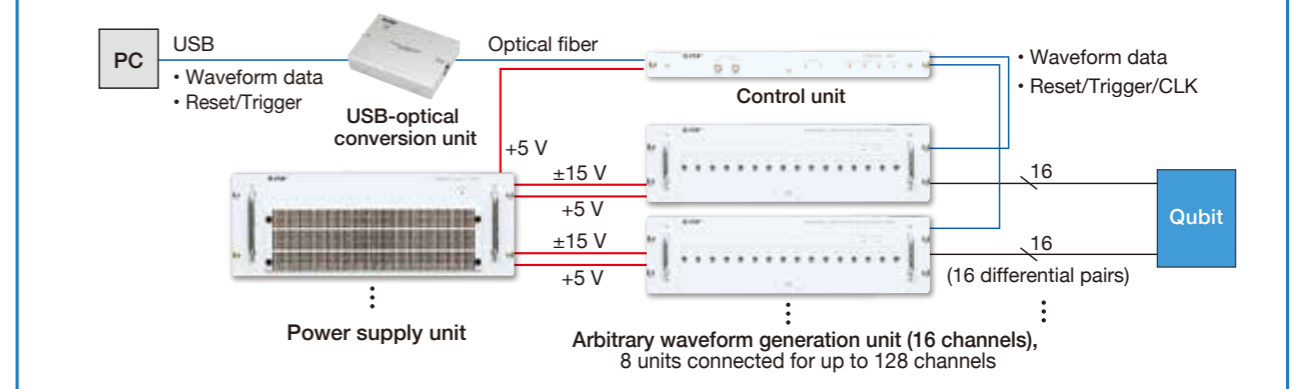
A signal source that controls quantum bits in a quantum annealing computer. Signal sources are 16 channels per unit, expandable up to 128 channels. Low noise output suitable for controlling multiple qubits.

- Up to 128 channels of differential sync output and arbitrary waveform output (expandable up to 1000 ch)
- Arbitrary waveform can be set for each channel
- Less than 50 ns channel-to-channel skew
- High linearity achieved by analog linear interpolation circuit and underclock
- Low noise design with enhanced noise immunity
 - Reduction of common mode noise by differential signal output
 - Optical fiber communication cuts off noise via PC
 - Low noise linear power supply reduces noise pickup through the power supply
- A system is constructed by combining a control unit with up to 128 channels an arbitrary waveform generation unit with 16 channels, and a low-noise linear power supply unit.

Specification examples are shown on page 6.

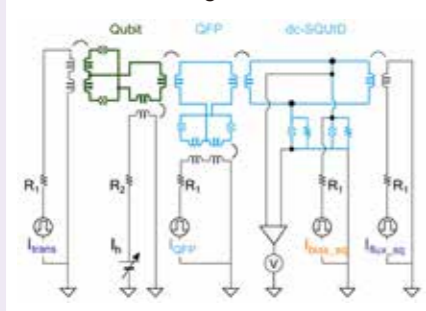


System configuration

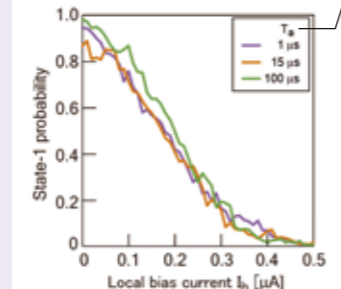


Measurement of superconducting flux qubits

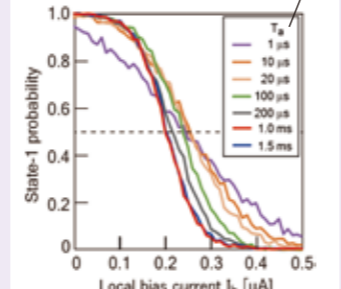
Quantum annealing circuit structure



• Noise floor of pA/√Hz (Equivalent to conventional system)



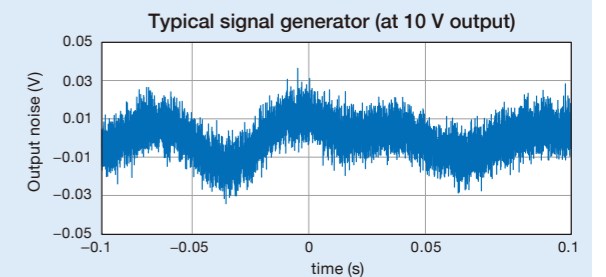
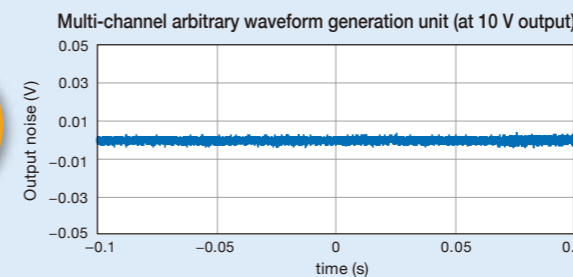
• Noise floor of fA/√Hz (Equivalent to NF system)



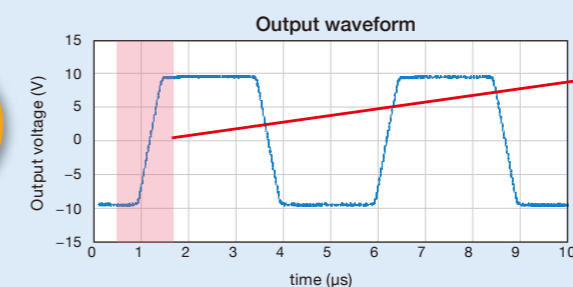
By using a low noise power supply and increasing the annealing time, the state transition occur in a narrow range

scientific reports "Supplementary Materials for Factorization by Quantum Annealing Using Superconducting Flux Qubits Implementing a Multiplier Hamiltonian", Daisuke SAIDA et al.

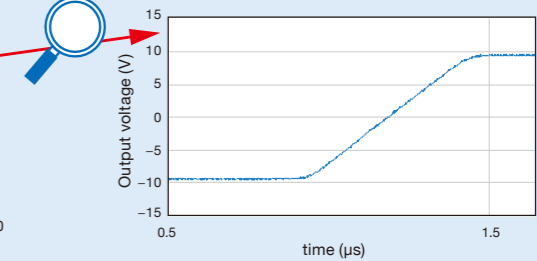
Achieves ultra-low noise



Smooth-voltage control



Expansion



Magnetic field control and low noise circuit drive under cryogenic temperature

Multi-channel precision low noise DC voltage source

Ultra-low noise, high accuracy, and high stability multi-channel low noise DC voltage source.

This voltage source reduces power supply noise for qubit magnetic field control in quantum annealing computer systems and circuit drive at cryogenic temperatures where thermal noise is very low.

Because of its high precision and high stability, it is suitable for adjusting variations in device characteristics.

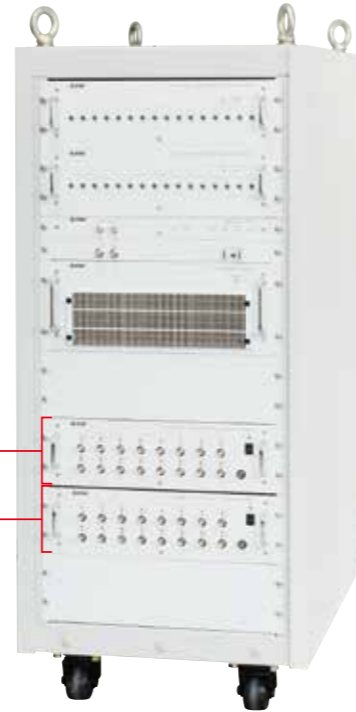
- Output noise voltage 10 μ Vrms (Bandwidth between 10 Hz and 1 MHz)
- Output voltage* 0 to +16.1 V
- Setting resolution 100 μ V
- Setting accuracy \pm (0.03 % + 125 μ V)
- Output stability \pm 10 ppm/ $^{\circ}$ C typ.
- Output current up to 15 mA per channel
- Number of channels 16
- Interface LAN/USB

*Bipolar outputs available.

Specification examples are shown on page 6.

Expandable in units of 16 channels

16 channels
16 channels



16 channels per unit
Output voltage of each channel can be set by external control

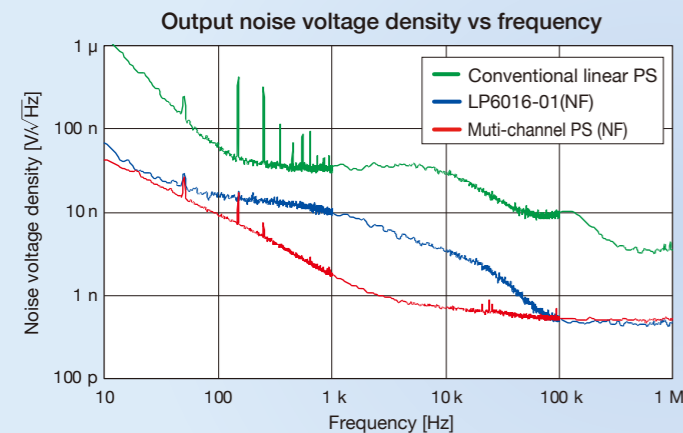


Low noise DC current source available

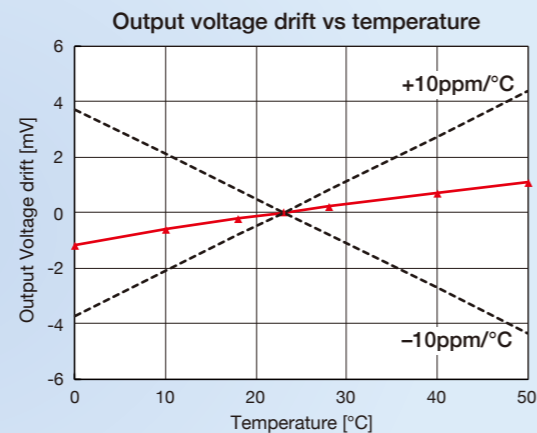
Specifications example

- Output current noise 0.1 μ Ap-p (BW10 kHz)
- Output current 0 to \pm 3 mA
- Setting resolution 100 nA
- Output Accuracy \pm 0.5%
- Output Stability \pm 25 ppm/ $^{\circ}$ C typ.

Output noise and output stability



▶ Excellent low noise performance



▶ Outstanding temperature stability

Signal amplification

Multi-channel low noise amplification system

Expandable in units of 4 channels

A signal amplification system suitable for low noise, number of channels and functions can be constructed.

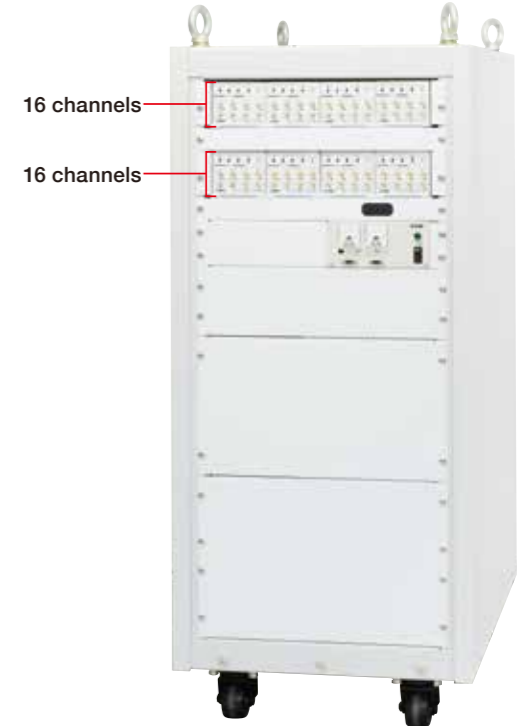
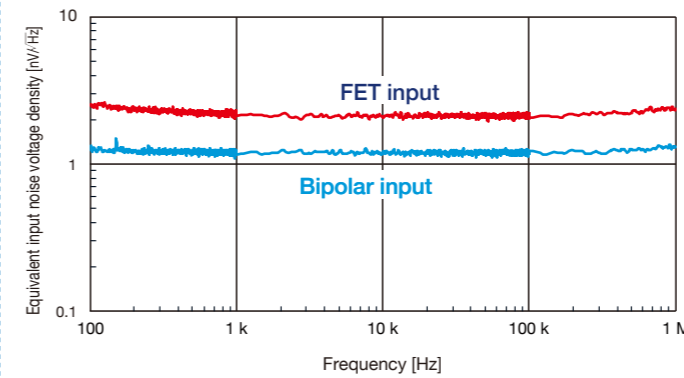
Ultra-low noise performance supports highly accurate measurements.

Selectable according to sensor type: differential input (bipolar input, FET input), single-ended input (bipolar input, FET input) There are 4 channels per unit, and a multi-channel system is possible by increasing the number of units.

- Low noise 1.3 nV/ $\sqrt{\text{Hz}}$ (bipolar input), 2.5 nV/ $\sqrt{\text{Hz}}$ (FET input)
- Compact housing suitable for multi-channel applications
- Multifunctional
 - Input coupling selection DC/AC
 - Input mode selection Differential/Single-ended/GND
 - Low-pass filter selection THRU/LPF ON (fc=1 MHz)
 - Input conversion offset voltage adjustment range \pm 100 μ V
 - Amplifier GND selection FLOAT/EXTERNAL

Specification examples are shown on page 6.

Ultra-low noise performance

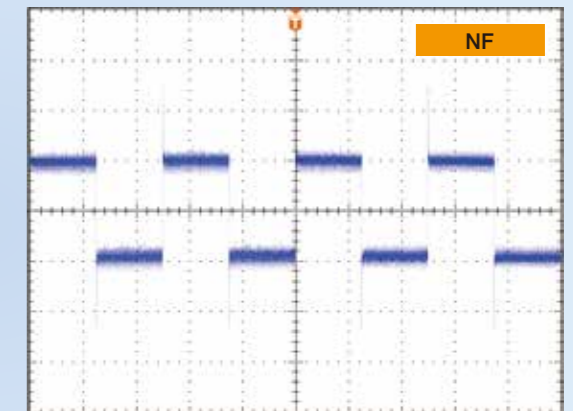
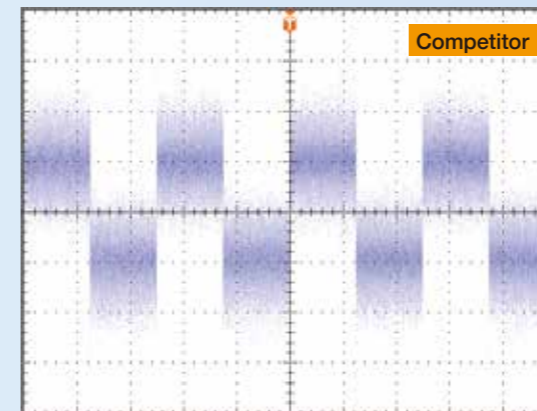


16 channels



4 channels

Noise level comparison



X-axis: 400 μ s/div. Y-axis: 2.5 mV/div.

▶ Output waveforms (differential input, gain 40 dB, DC to 1 MHz range)

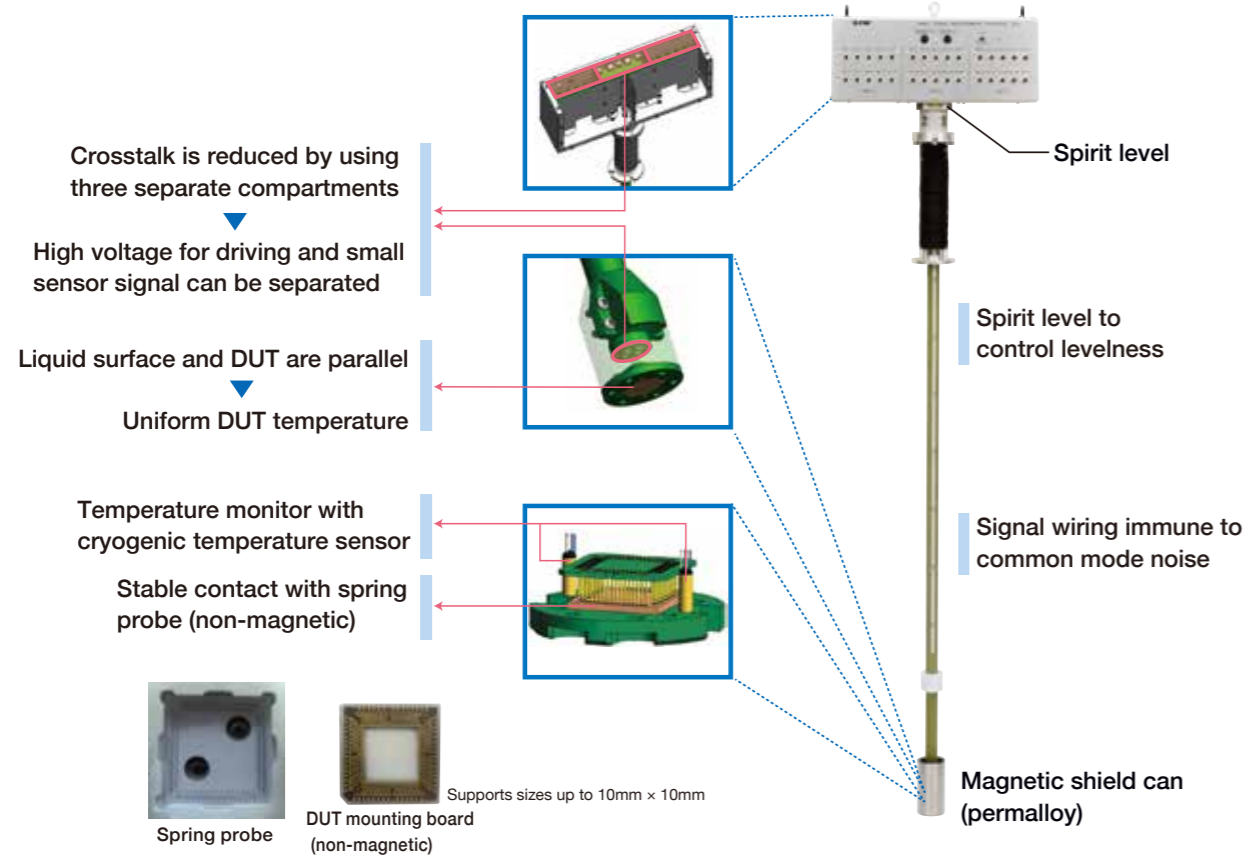
Low noise measurement under cryogenic temperature

Low noise DUT holder for cryostat

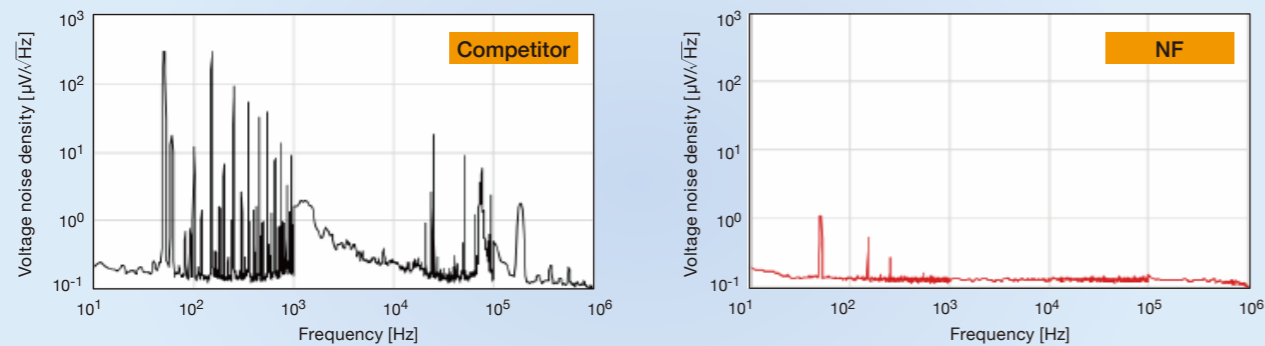
Enhanced noise immunity

A rod for cooling and measuring superconducting devices such as Josephson elements with liquid helium (4.2 K). Supports stable measurement and evaluation with various measures to improve noise immunity.

- Signals 60 pins, differential 30 signals (can be changed by custom request)
- Special wiring to reduce common mode noise
- The internal structure is divided into three compartments, enabling use while suppressing crosstalk between wiring.
- The temperature of the DUT is uniform because the liquid surface and the DUT are horizontal.
- Spring probe provides stable contact and easy maintenance
- It is possible to insert a rod with levelness controlled using a spirit level.
- Magnetic shield can (ferromagnetic material: permalloy) can be attached
- Built-in temperature sensor (non-magnetic compatible)



Noise level comparison



▶ Reduced voltage noise by 1/300 at 50 Hz and 1/500 at 150 Hz compared to competitor equipment

Application

- Superconducting devices
- Cryogenics and condensed matter physics

Specifications (example)

Multi-channel low noise arbitrary waveform generation system

Unless otherwise specified: temperature 23±5°C, load 1MΩ, LPF THRU, ATT THRU, linear interpolation circuit ON

Output waveform	Arbitrary waveform	
Maximum output voltage	±10 V (paired with COM; ±20 V differential)	
Sampling rate	2 M S/s	
Waveform length	10 words to 256 K words	
Number of stored waveforms	16 waveforms stored in volatile memory	
Output characteristics	Connectors	HR10-7R-4S
	Form	Differential output
	Maximum current	10 mA
	Impedance	50 Ω paired with COM
	Channel-to-channel skew	Within 50ns
	Noise	1.2 mVrms: linear interpolation circuit ON, bandwidth 20 MHz, paired with COM 0.1 mVrms: linear interpolator OFF, bandwidth 20 MHz, paired with COM
	Bandwidth	3 MHz: linear interpolation circuit ON, -3 dB typ. 1.6 kHz: linear interpolation circuit OFF -3 dB typ.
Linear interpolation	ON/OFF switching by PC	
Other features	Sequence, external synchronization	
Interface	USB2.0	
USB optical conversion adapter	Input	Input connector: USB2.0 Type B female, Connect with PC, Communication: USB2.0 high speed
	Output	Output connector: optical connector, Communication: Dedicated optical serial signal
Power supply unit	Input voltage: AC 100 V ±10 %, frequency: 50/60 ±2 Hz, power consumption: 270 W or less (for 16 channels)	

Multi-channel precision low noise DC voltage source

Type	Series regulator type	
Output characteristics	Number of outputs	16 channels
	Connectors	BNC receptacle connectors
	Voltage setting range	0.000 0 to +16.100 0 V, all channels, resolution 100 μV
	Voltage setting control	External control
	Voltage setting accuracy	±(0.03 % of setting + 125 μV), at 23 °C ±5 °C, no load
	Temperature coefficient	±10 ppm/°C typ.
	Maximum current	15 mA for each channel, at 0 to 40 °C
	Input fluctuation	Within ±0.1 mV, at power supply voltage ±10 %
Ripple noise	10 μVrms or less typ. , in a bandwidth of 10 Hz to 1 MHz, output current 0 to 15 mA	
Output ON/OFF	External control	
Interface	USB2.0, 10BASE-T/100BASE-TX, TCP/IP	
Power supply	Input voltage: AC 100 V ±10%, Input frequency: 50/60 ±2 Hz	

Multi-channel low noise amplification system (4 channels)

	Bipolar input	FET input
Input coupling	DC/AC	
Input mode	A-B/A-/B/GND	
Input impedance	100 kΩ, coupling capacitance 1 μF	1 MΩ, coupling capacitance 0.1 μF
Equivalent Input Noise Voltage Density	1.3 nV/√Hz	2.5 nV/√Hz
Offset voltage referred to input	Adjustable to zero (input shorted, DC coupled, potentiometer setting)	
Input bias current	30 nA	30 pA
Input voltage range	Within ±0.1 V	
Maximum output voltage/current	±10 V, ±10 mA	
Slew rate	22 V/μs	600 V/μs
Output impedance	50 Ω	
Voltage gain	40 dB (f=1 kHz)	
Voltage gain frequency response	DC to 1 MHz (within +0.5 dB / -3.0 dB)	DC to 20 MHz (within +0.5 dB / -3.0 dB)
Low pass filter	fc = 1 MHz (Linear phase 3rd order)	
External dimensions (mm)	105 (W) × 88 (H) × 210 (D)	
Power supply*	±15 V, current consumption: ±240 mA (maximum)	

*NF low-noise DC power supply is recommended.

*Note: The contents of this catalog are current as of November 7th, 2022.
Product appearance and specifications are subject to change without notice.
Before purchase, contact us to confirm the latest specifications, pricing and delivery date.

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