

MFLI and MFIA Specification

General specification

Storage temperature	+5°C to +65°C
Storage relative humidity	< 95%, non-condensing
Operating temperature	+5°C to +40°C
Operating relative humidity	< 90%, non-condensing
Specification temperature	+18°C to +28°C
Power consumption	< 40 W
DC power inlet	12 V, 2 A Connector: Switchcraft 760BK, ID 2.5 mm, OD 5.5 mm
Power supply AC line	100 - 240 V ($\pm 10\%$), 50/60 Hz
Line power fuse	250 V, 2 A, fast, 5 x 20 mm, F 2A L 250V
Dimensions including bumper	28.3 x 23.2 x 10.2 cm 11.1 x 9.1 x 4.0 inch Rack mount on request
Weight including bumper	3.8 kg
Recommended calibration interval	2 years (see sticker on back panel)
Warranty	1 year, extensible

Demodulators

Frequency range	0 to 500 kHz; 0 to 5 MHz, requires MF-F5M option
Number of demodulators	1 dual-phase (X, Y, R, Θ); 4 dual-phase, requires MF-MD option
Demodulator inputs	Signal Inputs (V/I), Auxiliary Inputs, Auxiliary Outputs, Trigger Inputs
Filter time constant	336 ns - 83 s
Filter bandwidth (-3 dB)	276 μ Hz - 206 kHz (4th order filter)
Harmonics	1 - 1023
Filter slope	6, 12, 18, 24, 30, 36, 42, 48 dB/oct
Additional filtering	Sinc filter
Phase resolution	10 μ deg
Frequency resolution	1 μ Hz
Output sample rate on Auxiliary Outputs	612 kSa/s (for each auxiliary output), 18 bit, ± 10 V
Maximum transfer rate over 1 GbE	200 kSa/s (all demodulators), 48-bit full range
Maximum rate to store on local USB drive	50 kSa/s (all demodulators), 48-bit full range
Trigger modes for data transfer	Continuous, edge, gated

Reference modes

External reference frequency range	1 Hz to 500 kHz; 1 Hz to 5 MHz, requires MF-F5M option
External reference input	Auxiliary Inputs, Trigger Inputs, Auxiliary Outputs, Current Signal Input, Voltage Signal Input
Lock time for external reference	Typically less than max(100 cycles, 1.2 ms)
Number of external references	1; 2 requires MF-MD option
Internal reference frequency range	DC to 500 kHz; DC to 5 MHz, requires MF-F5M option

Scope

Input channels	Signal Inputs (V,I), Auxiliary Inputs, Auxiliary Outputs, Trigger Inputs, Trigger Outputs, Signal Output, Oscillator Phase
Scope modes	Time domain, frequency domain (FFT)
Number display channels	1; 2, requires MF-DIG option
Trigger channels	Signal Inputs (V,I), Auxiliary Inputs, Auxiliary Outputs, Trigger Inputs, Trigger Outputs
Trigger modes	Edge
Trigger hysteresis	Full input range
Pretrigger	Full sample range
Sampling rates	1.8 kSa/s to 60 MSa/s
Vertical resolution	16 bit
Maximum number of samples per shot	16 kSa; 2.5 MSa per channel, requires MF-DIG option
Minimum hold time	1 ms
Bandwidth limit mode, vertical resolution increase	Down sampling by averaging; increase vertical resolution up to 24 bit, requires MF-DIG option
Cursor math	Location, Area, Wave, Peak, Tracking, Histogram

Spectrum Analyzer

Center frequency range	0 to 500 kHz; 0 to 5 MHz, requires MF-F5M option
Spectrum modes	FFT(X+iY), FFT(R), FFT(Θ), FFT(f) and FFT($(d\Theta/dt)/2\pi$)
Statistical options	Amplitude, Spectral density, Power
Averaging modes	None, Exponential moving average
Maximum number of samples per spectrum	8 kSa
Maximum span	58 kHz
Window functions	Rectangular, Hann, Hamming, Blackman Harris
Cursor math	Location, Area, Tracking, Wave, Peak, Histogram

Sweeper

Scan parameters	Oscillator frequency, Demodulator phase, Auxiliary Offset, Signal Output Offset, etc.
Parameter sweep ranges	Full range, Linear and Logarithmic
Parameter sweep resolution	Arbitrary, defined by start/stop value and number of sweep points
Display parameters	Demodulator Output (X, Y, R, Θ , f), Auxiliary Input
Display options	Single Plot, Dual Plot (e.g. Bode Plot), Multi-trace
Statistical options	Amplitude, Spectral density, Power
Preset measurement modes	Parameter sweep, Noise amplitude measurement, Frequency response analyzer, 3-Omega-Sweep

Voltage Signal Inputs

Connectors	2 BNC on front panel, single ended and differential
Shield connectivity	Floating or ground
Maximum float voltage versus ground	$\pm 1V$
Input impedance	50 Ω and 10 M Ω ; 27 pF for range ≥ 300 mV; 35 pF for range ≤ 100 mV
Input frequency range	DC to 500 kHz; DC to 5 MHz, requires MF-F5M option
Input A/D conversion	16 bit, 60 MSa/s
Input noise amplitude	2.5 nV/ \sqrt{Hz} above 1 kHz for 3.3 mV input range and

	shorting cap on input; 7 nV/√Hz at 10 Hz, 40 nV/√Hz at 1 Hz
Input noise corner frequency	Typically 100 Hz for range ≤ 10 mV
Input bias current	Typically ±10 pA, max ±200 pA
Input full range sensitivity (10 V lock-in amplifier output)	1 nV to 3 V
Input AC ranges	±1 mV to ±3 V, 8 steps
AC coupling cutoff frequency	1.6 Hz
Maximum DC offset for AC coupling	±10 V
Input DC ranges	1 mV to 3 V, 8 steps
Input gain inaccuracy	< 1% (< 2 MHz); for higher frequencies limited by analog input filter
Analog input filter (anti-aliasing)	1 dB suppression at 5 MHz, 3 dB at 12 MHz; 3rd order roll-off
Input amplitude stability	0.1%/°C
Input offset amplitude	< max(0.5 mV, 1% of range)
Dynamic reserve	Up to 120 dB
Harmonic distortion	80 dBc for frequencies ≤ 100 kHz; 65 dBc for frequencies ≤ 5 MHz; carrier amplitude 1 dBFS
Coherent pickup	< -140 dB for frequencies ≤ 5 MHz and 50 Ω input impedance; < -180 dB for frequencies ≤ 100 kHz and 50 Ω input impedance

Current Signal Input

Connector	BNC on front panel, float/gnd
Shield connectivity	Floating or ground
Maximum float voltage versus ground	±1 V
Input impedance	see Table 5.9
Input frequency range	DC to 500 kHz; DC to 5 MHz, requires MF-F5M option
Input A/D conversion	16 bit, 60 MSa/s
Input noise amplitude	20 fA/√Hz above 100 Hz for 10 nA input range; 200 fA/√Hz above 10 kHz for 1 μA input range; 3.5 pA/√Hz above 1 MHz for 100 μA input range; 300 pA/√Hz above 1 MHz for 10 mA input range;
Input leakage current	±10 pA
Input full range sensitivity (10 V lock-in amplifier output)	±10 fA to ±10 mA
Input gain inaccuracy	< 1% (for frequencies below 10% of the input bandwidth)
Input offset amplitude	1% of range
Input offset voltage	±2.2 mV max.
Dynamic reserve	up to 120 dB
Coherent pickup	< 90 GΩ for frequencies ≤ 5 MHz and 100 μA input range < 140 TΩ for frequencies ≤ 100 kHz and 10 nA input range

Current input range	Transimpedance gain	Bandwidth (-3 dB)	Input impedance at DC	Input noise
10 mA	100 V/A	5 MHz	50 Ω	300 pA / √Hz at 100 kHz
1 mA ¹	1 kV/A	5 MHz	50 Ω	200 pA / √Hz at 100 kHz

100 μ A	10 kV/A	5 MHz	60 Ω	3.5 pA / $\sqrt{\text{Hz}}$ at 100 kHz
10 μ A ¹	100 kV/A	5 MHz	60 Ω	2.5 pA / $\sqrt{\text{Hz}}$ at 100 kHz
1 μ A	1 MV/A	450 kHz	1 k Ω	200 fA / $\sqrt{\text{Hz}}$ at 1 kHz
100 nA ¹	10 MV/A	450 kHz	1 k Ω	150 fA / $\sqrt{\text{Hz}}$ at 1 kHz
10 nA	100 MV/A	2 kHz	160 k Ω	20 fA / $\sqrt{\text{Hz}}$ at 100 Hz
1 nA ¹	1 GV/A	2 kHz	160 k Ω	15 fA / $\sqrt{\text{Hz}}$ at 100 Hz

¹Range only available on MF Instruments with serial numbers MF-DEV3200 and higher.

Differential Signal Output

Connectors	2 BNC on front panel, single ended and differential
Output impedance	50 Ω
Output frequency range	DC to 500 kHz; DC to 5 MHz, requires MF-F5M option
Output frequency resolution	1 μ Hz
Output phase range	$\pm 180^\circ$
Output phase resolution	10 μ deg
Differential outputs	Sine waves shifted by 180°
Output D/A conversion	16 bit, 60 MSa/s
Output amplitude ranges	± 10 mV, ± 100 mV, ± 1 V, ± 10 V (single ended on high-impedance)
Output power	24 dBm (± 10 V, 250 mW), for each BNC
Output gain inaccuracy	< 1% at 100 kHz for all output ranges
Maximum output drive current	100 mA
Output offset amplitude	± 1 mV or 1% of range, whichever is bigger
Harmonic distortion	85 dBc for $f < 100$ kHz, 60 dBc for $f < 5$ MHz; for output ranges ≤ 1 V; 80 dBc for $f < 100$ kHz, 50 dBc for $f < 5$ MHz; for output range 10 V; carrier amplitude 1 dBFS
Analog adder	Auxiliary Input 1 can be added to the signal output, ± 10 V, DC-2 MHz

Output range	Output noise density (high load impedance setting)	RMS output noise at 12 MHz bandwidth
10 mV	43 nV/ $\sqrt{\text{Hz}}$	145 μ Vrms
100 mV	43 nV/ $\sqrt{\text{Hz}}$	145 μ Vrms
1 V	48 nV/ $\sqrt{\text{Hz}}$	161 μ Vrms
10 V	104 nV/ $\sqrt{\text{Hz}}$	310 μ Vrms

Auxiliary Inputs

Connectors	2 BNC on the front panel
A/D converter	16 bit, 15 MSa/s
A/D analog bandwidth	5 MHz
Input impedance	1 M Ω
Amplitude	± 10 V
Resolution	0.335 mV

Auxiliary Outputs

Connectors	4 BNC on the front panel
D/A converter	18 bit, 612 kSa/s
D/A analog bandwidth	200 kHz

Output impedance	50 Ω
Amplitude	± 10 V
Resolution	< 85 μ V
Drive current	20 mA
Noise density	200 μ V/ $\sqrt{\text{Hz}}$ into high-impedance load, frequency > 1 kHz
RMS noise	90 μ V _{rms} into high-impedance load, measurement bandwidth 12 MHz

Trigger Inputs

Connectors	2 BNC on the back panel
Trigger input impedance	1 k Ω
Frequency range external reference	1 Hz to 500 kHz; 1 Hz to 5 MHz, requires MF-F5M option
Trigger amplitude range	± 5 V
Minimum pulse width	35 ns
Trigger level	± 5 V, 3.66 mV resolution
Trigger hysteresis	< 20 mV

Trigger Outputs

Connectors	2 BNC on the back panel
Trigger output impedance	50 Ω
Frequency range external reference	1 μ Hz to 500 kHz; 1 μ Hz to 5 MHz, requires MF-F5M option
Trigger amplitude	5 V

10 MHz synchronization

Connectors	2 BNC, 10 MHz clock input and output on the back panel
10 MHz input, impedance	50 Ω
10 MHz input, frequency range	9.98 to 10.02 MHz
10 MHz input, amplitude range	200 mV to 3 V
10 MHz output, impedance	50 Ω
10 MHz output, amplitude	1 V _{pp} into 50 Ohm, sinusoidal

Internal frequency reference

Type	TCXO
Initial accuracy	< ± 1.5 ppm
Long term accuracy/aging	< ± 1 ppm in the first year
Short term stability (0.1 s)	< $2 \cdot 10^{-10}$
Temperature coefficient	0.05 ppm/ $^{\circ}$ C (@23 $^{\circ}$ C)
Phase noise at 1 kHz	-140 dBc/Hz
Phase noise at 10 kHz	-150 dBc/Hz

Connectivity & Others

Host connection	LAN, 1 GbE; USB 2.0, 480 Mbit/s
USB host	2 connectors on the back panel for mass storage or WLAN modules
DIO, digital I/O	4 x 8 bit, general purpose digital input/output port, 3.3 V TTL VHDCI 68 pin female connector

Internal memory	4.7 GB for measurement data, 250 MB for settings files, 250 MB for log files
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Maximum Ratings

Parameter	Lower	Upper
Damage threshold Current Signal Input I	-5 V	+5 V
Damage threshold Voltage Input +V/- V Diff	-12 V	+12 V
Damage threshold Signal Output +V/- V	-12 V	+12 V
Damage threshold Aux Input 1,2	-12 V	+12 V
Damage threshold Aux Outputs 1,2,3,4	-12 V	+12 V
Damage threshold Clock 10 MHz In/Out	-5 V	+5 V
Damage threshold Trigger Out 1,2	-1 V	+6 V
Damage threshold Trigger In 1,2	-8 V	+8 V
Damage threshold DIO 32 bit	-1 V	+6 V
Damage threshold DC In	0 V	26 V

LabOne UI requirements

Operating systems	Any, Web browser based
Input device	Touch screen, keyboard, mouse
CPU	2+ cores, hardware accelerated rendering on browser
Browser	Internet Explorer 10+, Firefox 27+, Chrome 36+, Safari 6+, Opera 23+
Connectivity	1 GbE, 100 MbE, USB 2.0

LabOne API requirements

Operating systems	Windows 8.x 64bit, Windows 7 64bit 32-bit and 64-bit of Linux, Ubuntu 14.04 LTS (i386, AMD64), 64-bit systems require the IA32 extension Mac OS X
CPU	AMD K8 (Athlon 64, Sempron 64, Turion 64, etc.), AMD Phenom, Intel Pentium 4, Xeon, Celeron, Celeron D, Pentium M, Celeron M, Core, Core 2, Core i5, Core i7, Atom
RAM	4GB+
Connectivity	1 GbE, 100 MbE, USB 2.0
Supported Languages	LabVIEW 2009 (32bit, 64bit) and later; Python 2.6x, 2.7x (32bit, 64bit); Matlab 2009 and later; C/C++