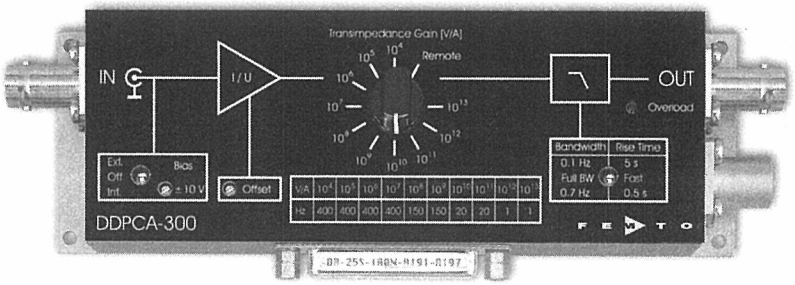
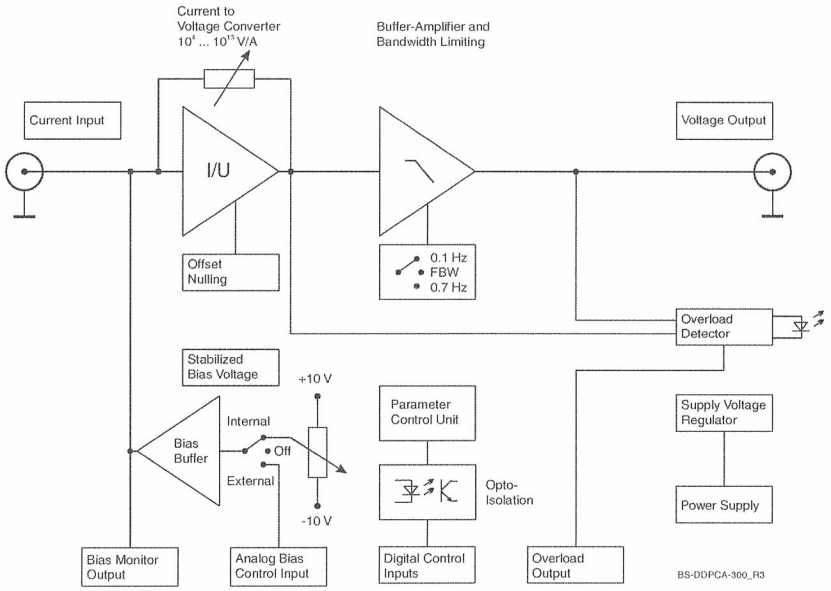
Variable Gain
Sub Femto Ampere Current Amplifier



Picture similar to actual device.

Features	• **0.4 fA Peak-Peak Noise** • **Very High Dynamic Range: Sub-fA to 1 mA (> 240 dB)** • **Transimpedance (Gain) Switchable from 1 x 10^4 to 1 x 10^{13} V/A** • **Bandwidth up to 400 Hz, Rise Time Down to 0.8 ms - Independent of Source Capacitance (up to 10 nF)** • **Adjustable Bias Voltage on Input Relative to Ground** • **Compact Housing for Use Close to the Signal Source** • **Local and Remote Control** • **Input Offset Voltage Adjustment** • **Easy to Use:** **Convert Your Standard Digital Voltmeter or DAQ Board to a High-End Digital Sub Femto Amperemeter**
Applications	• **Photodetector Amplifier** • **I/V Characterization of Small MOS Structures** • **DC Measurements of Ultra Low Currents** • **Ionization Detectors, Mass Spectrometry, Quantum and Biotech Experiments** • **Characterization of High Impedance Nanomaterials** • **Spectroscopy** • **High Resistance Measurements**
Block Diagram	

Variable Gain
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Specifications

Test Conditions — *Vs = ± 15 V, Ta = 25°C, Relative Humidity < 35 %*

Gain

Transimpedance	1 x 10^4 ... 1 x 10^{13} V/A
Gain Accuracy	± 1 %
Gain Drift	see table below

Frequency Response

Lower Cut-Off Frequency	DC
Upper Cut-Off Frequency	up to 400 Hz (see table below)
Adjustable Low Pass Filter	switchable to 3 settings (full bandwidth, 0.7 Hz and 0.1 Hz)

Upper Cut-Off	Rise Time
Full BW (see table below)	Fast (see table below)
0.7 Hz	0.5 s
0.1 Hz	5 s

Setting the low pass filter to full bandwidth is recommended for high measurement speed. By setting the low pass filter to 0.7 Hz or 0.1 Hz the peak-peak noise performance can be improved but the signal settling time will be longer.

Input

Equ. Input Noise Current	gain setting dependent, see table below minimum input noise is 0.4 fA peak-peak (at gain setting 10^{12} or 10^{13} V/A with low pass filter switched to 0.1 Hz)
Input Bias Current	< 10 fA typ.
Input Bias Current Drift	factor 2 / 10 °C
Max. Input Current (Full Scale)	see table below (value for linear amplification)
Input Offset Current Compensat.	adjustable by offset trimpot, ± 100 fA
Input Offset Voltage Compensat.	adjustable by offset trimpot, ± 200 µV

Performance Depending on Gain Setting

Gain Setting (V/A)	10^4	10^5	10^6	10^7	10^8
Upper Cut-Off Frequency (- 3 dB)*	400 Hz	400 Hz	400 Hz	400 Hz	150 Hz
Rise / Fall Time (10 % - 90 %)*	0.8 ms	0.8 ms	0.8 ms	0.8 ms	2.3 ms
Integrated Input Noise Current (Peak-Peak)*	7 nA	7 nA	70 pA	70 pA	1.2 pA
Spectral Input Noise Current Density (/√Hz)	45 pA	45 pA	0.45 pA	0.45 pA	15 fA
Measured at	10 Hz	10 Hz	10 Hz	10 Hz	10 Hz
Gain Drift (/°C)	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
Max. Input Current (± Full Scale)	1 mA	0.1 mA	10 µA	1 µA	0.1 µA
DC Input Impedance (// 5 pF)	< 1 Ω	< 1 Ω	< 1 Ω	< 1 Ω	< 100 Ω

Gain Setting (continued) (V/A)	10^9	10^{10}	10^{11}	10^{12}	10^{13}
Upper Cut-Off Frequency (- 3 dB)*	150 Hz	20 Hz	20 Hz	1 Hz	1 Hz
Rise / Fall Time (10 % - 90 %)*	2.3 ms	17 ms	17 ms	350 ms	350 ms
Integrated Input Noise Current (Peak-Peak)*	1.2 pA	50 fA	50 fA	2 fA	2 fA
Spectral Input Noise Current Density (/√Hz)	15 fA	1.3 fA	1.3 fA	0.2 fA	0.2 fA
Measured at	10 Hz	1 Hz	1 Hz	0.4 Hz	0.4 Hz
Gain Drift (/°C)	0.01 %	0.03 %	0.03 %	0.03 %	0.03 %
Max. Input Current (± Full Scale)	10 nA	1 nA	0.1 nA	10 pA	1 pA
DC Input Impedance (// 5 pF)	< 100 Ω	< 10 kΩ	< 10 kΩ	< 1 MΩ	< 1 MΩ

* The values for upper cut-off frequency, rise / fall time and integrated input noise current stated in the table above are achieved with the low pass filter set to "Full BW / Fast" (full bandwidth / fast rise time). Lower peak-peak noise values can be achieved by setting the low pass filter to 0.7 Hz or 0.1 Hz. In that case the bandwidth will be lower and the signal rise / fall time will be longer though.

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Specifications (continued)

Output	Output Voltage	± 10 V (@ ≥ 1 MΩ load)
	Output Impedance	50 Ω (terminate with ≥ 1 MΩ load for best performance)
	Max. Output Current	± 30 mA
Adjustable Bias Voltage	General	An adjustable bias voltage is provided for directly biasing the device under test DUT (e.g. photodiode, high resistance semiconductor component). The bias voltage is connected to the inner conductor of the BNC input socket; the BNC-shield is always connected to analog ground. The bias voltage can be set through a control voltage fed to the "Bias Control" BNC socket.
	Bias Voltage Range	± 100 mV at inner conductor of BNC input socket, set by a ± 10 V control voltage at the "Bias Control" BNC socket
	Bias Output Current	max. ± 10 mA
	Input Impedance of Bias Control	100 kΩ (recommended impedance for bias control voltage source: 50 Ω)
	Bias Control Voltage Range	± 10 V at "Bias Control" BNC socket
	Bias Control Polarity	inverting, transfer function: x (- 0.01)
	Example:	feeding a control voltage of + 2 V to "Bias Control" BNC socket leads to - 20 mV bias voltage at the inner conductor of the BNC input socket referred to BNC shield (analog ground, AGND)
Bias Monitor Output	Range	± 100 mV, mirrors the adjusted bias voltage at the BNC input (inner conductor referred to AGND pin 3)
	Connector	pin 7 of Sub-D connector (referred to AGND pin 3)
	Output Impedance	50 Ω (terminate with ≥ 1 MΩ load for best performance)
Overload Indication	LED	lights when overload is detected
	Digital Output	active when overload is detected (non active: 0 V, max. -1 mA, active: 5.1 V, max. 7 mA; referred to AGND pin 3)
Digital Control	Control Input Voltage Range	LOW bit: - 0.8 ...+ 1.2 V, HIGH bit: + 2.3 ... + 12 V
	Control Input Current	0 mA @ 0 V; 1.5 mA @ + 5 V; 4.5 mA @ + 12 V
Auxiliary Power Output	Voltage	± 12 VDC, stabilized, max. ± 50 mA (at Sub-D, may be used for supplying external devices up to ± 50 mA)
Power Supply	Supply Voltage	± 15 V
	Supply Current	+ 70 mA / -15 mA typ. (depends on operating conditions, recommended power supply capability minimum ± 150 mA)
Case	Weight	320 g (0.74 lb.)
	Material	AlMg4.5Mn, nickel-plated
Temperature Range	Storage Temperature	- 40 ... + 100 °C
	Operating Temperature	0 ... + 50 °C

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Absolute Maximum Ratings	Signal Input Voltage	± 15 V relative to bias
	Transient Input Voltage	± 2 kV (discharge from 1 nF source)
	Digital Control Input Voltage	- 5 V / + 16 V
	Bias Control Input Voltage	± 12 V
	Power Supply Voltage	± 20 V

Connectors

Input: BNC

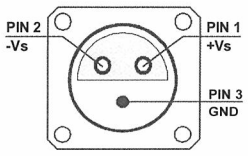
Output: BNC

Bias Voltage Output: center pin of BNC input socket

Bias Voltage Control Input: BNC

Power Supply: LEMO series 1S, 3-pin fixed socket

Pin 1: + 15V
Pin 2: - 15V
Pin 3: GND



Control Port: Sub-D 25-pin, female, qual. class 2

Pin 1: +12V (stabilized power supply output)
Pin 2: -12V (stabilized power supply output)
Pin 3: AGND (analog ground)
Pin 4: NC
Pin 5: overload output (refers to AGND)
Pin 6: signal output (connected to BNC output connector)
Pin 7: bias voltage monitor output (refers to AGND)
Pin 8: NC
Pin 9: DGND (ground for digital control pins 10 - 13)
Pin 10: digital control input: gain, LSB
Pin 11: digital control input: gain
Pin 12: digital control input: gain
Pin 13: digital control input: gain, MSB
Pin 14 - 25: NC

Variable Gain
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Remote Control Operation

General

Remote control input bits are opto-isolated. For remote control operation set the rotary gain switch to the "Remote" position and select the desired gain setting via a bit code at the digital inputs.

Switch setting "0.1 Hz / Full BW / 0.7 Hz" is not remote controllable.

Gain Setting

Gain (V/A)	Pin 13 MSB	Pin 12	Pin 11	Pin 10 LSB
10^4	LOW	LOW	LOW	LOW
10^5	LOW	LOW	LOW	HIGH
10^6	LOW	LOW	HIGH	LOW
10^7	LOW	LOW	HIGH	HIGH
10^8	LOW	HIGH	LOW	LOW
10^9	LOW	HIGH	LOW	HIGH
10^{10}	LOW	HIGH	HIGH	LOW
10^{11}	LOW	HIGH	HIGH	HIGH
10^{12}	HIGH	LOW	LOW	LOW
10^{13}	HIGH	LOW	LOW	HIGH

Variable Gain
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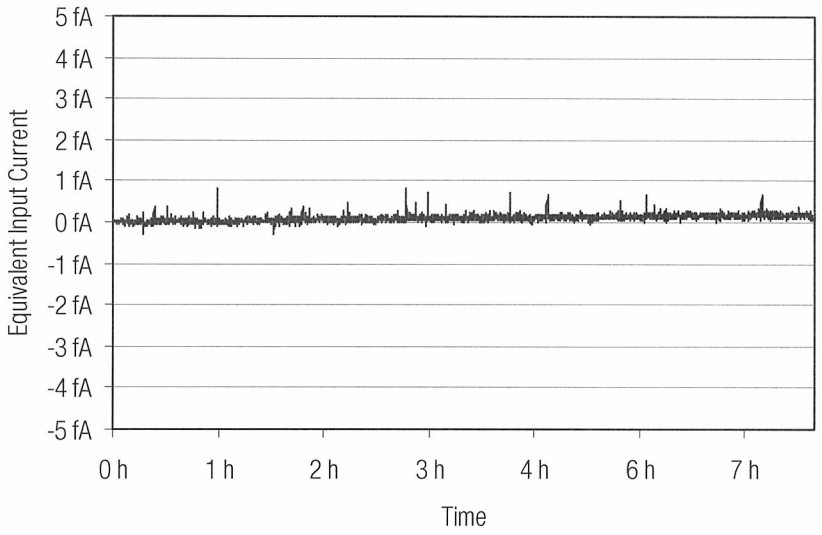
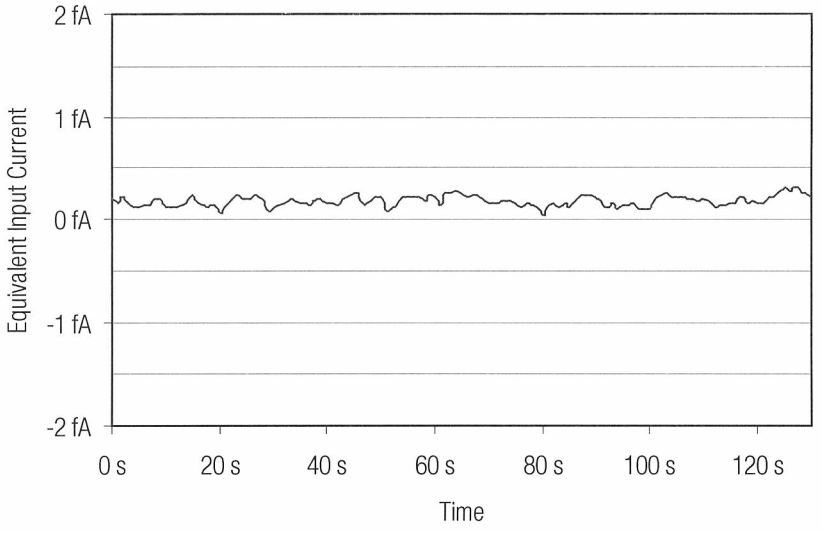
Typical Performance Characteristics

Long Term Drift



Short Term Drift



Both drift curves were recorded with shielded input in the gain setting 10^{12} V/A, filter setting 0.1 Hz.

Variable Gain
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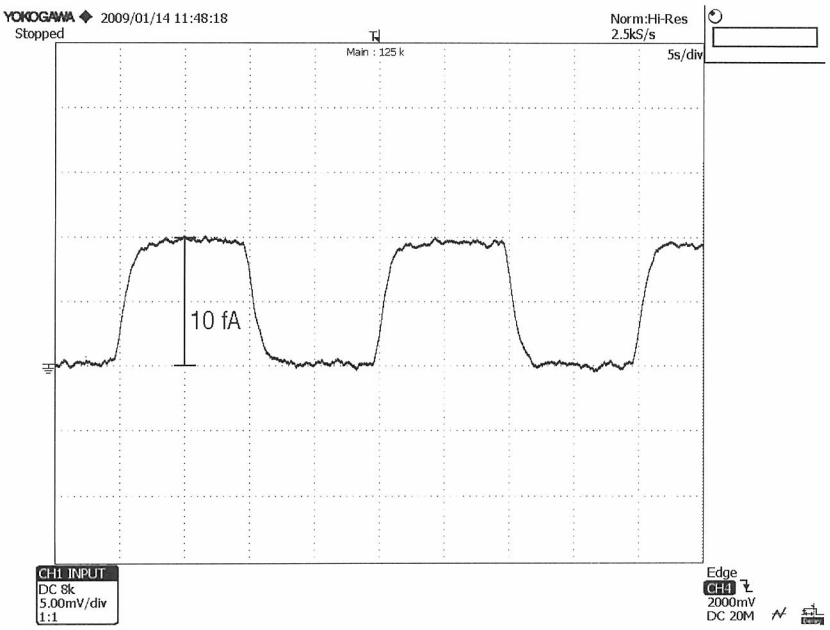
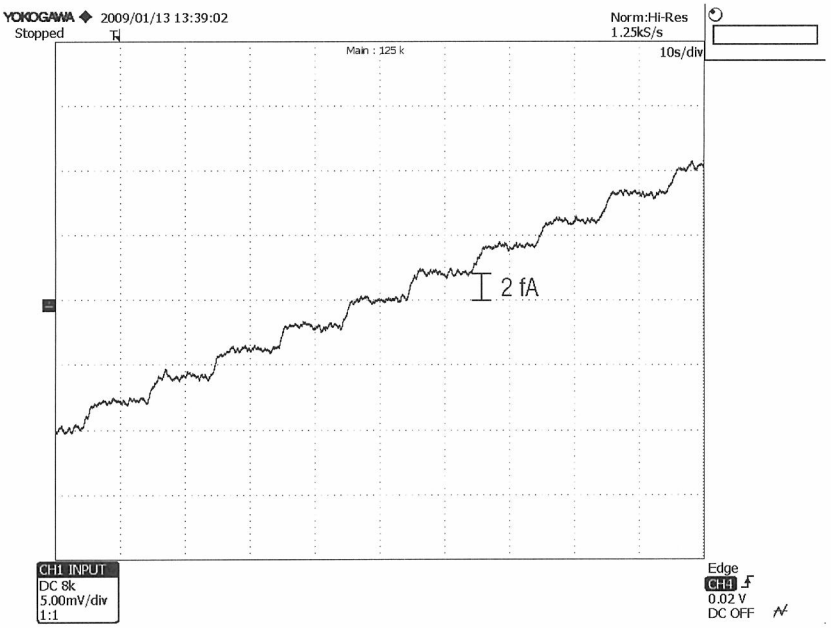
Typical Performance Characteristics

10 fA square wave



2 fA step curve



Both curves were recorded in the gain setting 10^{12} V/A, filter setting 0.7 Hz, no external averaging.

Variable Gain
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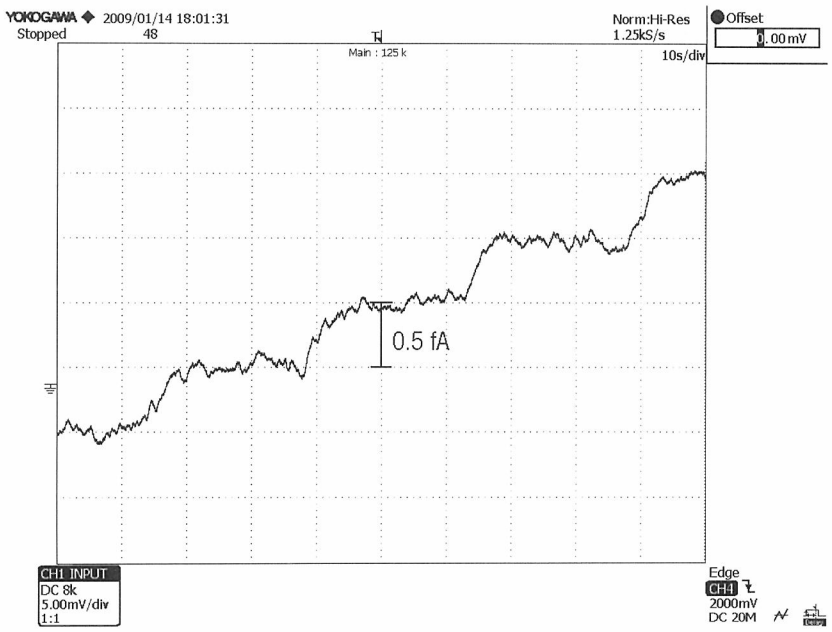
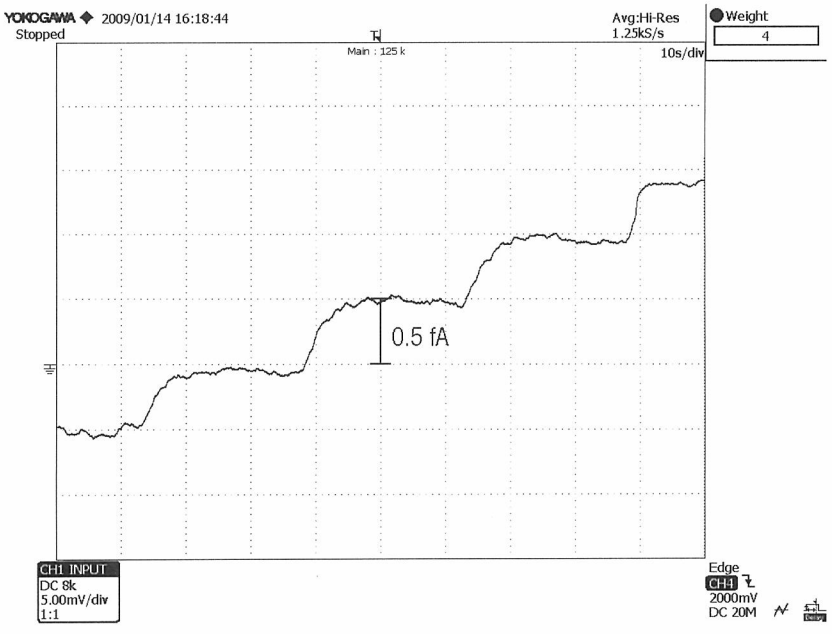
Typical Performance Characteristics

0.5 fA step curve, no averaging



0.5 fA step curve, 4 times external averaging



Both curves were recorded in the gain setting 10^{13} V/A, filter setting 0.1 Hz.

Variable Gain
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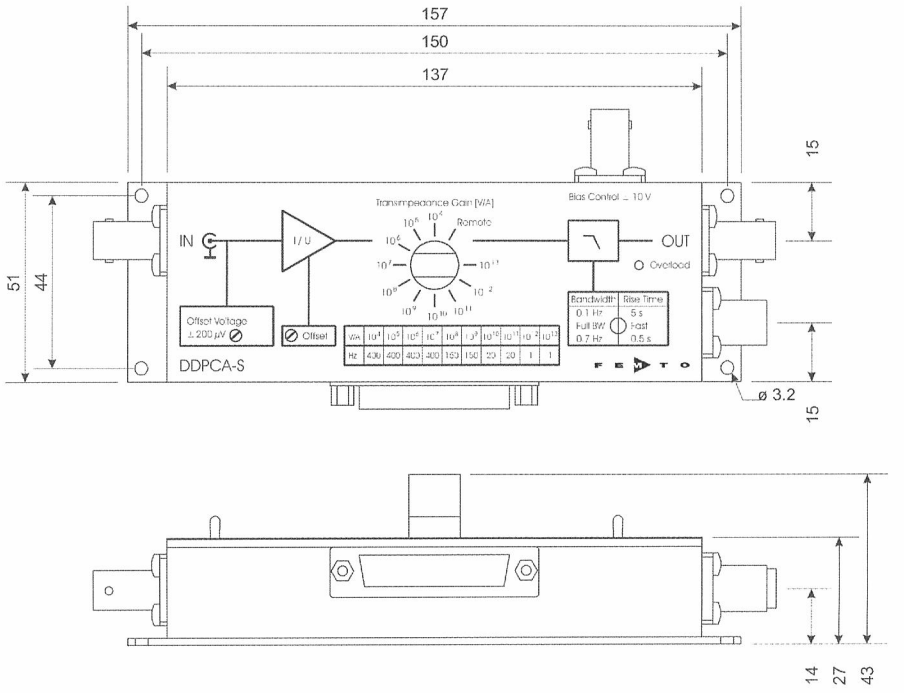
Dimensions



all measures in mm unless otherwise noted

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