SpectraDynamics, Inc.

Quantum Time and Frequency

SPECTRADYNAMICS, INC.

SpectraDynamics, Inc. (SDI) is a Colorado, USA-based company specializing in high performance instrumentation for quantum, timing and frequency applications. Years of experience form the basis of the novel frequency synthesis architectures and time and frequency measurement methods developed by SpectraDynamics. We are proud to have provided powerful tools to the Time and Frequency Community for over 29 years. We value the impact that our products have when used as essential tools in the development of cutting-edge projects, as well as the fact that they continue to be part of programs that contribute to the universal well-being.

The cRb-CLOCK is a cold rubidium microwave atomic clock, a product developed by SpectraDynamics under a DARPA SBIR. This clock embodies years of experience in research, development and manufacturing key products that form our portfolio such as microwave and low noise frequency synthesizers, low noise frequency and pulse distribution amplifiers, high performance frequency dividers, pulse generators, and optical to RF synthesizers.

Our customers include National Time and Frequency Laboratories, Universities, Government Agencies, Telecommunications Companies and Department of Defense Contractors.

SpectraDynamics is committed to offering quality services as well as custom solutions engineered to meet your specific needs. Let us help you determine whether customizing an existing product or creating something new is the right solution for you.

Located in Colorado ...

Serving the world.

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PRODUCT SELECTION

PRODUCT SELECTION

FREQUENCY SYNTHESIZERS

OPTICAL TO RF CONVERTER

LOW NOISE FREQUENCY DIVIDERS

CUSTOM PRODUCTS

GENERAL INFORMATION

Cold Rubidium Atomic Clock, cRb

DESCRIPTION

The cRb-CLOCK is the world's first commercially available portable cold Rubidium microwave atomic clock. The clock is designed for high frequency stability in the short term of 7 x 10-13 /$\sqrt{\tau}$ and for excellent long term frequency stability of 2.9 x 10^{-15} at one day and typically 2 x 10^{-15} at 10 days. With this level of performance the cRb-CLOCK can be used as a substitute for Hydrogen masers. The cRb-CLOCK has negligible long term frequency drift and low sensitivity to temperature ~ 1 X 10^{-15} /°C.

Exceptional performance is achieved in a small portable package. The entire clock is about the size of a desktop computer 8.77 ", H 15 ", L 18.75 " (22.3 cm X 38.1 cm X 47.6 cm) and weighs 31 kg. The clock can be powered with both 100-240 VAC as well as +24 VDC. Steady state power consumption is 80 W. The clock outputs 100 MHz, 10 MHz, 5 MHz and 1 PPS with synchronization capability.

FEATURES

- Excellent short term stability 7 x $10^{-13}/\sqrt{\tau}$
- Excellent long term stability 2 x 10^{-15}
- No long term frequency drift
- Clock output at 100 MHz, 10 MHz and 5 MHz
- 1 PPS output with synchronization
- Ethernet monitor port
- Small and portable

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- High performance testing facilities
- Laboratory frequency standard
- Trusted time in GPS denied environment
- Astronomy

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency stability	1 s 10 s 100 s 1000 s 10,000 s 100,000 s 10 days		7×10^{-13} 2×10^{-13} 7×10^{-14} 2×10^{-14} 7×10^{-15} 2.9×10^{-15} 2×10^{-15}	8×10^{-13} 3×10^{-13} 8×10^{-14} 3×10^{-14} 8×10^{-15} 3×10^{-15} 3×10^{-15}	
Output level	1 PPS 5 MHz 10 MHz 100 MHz	3.7 10 10 10	3.8 12 12 11	5 15 15 13	V dBm
1 PPS	Rise-time 10-90% Fall-time 90-10% Sync error		1.2 1.2 < 10	1.5 1.5 10	ns
Phase noise @ 5 MHz	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	- - - - -	-117 -145 -157 -175 -176	-110 -142 -158 -163 -168	dBc/Hz
Phase noise @ 10 MHz	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	- - - - -	-112 -138 -150 -172 -175	-108 -137 -147 -160 -165	dBc/Hz
Phase noise @ 100 MHz	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	- - - - -	-90 -120 -130 -160 -170	-89 -117 -127 -147 -168	dBc/Hz

POWER REQUIREMENTS

- AC Power: 100 - 240 VAC, 47 - 63 Hz, 110 W max, 80 W steady state
- DC Power: 24 +/- 2 VDC, 7 A, 120 W max, 85 W steady state
- Ion pump power: 12 +/- 1 VDC, 50 mA

ENVIRONMENT

- Storage Temperature 0 to +50 ºC
- Operation Temperature +5 to +35 ºC
- Humidity 5% to 95% Non-condensing
- Vertical Alignment +/- 1 degree
- Shock during operation < 5 G any axis
- Maximum shock vertical axis < 50 G
- Maximum shock width/length < 10 G

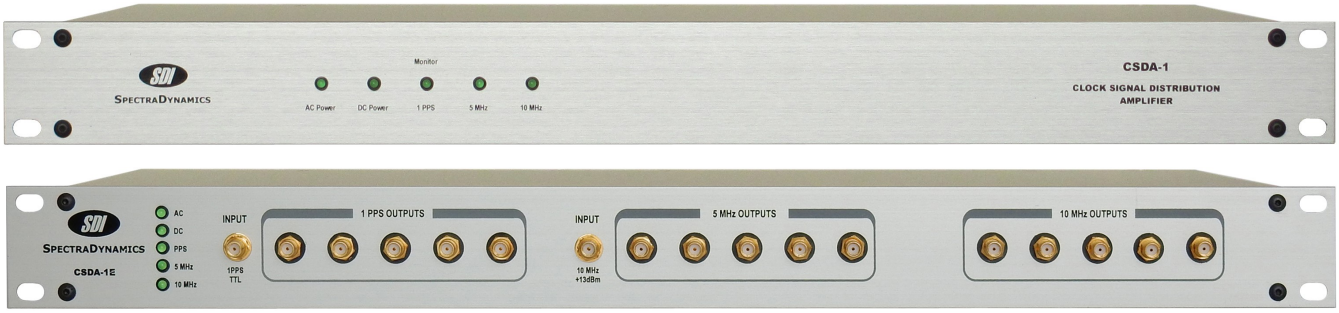
CHASSIS

- cRb-Clock W 8.77 ", H 15 ", L 18.75 " (22.3 cm X 38.1 cm X 47.6 cm)
- cRb-Clock (with handles and level) W 8.77 ", H 18.24 ", L 23.75 " (22.3 cm X 46.3 cm X 60.3 cm)
- Weight 31 kg

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

This Clock was developed with funding from the Defense Advanced Research Projects Agency (DARPA).
The views, opinions and/or findings expressed are those of the author and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.

CLOCK SIGNAL DISTRIBUTION AMPLIFIER, CSDA-1



DESCRIPTION

The CSDA-1 is a high performance clock signal distribution amplifier designed to distribute 1 PPS, 5 and 10 MHz signals. The CSDA-1 is a modular unit implemented with customizable functionality as per the CSDA-1 selection guide below. Module 1 distributes 1PPS signals, features small propagation delays, and can be manufactured with 10 Ω or 50 Ω **output** impedance. The RF distribution modules are designed to distribute signals from state-of-the-art atomic frequency standards. Inputs and outputs are matched to 50 ohms to obtain better than 25 dB return loss. All RF outputs are AC coupled and the grounds are DC isolated to reduce the effect of ground loops. Each module is equipped with visual fault monitoring. The output power levels are monitored and compared to a preset threshold of +7 dBm. Any signal with a power level below this threshold will turn off the monitor LED located on the front panel, indicating a fault condition.

FEATURES

- Distributes:
  1 PPS, 5 MHz & 10 MHz signals
- High Isolation
- Low phase noise
- Very high stability
- AC and DC voltage operation

APPLICATIONS

- Clock signal applications
- Atomic frequency standards
- Atomic time scales
- Laboratory frequency distribution
- Reference frequency distribution
- Time synchronization

CSDA-1 SELECTION GUIDE

Part Number	Module 1*	Module 2	Module 3
CSDA-1	1 PPS Input, five buffered outputs	5 MHz Input, five buffered outputs	Five 10 MHz outputs
CSDA-1A	1 PPS Input, five buffered outputs	1-50 MHz Input, five buffered outputs	Additional buffered outputs from M2
CSDA-1B	1 PPS Input, five buffered outputs	1-50 MHz Input, five buffered outputs	1-50 MHz Input, five buffered outputs
CSDA-1C	1 PPS Input, five buffered outputs	1 PPS Input, five buffered outputs	5 MHz Input, five 10 MHz outputs
CSDA-1D	1 PPS Input, five buffered outputs	5 MHz Input, five 10 MHz outputs	5 MHz Input, five 10 MHz outputs
CSDA-1E	1 PPS Input, five buffered outputs	10 MHz Input, five 5 MHz outputs	Five 10 MHz outputs

***** This module may be ordered with 10 or 50 ohms output impedance. See Pulse Distribution Specifications on next page.

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SPECIFICATIONS

Pulse Distribution Module

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Rise time	10 - 90 %	-	0.8	0.9	ns
Fall time	10 - 90 %	-	0.8	0.9	ns
Propagation delay	50 ohm load	-	7	9	ns
Differential delay	Channel - Channel	-	100	200	ps
Input High Level Input Low Level	Input signal into 50 ohm load Input signal into 50 ohm load	2 -0.7	- -	5 0.8	V
Frequency range	50% duty cycle	0	100	105	MHz
Temp-delay Coefficient	0 - 50 ºC	-	3	5	ps/ºC
Pulse Distribution Module manufactured with 50 ohm input impedance and 10 ohm output impedance					
Impedance	Input Output	- -	50 10	- -	Ohms
Output High Level Output Low Level	50 ohm load, 10 ohm output 50 ohm load, 10 ohm output	3.6 -	4.3 0.1	5.0 0.2	V
The following specifications are for a Pulse Distribution Module with 50 ohm input and output impedance To purchase this option, please add "-Opt 50/50" to your order.					
Impedance	Input Output	- -	50 50	- -	Ohms
Output High Level Output Low Level	50 ohm load, 50 ohm output impedance 50 ohm load, 50 ohm output impedance	2.4 -	2.6 0.1	2.8 0.2	V

The rise and fall times were tested with a TTL input signal at 100 kHz.

5 MHz Module

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Max Input Level	1 dB compression	16	17	-	dBm
Bandwidth	+/- 1 dB (Due to X2 on 3rd Module)	**0.5**	**0.6**	**1**	MHz
Gain	@ 5 MHz	0	0.5	1	dB
Impedance	Input Output	- -	50 50	- -	Ohms
Return Loss	Input (S_{11}) Output(S_{22})	-	-27 -30	-25 -25	dB
Distortion	+13 dBm	-	-45	-42	dBc
Isolation	Output to output Output to input	120 130	130 140	- -	dB
Phase Noise Referred to the input	1 Hz 10 Hz 100 Hz >10 kHz	- - - -	-150 -160 -170 -170	-147 -157 -167 -169	dBc/Hz
Temp-delay Coefficient	0 - 50 ºC	-	1.5	3	ps/ºC

10 MHz Module

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power Level	5 MHz input +13 dBm		14	15	dBm
Bandwidth	+/- 1 dB	0.5	0.6	1	MHz
Impedance	output		50		Ohms
Return loss	output (S22) 10 MHz		-25	-20	dB
Distortion	+13 dBm		-45	-42	dBc
Isolation	output to output	120	130		dB
Phase noise Referred to 5 MHz input	1 Hz 10 Hz 100 Hz >10 kHz		-148 -158 -165 -170	-146 -156 -161 -166	dBc/Hz
Temperature-delay coefficient	0 - 50 ºC		5	10	ps/ºC

1 GHz DISTRIBUTION AMPLIFIER, DA-1G

DESCRIPTION

The DA-1G is a general purpose isolation amplifier designed to distribute frequencies from 700 to 1,100 MHz. This amplifier offers 80 dB of channel-to-channel isolation and 85 dB of reverse isolation at 1 GHz. The low residual phase-noise of the amplifier (-130 dBc/Hz at 1 Hz and -160 dBc/Hz at 10 KHz) ensures that the distributed signals are not degraded. The outputs have a low VSWR, typically 1.2, to minimize environmental effects on frequency distribution through long transmission lines. The inputs and outputs are chassis grounded. The standard unit has 1 input and 12 outputs. This amplifier may operate on 100 to 240 VAC, and +12 to +36 VDC when the optional DC operation option is acquired. When the DA-1G is set up to operate with both AC and DC power sources at the same time, the DC power is used as backup power in case of AC power outages.

FEATURES

- Distributes:
  700 MHz to 1.1 GHz signals
- High Isolation
- Low phase noise
- Very high stability
- Optional DC voltage operation

APPLICATIONS

- Clock signal applications
- Atomic frequency standards
- Atomic time scales
- Laboratory frequency distribution
- Reference frequency distribution
- Time synchronization

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power Level	1 dB compression		13	-	dBm
Bandwidth	+/- 1 dB	800	1100	-	MHz
Gain	@ 1 GHz	-0.5	0.5	1.5	dB
Impedance	Input Output	- -	50 50	- -	Ohms
Return loss	Input (S11) 1 GHz Output (S22) 1 GHz	- -	-25 -25	-20 -20	dB
Distortion	+10 dBm output level	-	-45	-40	dBc
Isolation	Output to output Output to input	75 80	80 85	- -	dB
Phase noise	1 Hz 10 Hz 1 kHz 10 kHz	- - - -	-133 -145 -159 -161	-130 -140 -155 -160	dBc/Hz
Temperature Coefficient of Propagation Delay		-	1	1.5	ps/K

*All tests done at 1 GHz, +10 dBm output level unless otherwise specified.

Rackmount chassis	1U H, 19“ W, 14” D
Power consumption	25 Watts
Weight	10 lbs
Storage temperature	-10 to +75 ºC
Operation environment	0 to +50 ºC
Humidity	5% to 95% Non-condensing

100 to 600 MHz DISTRIBUTION AMPLIFIER, DA-500

The DA-500 is a general purpose isolation amplifier designed to distribute frequencies from 100 to 600 MHz. This amplifier offers 80 dB of channel-to-channel isolation and 85 dB of reverse isolation. The low phase-noise ensures that the distributed signals are not degraded. The outputs have a low VSWR, typically 1.2 (return loss of 20 dB), to minimize environmental effects on frequency distribution through long transmission lines. There are two inputs (SIGNAL A and B) each driving six outputs. The instrument is equipped with power level monitors that compare output power levels to a preset threshold of +7 dBm. If the signal on any output drops below this threshold, the monitor LED located on the front panel and corresponding to either SIGNAL A or B, will turn off indicating a fault condition. The inputs and outputs are chassis grounded.

This amplifier is offered in a stand-alone rack-mount enclosure with dimensions of 1U X 19" X 14". It may operate on 100 to 240 VAC, and +12 to +36 VDC when the optional DC operation option is acquired. When the DA-500 is set up to operate with both AC and DC power sources at the same time, the DC power is used as backup power in the event of an AC power outage.

FEATURES

- Distributes 100 MHz to 600 MHz signals
- High Isolation
- Low phase noise
- Very high stability
- Optional DC voltage operation

APPLICATIONS

- Clock signal applications
- Atomic frequency standards
- Atomic time scales
- Laboratory frequency distribution
- Reference frequency distribution
- Time synchronization

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power Level	1 dB compression		13	-	dBm
Bandwidth	+/- 1 dB	100	600	-	MHz
Gain	@ 500 MHz	0	1	2	dB
Impedance	Input Output	- -	50 50	- -	Ohms
Return loss	Input (S11) 1 GHz Output (S22) 1 GHz	- -	-21 -21	-20 -20	dB
Distortion	+10 dBm output level	-	-40	-35	dBc
Isolation	Output to output Output to input	75 80	80 85	- -	dB
Phase noise (+13 dBm)	1 Hz 10 Hz 1 kHz 10 kHz	- - - -	-133 -145 -159 -161	-130 -140 -155 -160	dBc/Hz

*All tests done at 100 MHz, +10 dBm output level unless otherwise specified.

Rackmount chassis	1U H, 19“ W, 14” D
Power consumption	25 Watts
Weight	11 lbs
Storage temperature	-10 to +75 ºC
Operation environment	0 to +50 ºC
Humidity	5% to 95% Non-condensing

HIGH PERFORMANCE DISTRIBUTION AMPLIFIER, HPDA-15RMi

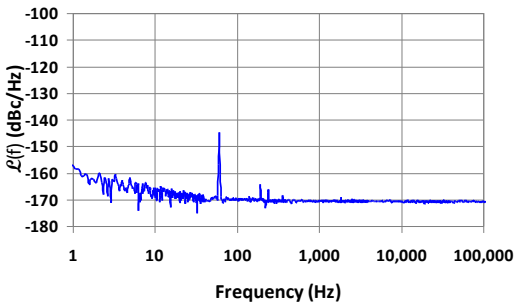
DESCRIPTION

The HPDA-15RMi is a High Performance Distribution and Isolation Amplifier designed to distribute state-of-the-art atomic frequency standards. This model offers exceptionally low additive phase noise and has a frequency bandwidth of 1 MHz to 50 MHz. This amplifier may be used in time scale applications where phase stability is of paramount importance.

The amplifier is designed in a 19 inch rackmount, 1U enclosure for maximum flexibility in system configuration with the possibility of housing up to three RF signal distribution modules. Each module takes one RF input and provides five isolated outputs. All output power levels are monitored and compared to a preset threshold of +7 dBm. If the signal level on any output drops below this threshold, the monitor LED for the corresponding module will turn off indicating a fault condition.

The HPDA-15RMi-B Model is designed to be powered by a 100 to 240 VAC mains source. The HPDA-15RMi-C Model is designed to be powered by a 100 to 240 VAC mains source and by a +12 to +36 VDC power source. When the Amplifier is set up to operate with both AC and DC power sources at the same time, the DC power is used as backup power in the event of an AC power outage.

HPDA-15RMi Phase Noise Plot



FEATURES

- 1-50 MHz
- Unity gain
- Low VSWR
- High isolation: 140 dB
- High output: +18 dBm
- Low phase noise: -155 dBc/Hz @ 1 Hz
  -171 dBc/Hz @ 10 kHz
- Low distortion: -48 dBc
- Low temperature coefficient: 1.2 ps/ºC

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- High performance testing facilities
- Laboratory frequency distribution
- Reference frequency distribution

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SPECIFICATIONS

		HPDA-15RMi-B, C HPDA-15RMi-B2, C2			HPDA-15RMi-B1, C1 HPDA-15RMi-B3, C3			
PARAMETER	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**UNITS**
Output power level	1 dB compression	17	18	-	17	18	-	dBm
Bandwidth	+/- 1 dB	1 - 50	0.5 - 65	-	1 - 50	0.5 - 65	-	MHz
Gain	@ 5 MHz	0	0.2	0.5	0	0.2	0.5	dB
Impedance	Input	-	50	-	-	50	-	Ohms
	Output	-	50	-	-	50	-	
Return loss	Input (S11) 5 MHz	-	-35	-30	-	-35	-30	dB
	Output (S22) 5 MHz	-	-35	-30	-	-35	-30	
Distortion	+13 dBm	-	-48	-45	-	-45	-40	dBc
	+17 dBm	-	-42	-40	-	-42	-40	
Isolation	Output to output	130	140	-	130	140	-	dB
	Output to input	140	145	-	140	145	-	
Phase noise	1 Hz	-	-155	-150	-	-150	-147	dBc/Hz
	10 Hz	-	-165	-160	-	-160	-157	
	1 kHz	-	-170	-168	-	-169	-167	
	10 kHz	-	-171	-170	-	-169	-167	
Temp.-delay Coefficient	0 - 50 ºC	-	1.2	1.5	-	1.2	1.5	ps/ºC

All tests are done at 5 MHz and +13 dBm input unless otherwise specified.

HPDA-15RMi SELECTION GUIDE

Part Number	Number of Inputs	Number of Outputs	AC Voltage Operation	DC Voltage Operation
HPDA-5i	1	5		√
HPDA-15RMi-A	1	5	√	Optional
HPDA-15RMi-B	3	15	√	
HPDA-15RMi-B1	1	10	√	
HPDA-15RMi-B2	2	10	√	
HPDA-15RMi-B3	1	15	√	
HPDA-15RMi-C	3	15	√	√
HPDA-15RMi-C1	1	10	√	√
HPDA-15RMi-C2	2	10	√	√
HPDA-15RMi-C3	1	15	√	√
HPDA-15RMi-S	2 Autoswitch	10	√	√

HIGH PERFORMANCE DISTRIBUTION AMPLIFIER, HPDA-15RMi-CW

DESCRIPTION

The HPDA-15RMi-CW is a High Performance Distribution and Isolation Amplifier designed to distribute signals from state-of-the-art atomic frequency standards. This wide range model with a frequency bandwidth of 1 to 100 MHz offers low additive phase noise, making it ideal for use without concern in time scale applications where phase stability is of paramount importance.

The amplifier is designed for maximum flexibility in system configuration in a 19 inch rackmount, 1U enclosure, and may contain up to three RF signal distribution modules. Each module takes a signal from 1 to 100 MHz and provides five buffered and isolated outputs. The table on page 19 shows the available options identified by part number.

All HPDA-15RMi-CW options are equipped with LED signal monitors. Every RF output signal is compared to a preset threshold of 0 dBm, for 5 MHz and 10 MHz signals, and a threshold of +5 dBm for 100 MHz signals. If the signal level on any output drops below this threshold, the monitor LED for the corresponding module turns off indicating a fault condition.

The amplifier is designed to be powered by a 100 to 240 VAC mains source with the option of being powered by a +12 to +36 VDC power source. When the amplifier is set up to operate with both AC and DC power sources at the same time, the DC power is used as a backup power source in the event of an AC power outage. The switching from AC to DC operation is done with a Schottky diode network and charge storage capacitors to avoid glitches and ensure uninterrupted continuous operation.

FEATURES

- 1-100 MHz
- Unity gain
- Low VSWR
- High isolation
- High output
- Low phase noise
- Low distortion
- Low temperature coefficient

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- High performance testing facilities
- Laboratory frequency distribution
- Reference frequency distribution

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SPECIFICATIONS

		HPDA-15RMi-CW HPDA-15RMi-C2W			HPDA-15RMi-C1W HPDA-15RMi-C3W			
PARAMETER	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**UNITS**
Bandwidth	+/- 1 dB		1 - 100	-		1 - 100	-	MHz
Impedance	Input Output	- -	50 50	- -	- -	50 50	- -	Ohms
Gain	@ **10 MHz**	0	0.2	0.5	0	0.2	0.5	dB
Output level @ **10 MHz**	1 dB compression	17	18	-	17	18	-	dBm
Return loss @ **10 MHz**	Input (S11) Output (S22)	- -	-35 -35	-30 -30	- -	-35 -35	-30 -30	dB
Distortion @ **10 MHz**	+13 dBm +17 dBm	- -	-48 -42	-45 -40	- -	-45 -42	-40 -40	dBc
Isolation @ **10 MHz**	Output to output Output to input	130 140	140 145	- -	130 140	140 145	- -	dB
Phase noise At **10 MHz**	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	- - - - -	-155 -165 -167 -170 -171	-150 -160 -166 -170 -170	- - - - -	-150 -160 -166 -169 -169	-147 -157 -165 -167 -167	dBc/Hz
Gain	@ **100 MHz**	-1	-0.5	0.5	-1	-0.5	0.5	dB
Output level @ **100 MHz**	1 dB compression	16	17	-	16	17	-	dBm
Return loss @ **100 MHz**	Input (S11) Output (S22)	- -	-13 -25	-10 -20	- -	-13 -25	-10 -20	dB
Distortion @ **100 MHz**	+10 dBm +13 dBm	- -	-33 -30	-31 -28	- -	-33 -30	-31 -28	dBc
Isolation @ **100 MHz**	Output to output Output to input	80 80	90 90	- -	80 80	90 90	- -	dB
Phase noise @ **100 MHz**	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	- - - - -	-136 -146 -154 -160 -161	-133 -143 -152 -158 -159	- - - - -	-136 -146 -154 -159 -160	-133 -143 -151 -156 -157	dBc/Hz
Allan Deviation	Averaging Time (s) 1 10 100 1000 10000	 - - - - -	 4×10^{-14} 5×10^{-15} 2×10^{-15} 6×10^{-16} 4×10^{-16}	 5×10^{-14} 7×10^{-15} 3×10^{-15} 1×10^{-15} 5×10^{-16}	 - - - - -	 4×10^{-14} 5×10^{-15} 2×10^{-15} 6×10^{-16} 4×10^{-16}	 5×10^{-14} 7×10^{-15} 3×10^{-15} 1×10^{-15} 5×10^{-16}	

All tests done at 10 MHz, +13 dBm input unless otherwise specified

HPDA-15RMi SELECTION GUIDE

Part Number	Number of Independent Inputs	Number of Outputs
HPDA-15RMi-CW	3	15 (five per input)
HPDA-15RMi-C1W	1	10
HPDA-15RMi-C2W	2	10 (five per input)
HPDA-15RMi-C3W	1	15

AUTOSWITCH AMPLIFIER, HPDA-15RMi-S

DESCRIPTION

The HPDA-15RMi-S is a high performance frequency distribution amplifier with an autoswitch function that allows the selection of the RF input to be distributed. The selected RF input supplies 10 buffered unity gain outputs. The instrument has a manual mode and autoswitch mode of operation. In manual mode, the RF input can be selected with a toggle switch on the front panel, or by sending a command through the Ethernet interface. In autoswitch mode, the two RF input levels are monitored and compared to a set threshold of +7 dBm. Upon failure of a selected input channel the amplifier switches over to the alternate RF input with a switching time less than 1 µs.

The selected RF input is buffered and distributed to ten unity gain outputs. The typical cross-channel isolation of the RF distribution is 140 dB and reverse isolation is typically greater than 145 dB. The phase noise of the amplifier is exceptionally low, typically -147 dBc/Hz @ Fourier frequency of 1 Hz and -171 dBc/Hz @ Fourier frequencies greater than 10 kHz. Both the input and output are matched to 50 ohms to obtain better than 25 dB return loss. All outputs are AC coupled and the grounds are DC isolated to reduce the effect of ground loops.

The HPDA-15RMi-S is designed to be powered by a 100 to 240 VAC mains source with the option of being powered by a +12 to +36 VDC power source. When the amplifier is set up to operate with both AC and DC power sources at the same time, the DC power is used as a backup power source in the event of an AC power outage. The switching from AC to DC operation is done with a Schottky diode network and charge storage capacitors to avoid glitches and ensure uninterrupted continuous operation.

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FEATURES

- 1-50 MHz
- Unity gain
- Low VSWR
- High isolation
- High output: +18 dBm
- Low phase noise: -147 dBc/Hz @ 1 Hz
  -171 dBc/Hz @ 10 kHz
- Low distortion: -45 dBc
- Low temperature coefficient: 1.5 ps/ºC

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- High performance testing facilities
- Laboratory frequency distribution
- Reference frequency distribution

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output power level	1 dB compression	17	18	-	dBm
Minimum input level	No fault	7	8	-	dBm
Bandwidth	+/- 1 dB	1 - 50	0.5- 65	-	MHz
Gain	5 MHz	0	0.2	0.5	dB
Impedance	Output	-	50	-	Ohms
Return loss	Input (S11) 5 MHz Output (S22) 5 MHz	- -	-25 -35	-20 -30	dB
Distortion	+13 dBm	-	-45	-42	dBc
Isolation	Output to output Output to input	130 140	140 145	- -	dB
Isolation	Input 1 to input 2	100	110	-	dB
Switching time	Autoswitch mode	-	0.5	1	µs
Phase noise Referred to the Input	1 Hz 10 Hz 1 kHz 10 kHz	- - - -	-147 -157 -167 -171	-145 -155 -166 -170	dBc/Hz
Temperature-delay coefficient	0 - 50 ºC	-	1.5	3	ps/ºC

All tests done at 5 MHz and 10 MHz, +13 dBm input unless otherwise specified.

LOW NOISE DISTRIBUTION AMPLIFIER, LNDA-5, -10 & 100

DESCRIPTION

The **LNDA-5, LNDA-10** and **LNDA-100** are High Performance Distribution and Isolation Amplifiers designed to distribute signals from state-of-the-art atomic frequency standards. They offer exceptionally low additive phase noise and are designed for operation at 5, 10 and 100 MHz.

The amplifiers are 1HU, 19-inch rackmount instruments with 12 buffered and isolated outputs. All the input and output power levels are monitored and compared to a user set threshold. If the signal level on the input or any output drops below the set threshold, the monitor LED will turn off indicating a fault condition, and this fault will be reported through the Ethernet interface.

These amplifiers are designed with a redundant power supply system, it can be powered by one or two 100 to 240 VAC mains sources. In the event that two AC sources power the amplifier and one of them fails, the instrument will continue uninterrupted operation. The loss of one of the AC sources results in the front panel monitor LED corresponding to that AC source turning off and an alarm being triggered and sent through the Ethernet interface.

FEATURES

- Distribution options: 5, 10 or 100 MHz
- Ethernet monitoring
- Unity gain
- Low VSWR
- High isolation
- High output
- Low phase noise
- Low distortion
- Low temperature coefficient
- Redundant AC power

APPLICATIONS

- Calibration laboratories
- Engineering facilities
- Laboratory frequency distribution
- Production and testing facilities

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SPECIFICATIONS

Specifications are for model LNDA-10.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Max Input Level	1 dB compression	19	18	-	dBm
Min Input Level**	no fault	7	8	-	dBm
Bandwidth	+/- 1 dB	1-14	1-15	-	MHz
Gain	@ 10 MHz	-0.5	-0.3	0.5	dB
Impedance	output	-	50	-	Ohms
Return Loss	input(S_{11})	-	-30	-25	dB
Return Loss	output(S_{22})	-	-40	-35	dB
Distortion*	+13 dBm	-	-57	-55	dBc
Isolation	output to output output to input	80 80	110 130	- -	dB dB
Spurious		-	-	-90	dBc
Phase Noise* (Referred to the Input)	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz	- - - - - -	-147 -158 -164 -169 -171 -171	-144 -155 -161 -166 -168 -168	dBc/Hz
Allen Deviation (ADEV)	1 s 10 s 100 s 1000 s 10000 s		2.7 E –14 3.6 E –15 5.4 E –16 1.4 E –16 6.9 E –17	5 E –14 5 E –15 6 E –16 2 E –16 9 E –17	
Temperature-delay Coefficient	0 - 50 ºC	-	1.5	3	ps/ºC

*All tests done at 10 MHz and +13 dBm input unless otherwise specified.

**Default setting is +7 dBm, this can be changed by the user through a Telnet command interface.

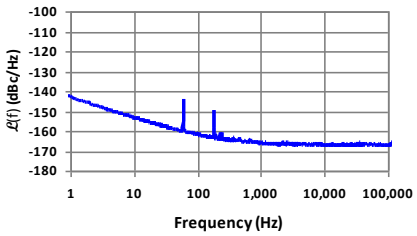
LOW NOISE DISTRIBUTION AMPLIFIER, LNDA-15RM

DESCRIPTION

The LNDA-15RM is an inexpensive low noise distribution and isolation amplifier. This instrument may contain up to three amplifier modules. Each module takes one input signal in the range of 1 to 50 MHz and provides five buffered outputs of the input signal with unity gain. All outputs are AC coupled and the grounds are DC isolated to reduce the effect of ground loops. The channel-to-channel and reverse isolation are greater than 95 dB which provides ample protection for the signal source and downstream users.

The LNDA-15RM is designed in a 1U high, 19" rack-mount enclosure with signal monitors visible on the front panel. If the signal level on any output drops below a predetermined threshold, the monitor LED for that module will turn off indicating a fault condition. The LNDA-15RM-B model operates on 100 to 240 VAC. The LNDA-15RM-C model operates on 100 to 240 VAC and +12 to +36 VDC. When the amplifier is set up to operate with both AC and DC power sources at the same time, the DC power is used as backup power in the event of an AC power outage. The switch from AC to DC power supply is automatic and glitch free ensuring uninterrupted continuous operation.

LNDA-15RM Phase Noise Plot



FEATURES

- 1-50 MHz
- Unity gain
- Low VSWR
- Isolation: 100 dB
- High output: +18 dBm
- Low phase noise: -143 dBc/Hz @ 1 Hz
  -165 dBc/Hz @ 10 kHz
- Low distortion: -45 dBc
- Low temperature coefficient: 3 ps/ºC

APPLICATIONS

- Calibration laboratories
- Engineering facilities
- Laboratory frequency distribution
- Production and testing facilities

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output power level	1 dB compression	17	18	-	dBm
Bandwidth	+/- 1 dB	1 - 50	0.5- 65	-	MHz
Gain	5 MHz	0	0.2	0.5	dB
Impedance	input output	- -	50 50	- -	Ohms
Return loss	input (S11) 5 MHz output (S22) 5 MHz	- -	-30 -30	-25 -25	dB
Distortion	+13 dBm +17 dBm	- -	-45 -40	-40 -35	dBc
Isolation	output to output output to input	95 100	100 105	- -	dB
Phase noise Referred to the Input	1 Hz 10 Hz 1 kHz 10 kHz	- - - -	-143 -153 -162 -165	-140 -150 -159 -162	dBc/Hz
Temperature-delay coefficient	0 - 50 ºC	-	3	5	ps/ºC

All tests done at 5 MHz and +13 dBm input unless otherwise specified

LNDA-15RM SELECTION GUIDE

Part Number	Number of Inputs	Number of Outputs	AC Voltage Operation	DC Voltage Operation
LNDA-15RM-B	3	15 (five per input)	√	
LNDA-15RM-B1	1	10	√	
LNDA-15RM-B2	2	10 (five per input)	√	
LNDA-15RM-B3	1	15	√	
LNDA-15RM-C	3	15 (five per input)	√	√
LNDA-15RM-C1	1	10	√	√
LNDA-15RM-C2	2	10 (five per input)	√	√
LNDA-15RM-C3	1	15	√	√

Specifications are valid for all options of LNDA-15RM.

HIGH PERFORMANCE DISTRIBUTION AMPLIFIER, HPDA-100

DESCRIPTION

The HPDA-100RM is a high performance distribution and isolation amplifier that may contain up to three distribution amplifier modules. Each module provides five unity gain outputs, 100 dB of channel-to-channel isolation, and 110 dB of reverse isolation. The phase noise of the modules is exceptionally low, typically -158 dBc/Hz @ 10 Hz and -174 dBc/Hz @ 10 kHz from the carrier. All the outputs are AC-coupled and the grounds are DC-isolated to reduce the effects of ground loops. The input and outputs have a low VSWR to minimize environmental effects on frequency distribution through long transmission lines.

The HPDA-100RM is available in a 1 U high 19" rack-mount enclosure. The HPDA-100M-B Model is designed to be powered by a 100 to 240 VAC mains source. The HPDA-100RM-C Model is designed to be powered by a 100 to 240 VAC mains source and by a +12 to +36 VDC power source. When the amplifier is set up to operate with both AC and DC power sources at the same time, the DC power is used as backup power in the event of an AC power outage.

FEATURES

- 80-120 MHz
- Unity gain
- Return loss -25 dB
- High isolation: 100 dB
- Low phase noise: -158 dBc/Hz @ 10 Hz
  -174 dBc/Hz @ 10 kHz
- Low distortion: -43 dBc
- High output: +16 dBm

APPLICATIONS

- Atomic frequency standards
- Instrumentation
- Reference frequency distribution
- Time scales

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output power level	1 dB compression	15	16	-	dBm
Bandwidth	+/- 1 dB		80 - 120	-	MHz
Gain	100 MHz	0	0.2	0.5	dB
Impedance	input output	- -	50 50	- -	Ohms
Return loss	input (S11) 100 MHz output (S22) 100 MHz	- -	-22 -30	-20 -25	dB
Distortion	+13 dBm	-	-43	-40	dBc
Isolation	output to output output to input	95 105	100 110	- -	dB
Phase noise	10 Hz 100 Hz 1 kHz 10 kHz	- - - -	-158 -165 -171 -174	-155 -162 -168 -171	dBc/Hz

All tests done at 100 MHz and +13 dBm input unless otherwise specified.

HPDA-100 SELECTION GUIDE

PART NUMBER	NUMBER OF INPUTS	NUMBER OF OUTPUTS	AC VOLTAGE OPERATION	DC VOLTAGE OPERATION
HPDA-100RM-A	1	5	√	
HPDA-100RM-B	3	15 (five per input)	√	
HPDA-100RM-B1	1	10	√	
HPDA-100RM-B2	2	10 (five per input)	√	
HPDA-100RM-B3	1	15	√	
HPDA-100RM-B3FA Alarm: TNC Connector	1	15	√	√
HPDA-100RM-C	3	15 (five per input)	√	√
HPDA-100RM-C1	1	10	√	√
HPDA-100RM-C2	2	10 (five per input)	√	√
HPDA-100RM-C3	1	15	√	√
HPDA-100RM-D	3	15 (five per input)		√

Specifications may vary per part number, please contact SpectraDynamics for data sheets.

PULSE DISTRIBUTION AMPLIFIER, PD-15RMi

DESCRIPTION

The PD-15RMi-C is a TTL Pulse Distribution Amplifier that provides distribution for one pulse-per-second (1PPS) signals. The amplifier may also be used to distribute pulses with a repetition rate of up to 100 MHz. The PD-15RMi-C has three inputs which drive three distribution modules. Each module supplies five buffered outputs designed to drive low impedance loads and long 50 or 75 ohm cables. The outputs provide a 4.3 volt peak-to-peak signal into a 50 ohm load. The channel-to-channel delay differences are typically less than 100 ps. The distribution modules typically have 3 ps/ºC temperature coefficient of propagation delay. The small propagation delay characteristics and low temperature coefficient of delay are essential for the distribution of high quality timing signals.

This instrument is designed to be powered by a 100 to 240 VAC mains source or by a +12 to +36 VDC power source. If both AC and DC sources are powering the instrument, the DC source will be used as backup power in case of AC power outages. The instrument is designed to automatically switch from AC to DC supply operation using a Schottky diode network and charge storage capacitors to avoid any glitches and ensure uninterrupted continuous operation. The PD-15RMi-C comes in a 1U high, 19” rack-mount enclosure.

FEATURES

- 1PPS - 100 MHz
- 50 ohm output: 4.3 Vp-p
- Low temperature coefficient: 3 ps/ºC
- Matched channel delays: 100 ps typical

APPLICATIONS

- 1 PPS distribution
- Atomic time scales
- Reference clock distribution
- Time synchronization

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Rise time	10 - 90 %	-	0.8	0.9	ns
Fall time	10 - 90 %	-	0.8	0.9	ns
Propagation delay	50 ohm load	-	7	9	ns
Differential delay	Channel - Channel	-	100	200	ps
Input High Level	Input signal into 50 ohm load	2	-	5	V
Input Low Level	Input signal into 50 ohm load	-0.7	-	0.8	
Frequency range	50% duty cycle	0	100	105	MHz
Temp-delay Coefficient	0 - 50 ºC	-	3	5	ps/ºC
Pulse Distribution Amplifiers are manufactured with 50 ohm input impedance and 10 ohm output impedance					
Impedance	Input	-	50	-	Ohms
	Output	-	10	-	
Output High Level	50 ohm load, 10 ohm output	3.6	4.3	5.0	V
Output Low Level	50 ohm load, 10 ohm output	-	0.1	0.2	
The following specifications are for a Pulse Distribution Amplifier with 50 ohm input and output impedance To purchase this option, please add "-Opt 50/50" to your order.					
Impedance	Input	-	50	-	Ohms
	Output	-	50	-	
Output High Level	50 ohm load, 50 ohm output impedance	2.4	2.6	2.8	V
Output Low Level	50 ohm load, 50 ohm output impedance	-	0.1	0.2	

PULSE DISTRIBUTION SELECTION GUIDE

Part Number	Number of Inputs	Number of Outputs	AC Voltage Operation	DC Voltage Operation
PD-15RMi-A	1	5	√	√
PD-15RMi-C	3	15 (five per input)	√	√
PD-15RMi-C1	1	10	√	√
PD-15RMi-C2	2	10 (five per input)	√	√
PD-15RMi-C3	1	15	√	√

FRONT PANEL

- AC and DC Power Monitor LEDs.
- PPS Signal Monitor LEDs.

BACK PANEL

- SMA Input connectors
- SMA Output connectors
- AC and DC power connectors

PULSE DISTRIBUTION AMPLIFIER, PD-100i

DESCRIPTION

The PD-100i is a high speed pulse signal distribution amplifier that provides distribution for 1 PPS signals and RF signals with a frequency range of 1-100 MHz.

The first module receives a 1PPS signal and supplies six buffered outputs designed to drive low impedance loads and long 50 or 75 ohm cables. The outputs provide a 3.8 volt peak-to-peak signal into a 50 ohm load. The channel-to-channel delay differences are less than 200ps. The distribution module has the low temperature coefficient of propagation delay that is essential for the distribution of high quality timing signals.

The second module of the instrument receives a 1-100 MHz RF signals and provides six buffered square wave outputs. The typical cross-channel isolation on the RF distribution modules is 100 dB and reverse isolation is typically greater than 110 dB. The phase noise of the modules is exceptionally low, typically -148 dBc/Hz @ Fourier frequency of 1 Hz and -170 dBc/Hz @ Fourier frequencies greater than 10 kHz. All outputs are DC coupled and conform to TTL specifications.

The PD-100i is designed to be powered by a 100 to 240 VAC mains source or by a +12 to +36 VDC power source. The DC power may be used as a main power source for the instrument or in conjunction with the AC power as a backup power supply in case of loss of the main AC power. The instrument is designed to automatically switch from AC to DC supply operation using a Schottky diode network and charge storage capacitors to avoid any glitches and ensure uninterrupted continuous operation. The PD-100i comes in a 1U high, 19” rack-mount enclosure.

PPS FEATURES

- Distribution of 1PPS - 100 MHz
- 50 ohm output: 3.8 Vp-p
- Low temperature coefficient: 3 ps/ºC
- PPS Propagation Delay: 7ns typical

RF FEATURES

- 1 - 100 MHz
- Square wave digital outputs
- High isolation: 110 dB
- Low phase noise: -148 dBc/Hz @ 1 Hz
- -170 dBc/Hz @ 10 kHz
- Low temperature coefficient: 3 ps/ºC

SPECIFICATIONS

PPS Distribution Module

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Rise time	10 - 90 %	-	0.9	1	ns
Fall time	10 - 90 %	-	0.9	1	ns
Propagation delay	50 ohm load	-	7	8	ns
Differential delay	channel - channel	-	100	200	ps
Impedance	input Output	-	50 9	- -	Ohms
Input high level Input low level	input signal into 50 ohm load input signal into 50 ohm load	3.7 0	3.8 -	5 0.8	V
Output high level Output low level	50 ohm load 50 ohm load	3.7 -	3.8 0.4	5 0.5	V
Temperature-delay coefficient	0 - 50 ºC	-	3	5	ps/ºC

RF / CLOCK Distribution Module

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Level		7	13	20	dBm
Bandwidth		-	1-100	-	MHz
Impedance	output	-	9	-	Ohms
Rise Time	+13 dBm	-	0.9	1	ns
Fall Time	+13 dBm	-	0.9	1	ns
Isolation	output to output	100	110	-	dB
Phase Noise (Referred to the Input)	1 Hz 10 Hz 100 Hz >10 kHz	- - - -	-148 -163 -168 -170	-145 -160 -165 -167	dBc/Hz
Temperature-delay Coefficient	0 - 50 ºC	-	3	-	ps/ºC

FRONT PANEL

- AC, DC, PPS & RF Monitor LEDs.
- SMA 1PPS Output connectors
- SMA RF Output connectors

BACK PANEL

- SMA 1PPS Input connector
- SMA RF Input connector
- AC and DC power connectors

PULSE DISTRIBUTION AMPLIFIER, PD-110i

DESCRIPTION

The PD-110i is a high speed pulse signal distribution amplifier that provides distribution for RF signals with a frequency range of 1 to 100 MHz.

The instrument receives a 1-100 MHz signal and provides twelve buffered square wave outputs. The input may be a sinewave or any other signal that needs to be converted to a square wave. The typical cross-channel isolation on the RF distribution modules is 100 dB and the reverse isolation is typically greater than 110 dB. The phase noise of the modules is exceptionally low, typically –148 dBc/Hz @ Fourier frequency of 1 Hz and –169 dBc/Hz @ Fourier frequencies greater than 10 kHz. All outputs are DC coupled and conform to TTL specifications.

The PD-110i is designed to be powered by a 100 to 240 VAC mains source or by a +12 to +36 VDC power source. The DC power may be used as a main power source for the instrument or in conjunction with the AC power as a backup power supply in case of loss of the main AC power. The instrument is designed to automatically switch from AC to DC supply operation using a Schottky diode network and charge storage capacitors to avoid any glitches and ensure uninterrupted continuous operation. The PD-110i comes in a 1U high, 19" rack-mount enclosure.

RF FEATURES

- 1 - 100 MHz
- Square wave digital outputs
- High isolation: 110 dB
- Low phase noise: -148 dBc/Hz @ 1 Hz
- -160 dBc/Hz @ 10 kHz
- Low temperature coefficient: 3 ps/ºC

FRONT PANEL

- AC, DC, Clock A & B outputs
- SMA RF Output connectors

BACK PANEL

- SMA RF Input connector
- AC and DC power connectors

SPECIFICATIONS

RF / CLOCK Distribution

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Level		7	13	20	dBm
Bandwidth		-	1-100	-	MHz
Impedance	output	-	12	-	Ohms
Rise Time	+13 dBm	-	0.8	1	ns
Fall Time	+13 dBm	-	0.8	1	ns
Isolation	output to output	100	110	-	dB
Phase Noise (Referred to the Input)	1 Hz 10 Hz 100 Hz >10 kHz	- - - -	-148 -160 -167 -169	-145 -159 -165 -167	dBc/Hz
Temperature-delay Coefficient	0 - 50 ºC	-	3	-	ps/ºC

ENVIRONMENT

- Storage Temperature -10 to +75 ºC
- Operation Temperature 0 to +50 ºC
- Humidity 5% to 95% Non-condensing

LOW NOISE FREQUENCY MULTIPLIER
FS020-5RM

DESCRIPTION

The FS020-5RM is ultra-low noise frequency multiplier that may be used with state-of-the-art crystal frequency sources without degrading phase noise. A 5 MHz input signal is multiplied to provide an output at 10 MHz. This instrument is designed to be powered by a 100 to 240 VAC mains source or by a +12 to +36 VDC power source. If both AC and DC sources are powering the instrument, the DC source will be used as backup power in case of AC power outages. The switch from AC to DC power supply is automatic and glitch free ensuring uninterrupted continuous operation.

Available options:

- **FS020-5RM:** One 10 MHz output
- **FS020-5RM OPT 2:** Two 10 MHz outputs
- **FS020-5RM OPT 4:** Four 10 MHz outputs

FEATURES

- 5 MHz input
- Ultra-low phase noise
- Very low spurious
- Optional DC voltage operation

APPLICATIONS

- Frequency multiplication
- Phase noise measurements
- Reference frequency generation
- Telecommunications standards

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output level	+13 dBm input	11	13	15	dBm
Impedance	input output	- -	50 50	- -	Ohms
Return loss	input (S11) output (S22)	- -	-20 -20	-15 -15	dB
Spurious		-	-55	-45	dBc
Harmonic distortion	+10 dBm output	-	-55	-45	dBc
Phase noise referred to input	1 Hz 1 kHz 10 kHz	- - -	-143 -170 -176	-140 -167 -173	dBc/Hz
Temperature-delay coefficient	0 - 50 ºC	-	45	50	ps/ºC

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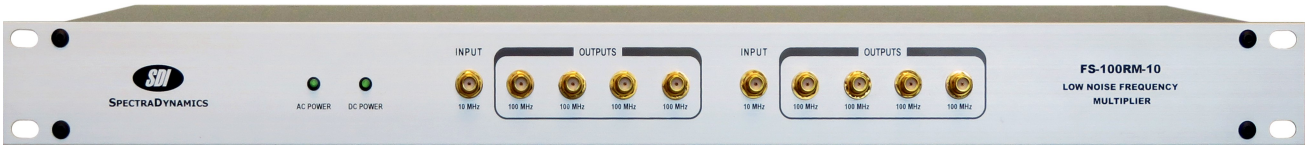
LOW NOISE FREQUENCY MULTIPLIER
FS100-RM

DESCRIPTION

The FS-100RM is a versatile low noise frequency multiplier that can be configured to meet the customers needs. The image above represents one of the options available in which the customer can select one or more of the multiplied outputs. The image below shows another multiplier option that adds distribution and provides buffered 100 MHz outputs.

All FS-100RM outputs are bandpass filtered to allowed better than 50 dB of rejection for all spurious and harmonic signals. The low residual phase noise of the multiplier enables it to be used with state-of-the-art crystal frequency sources without degrading phase noise or environmental stability. The multipliers may be used for phase locking 100 MHz crystal sources to 5 or 10 MHz references.



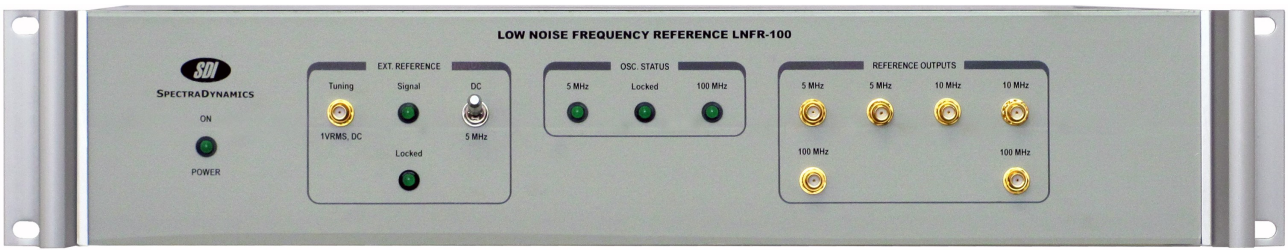
Available options:
FS-100RM-5: 5 MHz input, provides: 10, 20, 40, 80, 90 and 100 MHz outputs
FS-100RM-10: 10 MHz input, provides: 10, 20, 40, 80, 90 and 100 MHz outputs
FS-100RM-10 OPT4: 10 MHz input, provides four 100 MHz outputs
FS-100RM-10 OPT8: 10 MHz input, provides four 100 MHz outputs - Two independent modules.

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output level	+13 dBm input	10	13	15	dBm
Impedance	input output	- -	50 50	- -	Ohms
Return loss	input (S11) output (S22)	- -	-20 -20	-15 -15	dB
Spurious		-	-55	-45	dBc
Harmonic distortion	+10 dBm output +13 dBm output	-	-55 -41	-45 -39	dBc
Phase noise referred to input	1 Hz 10 Hz 1 kHz 10 kHz 100 kHz	- - - -	-143 -153 -170 -176 -176	-140 -150 -167 -173 -173	dBc/Hz
Temp-delay coefficient	0 - 50 ºC	-	45	50	ps/ºC

All tests done at 10 MHz +13 dBm input unless otherwise specified.

LOW NOISE FREQUENCY REFERENCE, LNFR-100



DESCRIPTION

The LNFR-100 is an ultra-low noise frequency reference. The LNFR-100 contains 5 MHz and 100 MHz ultra-low noise ovenized oscillators. The outputs at 10 MHz are obtained by multiplying the signal from the 5 MHz oscillator. The 100 MHz oscillator is phase locked to the 5 MHz oscillator to provide a lower phase noise signal inside the bandwidth of the phase-locked loop. The device can be used as a low noise source in phase noise measurement systems. Other applications include high stability frequency synthesizers, reference frequency generation and frequency synthesis chains for atomic standards. The LNFR-100 can be controlled via a +/- 5 VDC tuning signal or with a 5 MHz 1 VRMS signal. This synthesizer is offered in a stand-alone rack mount package. For frequency synthesis chain applications the synthesizer is available in modular form.

FEATURES

- Low environmental sensitivity
- Ultra-low phase noise
- Very low spurious

APPLICATIONS

- Atomic frequency standards
- Phase noise measurements
- Reference frequency generation
- Telecommunications standard

LNFR-100 SELECTION GUIDE

Part Number	Standard Outputs (MHz)	Optional Outputs (MHz)
LNFR-100	5, 10, 100	20, 40, 80
LNFR-100 A	5, 10 two each	-
LNFR-100 Opt 100	5, 10, 100 two each	-
LNFR-100 HS - High Stability Option Temperature stability @ 5MHz, 0 to 60 ^{o}C = +/-5 E-10	5, 10, 100	20, 40, 80

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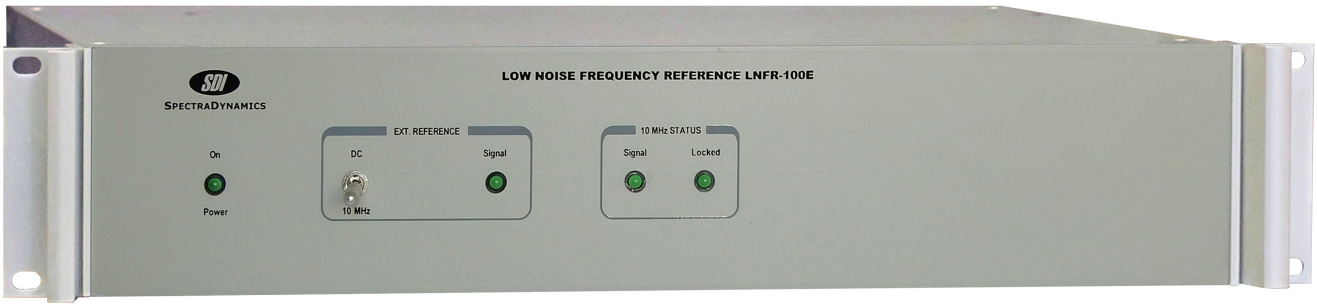
SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power Level	5 MHz	+12	+14	+17	dBm
Output Power Level	10 MHz	+12	+14	+17	dBm
Output Power Level	100 MHz	+12	+14	+17	dBm
Electrical Tuning Range	5 MHz, 10 MHz	+/- 2 x 10^{-7}	-	-	-
Tuning Port Voltage			+/- 5		VDC
Temperature Stability	@ 5 MHz, 0 – 50 C	-	+/- 5 x 10^{-9}	+/- 1 x 10^{-8}	-
Phase Noise measured at 5MHz	1 Hz 10 Hz 100 Hz 1 kHz > 10 kHz	- - - - -	-120 -150 -169 -175 -175	-118 -145 -164 -173 -173	dBc/Hz
Phase Noise measured at 10MHz	1 Hz 10 Hz 100 Hz 1 kHz >10 kHz	- - - - -	-114 -144 -160 -167 -170	-112 -141 -156 -164 -167	dBc/Hz
Phase Noise measured at 100MHz	10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-124 -134 -157 -177	-121 -132 -154 -172	dBc/Hz
Harmonics	5 MHz	-	-40	-30	dBc
Harmonics	10 MHz	-	-40	-30	dBc
Harmonics	100 MHz	-	-40	-30	dBc
Spurious	5 MHz	-	-110	-100	dBc
Spurious	10 MHz	-	-110	-100	dBc
Spurious	100 MHz	-	-110	-100	dBc

Rackmount chassis	2U H, 19“ W, 16” D
Storage temperature	-10 to +75 ºC
Operation environment	0 to +50 ºC
Humidity	5% to 95% Non-condensing

LOW NOISE FREQUENCY REFERENCE, LNFR-100E



DESCRIPTION

The LNFR-100E is a high performance 10 MHz distributed frequency reference. It contains a 5 MHz SC-cut ovenized oscillator, a low noise frequency doubler and a distribution amplifier module. The 10 MHz signal is distributed by the distribution amplifier to provide four 10 MHz outputs on the back panel. Typical cross-channel isolation is 70 dB and reverse isolation is typically greater than 75 dB. The distribution module does not degrade the phase noise performance of the oscillator that is typically –142 dBc/Hz @ Fourier frequency of 10 Hz and –170 dBc/Hz @ Fourier frequency greater than 10 kHz. The LNFR-100E outputs are matched to 50 ohms to obtain better than 25 dB return loss. The LNFR-100E can be phase locked via an electrical tuning port or by providing an external 10 MHz reference. A 6-pin alarm output on the rear panel with positive contact closure between pins A and D indicate an external locked status. The alarm load should not exceed 0.5 A at 30 VDC.

FEATURES

- Low environmental sensitivity
- Ultra-low phase noise
- Very low spurious

APPLICATIONS

- Earth station frequency reference
- Phase noise measurements
- Reference frequency generation
- Telecommunications standard

LNFR-100 SELECTION GUIDE

Part Number	Output Frequency (MHz)	Number of Outputs
LNFR-100E	10	Four buffered outputs
LNFR-100E8	10	Eight buffered outputs

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SPECIFICATIONS

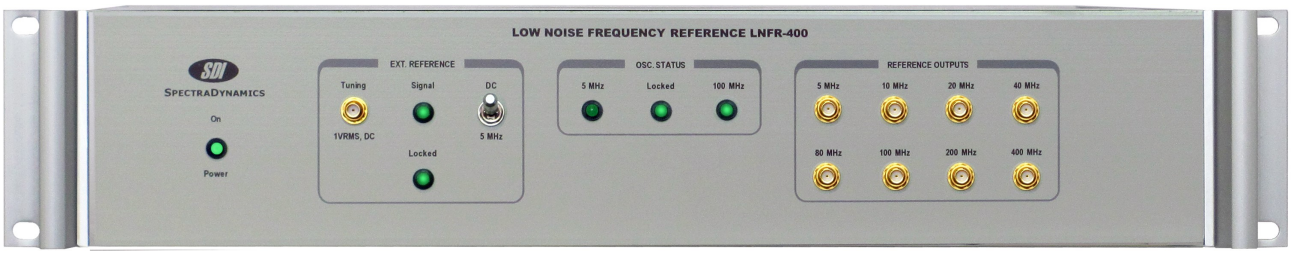
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output level	50 ohm load	+11	+14	+15	dBm
Output impedance	return loss @ 10 MHz		-25		dB
Harmonic distortion	50 ohm load		-40	-38	dBc
Isolation	output to output	60	70		dB
Temperature stability	0 - 50 ºC		+/- $5x10^{-9}$		-
Mechanical tuning			+/- $1x10^{-6}$		-
Electrical Tuning	+/-5VDC		+/- $2x10^{-7}$		-
Stability	Allan variance t=1s		1E-12		-
Phase noise @ 10 MHz	1 Hz 10 Hz 100 Hz 1 kHz 10 kHz		-112 -142 -160 -167 -170	-109 -138 -156 -165 -166	dBc/Hz
Spurious		-	-120	-110	dBc

Absolute Maximum Ratings

RF power on tuning port +20 dBm Maximum
DC Voltage on tuning port ± 10 VDC Maximum
RF Power on outputs +20 dBm Maximum
DC Voltage on outputs 50 VDC Maximum
Storage Temperature -10 to +75 ºC
Operation Environment 0 to + 50 ºC
Alarm Connector Load 0.5 A at 30VDC Maximum

Chassis 2U H, 19 " W, 16" D

LOW NOISE FREQUENCY REFERENCE, LNFR-400



DESCRIPTION

The LNFR-400 is an ultra-low noise frequency reference. The device can be used as a low noise source in phase noise measurement systems. Other applications include high stability frequency synthesizers, reference frequency generation and frequency synthesis chains for atomic standards.

The LNFR-400 contains 5 MHz and 100 MHz ultra-low noise ovenized oscillators. The outputs at 10 MHz, 20 MHz, 40 MHz and 80 MHz are obtained by multiplying the signal from the 5 MHz oscillator. The 100 MHz oscillator is phase locked to the 5 MHz oscillator to provide a lower phase noise signal inside the bandwidth of the phase-locked loop. The output of the 100 MHz oscillator is doubled to obtain 200 MHz and doubled again to obtain 400 MHz. All outputs to the front panel are buffered with low noise isolation amplifiers. The LNFR-400 can be controlled via a +/- 5 VDC tuning signal or phase locked to a 5 MHz 1 VRMS signal. The synthesizer is offered in a stand-alone rack-mount

FEATURES

- External 5 MHz/DC tuning
- Low environmental sensitivity
- Ultra-low phase noise
- Very low spurious: -100 dBc

APPLICATIONS

- Atomic frequency standards
- Phase noise measurements
- Reference frequency generation
- Telecommunications standards

LNFR-100 SELECTION GUIDE

Part Number	Standard Outputs (MHz)	Optional Outputs (MHz)
LNFR-400	5, 10, 100	20, 40, 80, 200, 400
LNFR-400 HS - High Stability Option Temperature stability @ 5MHz, 0 to 60 ^{o}C = +/- 5 E^{-10}	5, 10, 100	20, 40, 80, 200, 400

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power Level		+13	+15	-	dBm
Electrical Tuning Range	5 MHz	+/- 2 E^{-7}	-	-	-
Tuning Port Voltage			+/- 5		VDC
Temperature Stability	@ 5 MHz, 0 – 60 C	-	+/- 1 x 10^{-8}	-	-
Phase Noise measured	1 Hz	-	-120	-118	dBc/Hz
at 5MHz	10 Hz	-	-150	-145	
	100 Hz	-	-167	-164	
	>1 kHz	-	-175	-171	
Phase Noise measured	1 Hz	-	-114	-112	dBc/Hz
at 10MHz	10 Hz	-	-144	-141	
	100 Hz	-	-160	-156	
	>1 kHz	-	-169	-166	
Phase Noise measured	10 Hz	-	-124	-121	dBc/Hz
at 100MHz	100 Hz	-	-134	-131	
	1 kHz	-	-156	-153	
	>10 kHz	-	-175	-174	
Phase Noise measured	10 Hz	-	-110	-106	dBc/Hz
at 400MHz (when output is present)	100 Hz	-	-120	-117	
	1 kHz	-	-144	-141	
	>10 kHz	-	-163	-161	
Harmonics	5 MHz	-	-40	-35	dBc
Harmonics	10 MHz	-	-40	-35	dBc
Harmonics	100 MHz	-	-40	-35	dBc
Spurious	5 MHz	-	-	-110	dBc
Spurious	10 MHz	-	-	-110	dBc
Spurious	100 MHz	-	-	-110	dBc

9.192 GHz FREQUENCY SYNTHESIZER, CS-1

DESCRIPTION

The CS-1, 9.192 GHz Frequency Synthesizer is a high stability and high resolution signal source designed to be used in the implementation of a Cesium atomic clock. The CS-1 is provided as two separate modules, the Synthesizer Module and the DC Power Module. Both modules come in a 2U, 19 inch rack-mount enclosure. All synthesizer functions are accessed from the front panel or a RS232 interface. An external trigger input may be used to synchronize programmable events such as frequency sweeps, phase modulation and amplitude modulation with external events. The synthesizer is implemented with a flexible modular topology. Two ultra-low noise quartz oscillators are part of the multiplication chain from 5 MHz to 100 MHz. Buffered outputs are provided at the front panel for 5 MHz, 10 MHz and 100 MHz signals. The 100 MHz signal is the highest frequency in the low frequency section of the synthesizer. This 100 MHz signal is distributed using a one input, four output isolation amplifier. One of these 100 MHz signal is used as the reference for a 9.2 GHz DRO. The output of the 9.2 GHz DRO is buffered and used to drive the LO port of a single-sideband mixer. The second 100 MHz signal is used to clock a DDS synthesizer module. The DDS synthesizer generates an IF signal with 48 bit resolution and complete modulation capabilities. The DDS synthesizer output drives the IF port of the single-sideband mixer. The lower sideband of the mixer is selected as the output generating the 9.XXX GHz output signal. The amplitude of the 9.XXX GHz output is controlled with 12 bits of resolution and an internal relay may be used to turn off the RF signal.

FEATURES

- Output signals:
- 5 MHz, 10 MHz, 100 MHz, 7 MHz, 9.2 GHz, 9.192 GHz
- Synchronization capabilities with external events:
  Amplitude modulation
  Frequency sweeps
  Phase modulation
- Low phase noise
- State machine operation

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- Reference frequency generation

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SPECIFICATIONS

PARAMETER	CONDITIONS	TYP	MAX	UNITS
Frequency Stability $\sigma_y(t)$ Ref. 5 MHz, +13 dBm Pair measurement, Locked	Averaging time 1 s 10 s 100 s 1000 s 100000 s 1000000 s	 $1 \cdot 10^{-13}$ $1 \cdot 10^{-14}$ $1 \cdot 10^{-15}$ $2 \cdot 10^{-16}$ $2 \cdot 10^{-17}$ $2 \cdot 10^{-17}$		
Phase Noise L(f) * Carrier 9.192 GHz	Offset frequency 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz 1 MHz	 -54 -84 -96 -113 -120 -120 -140	 -52 -80 -93 -110 -117 -117 -130	dBc/Hz
Phase Noise L(f) Carrier 100 MHz	Offset frequency 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	 -94 -124 -138 -158 -175	 -93 -122 -134 -155 -173	dBc/Hz
Phase Noise L(f) Carrier 10 MHz	Offset frequency 1 Hz 10 Hz 100Hz 1 kHz 10 kHz	 -114 -144 -165 -170 -170	 -113 -142 -160 -168 -168	dBc/Hz
Phase Noise L(f) Carrier 5 MHz	Offset frequency 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	 -120 -150 -170 -175 -175	 -118 -148 -167 -173 -174	dBc/Hz

* The PM Noise at 1 Hz for Carrier 9.192 GHz (locked 5 Hz BW) -72 dBc/Hz.

External Reference: 5.0 MHz ± $2.0 \cdot 10^{-8}$, +7 dBm to +15 dBm
Rack-mount enclosure: 2U X 16" X 19", Weight: 20 lbs

CS-1 SELECTION GUIDE

Part Number	Phase Noise @ 1 Hz 5 MHz Output	Phase Noise @ 1 Hz 9.192 GHz Output
CS-1	-120 dBc/Hz	-54 dBc/Hz
CS-1 Opt C	-130 dBc/Hz	-64 dBc/Hz

HIGH RESOLUTION PHASE AND FREQUENCY OFFSET GENERATOR

US Patent 6,278,330

HROG-5

DESCRIPTION

The HROG-5 is a high-resolution phase and frequency offset generator. The phase and frequency of the output signals are adjustable with respect to a 5 MHz user supplied reference. The output phase resolution of the generator is $2\pi/2^{32}$ radians or an output time step resolution of 0.047 fs. The output frequency resolution is 5×10^{-19}. Both phase and frequency steps are phase continuous. The instrument provides two sine-wave outputs and two pulse outputs. The sine-wave outputs are buffered to provide greater than 80 dB of port to port and reverse isolation. The outputs are at a level of +13 dBm. The pulse outputs are derived from the sine wave outputs by dividing by a factor of $5.0E^{6}$. The pulse outputs can be synchronized to an external reference pulse to within 200 ns. All instrument functions are displayed and controlled via the front panel LCD display and keypad. Remote control of the instrument is possible through RS-232 communications.

FEATURES

- High isolation: > 80 dB
- High phase resolution: 0.047 fs
- Low harmonic distortion: -45 dBc
- Phase noise (1 kHz) : -165 dBc/Hz

Option Low Noise:

- Phase Noise (1 kHz): -169 dBc/Hz

APPLICATIONS

- Atomic frequency standards
- Clock synchronization
- Time-scales
- Clock steering
- Frequency offset generation

Optional DC voltage operation: +20 to +33 VDC, 2 A or –48 VDC, 2A (Telecom Industry)

* Please mention the DC option of your choice when placing an order or requesting a quote.

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HROG-5-LN SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Phase resolution		-	$2\pi / 2^{32}$	-	radians
Phase offset range		-	infinite	-	-
Time offset resolution	5 MHz external reference	-	0.047	-	fs
Frequency resolution		-	5 E-19	-	-
Frequency tuning range		-	+/- 2 E-7	-	-
Mech. tuning range		-	+/-1 E-6	-	-
Int. oscillator aging	after 30 days of operation	-	1 E-10	-	Per day
5 MHz output level	50 ohm load	+10	+13	+15	dBm
1PPS output level	50 ohm load	3.7	4.2	5	V
1 PPS rise time	50 ohm load		1.4	2	
1 PPS fall time	50 ohm load		1.0	2	
Output isolation	Channel-to-channel reverse	- -	80 80	- -	dB
Phase noise L(f)	1Hz 10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-132 -145 -163 -169 -171	-130 -142 -160 -167 -168	dBc/Hz
Allan deviation $\sigma_y(t)$	$\Delta f = 1.0\ E^{-12}$ 1 s 10 s 100 s	 - - -	 5 E-14 5 E-15 2 E-15	 6 E-14 8 E-15 3 E-15	-
Allan deviation $\sigma_y(t)$	$\Delta f = 0$ 1 s 10 s 100 s 1000 s	 - - -	 4 E-14 5 E-15 6 E-16 3 E-16	 6 E-14 7 E-15 8 E-16 5 E-16	-
Spurious		-	-110	-100	dBc
Harmonics		-	-45	-40	dBc

External reference: 5.0 MHz ± 2.0 E^{-8}, +7 dBm to +15 dBm
External 1PPS: 800 ns min. pulse width, TTL compatible levels
AC power: 110-120 or 220-240 VAC

Rack-mount enclosure: 3.5" X 16" X 19", Weight: 20 lbs.

HROG-5 SELECTION GUIDE

Part Number	Phase Noise @ 10 Hz	Phase Noise @ 10 kHz
HROG-5	-140 dBc/Hz	-167 dBc/Hz
HROG-5-**LN** (Low Noise Option)	-145 dBc/Hz	-171 dBc/Hz

HIGH RESOLUTION PHASE AND FREQUENCY OFFSET GENERATOR

US Patent 6,278,330

HROG-10

DESCRIPTION

The HROG-10 is a high-resolution phase and frequency offset generator. The phase and frequency of the output signals are adjustable with respect to a 10 MHz user supplied reference. The output phase resolution of the generator is $2\pi/2^{32}$ radians or an output time step resolution of 0.024 fs. The output frequency resolution is 5×10^{-19}. Both phase and frequency steps are phase continuous. The instrument provides two sine-wave outputs and two pulse outputs. The sine-wave outputs are buffered to provide greater than 80 dB of port-to-port and reverse isolation. The outputs are at a level of +13 dBm. The pulse outputs are derived from the sine-wave outputs by dividing by a factor of 10.0E6. The pulse outputs can be synchronized to an external reference pulse to within 100 ns. All instrument functions are displayed and controlled via the front panel LCD display and keypad. Remote control of the instrument is possible through RS-232 communications.

FEATURES

- High isolation: > 80 dB
- High phase resolution: 0.024 fs
- Low harmonic distortion: -45 dBc
- Phase noise (1 kHz) : -165 dBc/Hz

Option Low Noise:

- Phase Noise (1 kHz): -168 dBc/Hz

APPLICATIONS

- Atomic frequency standards
- Clock synchronization
- Time-scales
- Clock steering
- Frequency offset generation

Optional DC voltage operation: +20 to +33 VDC, 2 A or –48 VDC, 2A (Telecom Industry)

* Please mention the DC option of your choice when placing an order or requesting a quote.

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HROG-10-LN SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Phase resolution		-	$2\pi / 2^{32}$	-	radians
Phase offset range		-	infinite	-	-
Time offset resolution	10 MHz external reference	-	0.024	-	fs
Frequency resolution		-	5 E-19	-	-
Frequency tuning range		-	+/- 2 E-7	-	-
Mech. tuning range		-	+/-1 E-6	-	-
Int. oscillator aging	after 30 days of operation	-	2 E-10	-	Per day
10 MHz output level	50 Ohm load	+10	+13	+15	dBm
1PPS output level	50 Ohm load	3.7	4.2	5	V
1 PPS rise time	50 ohm load		1.4	2	
1 PPS fall time	50 ohm load		1.0	2	
Output Isolation	Channel-to-channel reverse	- -	80 80	- -	dB
Phase noise L(f)	1 Hz 10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-131 -140 -160 -168 -168	-127 -137 -158 -167 -167	dBc/Hz
Allan deviation $\sigma_y(t)$	$\Delta f = 1.0\ E^{-12}$ 1 s 10 s 100 s	 - - -	 4 E-14 5 E-15 2 E-15	 5 E-14 7 E-15 3 E-15	
Allan deviation $\sigma_y(t)$	$\Delta f = 0$ 1 s 10 s 100 s 1000 s	 - - -	 4 E-14 5 E-15 6 E-16 1 E-16	 5 E-14 7 E-15 8 E-16 2 E-16	
Spurious		-	-110	-100	dBc
Harmonics		-	-45	-40	dBc

External reference: 10.0 MHz ± 2.0 E^{-8}, +7 dBm to +15 dBm
External 1PPS: 400 ns min. pulse width, TTL compatible levels
AC power: 110-120 or 220-240VAC

Rack-mount enclosure: 3.5" X 16" X 19", Weight: 20 lbs.

HROG-10 SELECTION GUIDE

Product Name	Phase Noise @ 10 Hz	Phase Noise @ 10 kHz
HROG-10	-135 dBc/Hz	-165 dBc/Hz
HROG-10-LN (Low Noise Option)	-140 dBc/Hz	-168 dBc/Hz

LOW NOISE FREQUENCY SYNTHESIZER, LNFS-100

DESCRIPTION

The LNFS-100 is a low noise synthesizer with an output frequency range of 1μHz to 120 MHz. The synthesizer has 48 bit frequency resolution, 14 bit phase resolution and 12 bit amplitude control. The low noise internal time base can be phase-locked to an external 5 or 10 MHz signal for long term stability and accuracy. The synthesizer can be used as a frequency source for instrumentation, microwave synthesis, phase noise characterization, radar synthesizers and telecommunication clock systems. The LNFS-100 has AM, FM, PM, FSK, ASK, and BPSK modulation capabilities. The synthesizer is available in a 2U rack-mount enclosure with LCD display and keypad. Remote control of the instrument is available through a RS-232 interface. This unit may be ordered with up to three independent synthesizers locked to the internal time base.

FEATURES

- Frequency range: 1μHz - 120 MHz
- Amplitude range: -30 to 15 dBm into 50 Ω
- Frequency resolution: 1 μHz
- Phase resolution: 0.38 mRadians
- Low phase noise : 5 MHz, +10 dBm output
  -140 dBc/Hz @ 100 Hz
  -160 dBc/Hz @ 1 kHz

APPLICATIONS

- Instrumentation
- Microwave synthesis
- Phase noise characterization
- Radar synthesizers
- Telecom clock generation

LNFS-100 SELECTION GUIDE

Part Number	Number of Synthesizers
LNFS-100	1
LNFS-100 OPT2	2
LNFS-100 OPT3	3

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Phase resolution		-	0.022	-	degrees
Phase offset range		-	+/- 360	-	degrees
Amplitude resolution		-	0.01	-	Vrms
Frequency resolution		-	1 E-6	-	Hz
Frequency tuning range		-	0 – 120	-	MHz
Mech. tuning range		-	+/-1 E-6	-	-
Int. oscillator aging	after 30 days of operation	-	5 E-10	-	Per day
Max sine output level	50 Ohm Load, accuracy +/-2	+14	+15	+16	dBm
Output isolation	channel to channel reverse	- -	80 80	- -	dB
Phase noise L(f) 5 MHz output, +15 dBm	10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-135 -147 -154 -160	-133 -145 -152 -155	dBc/Hz
Phase noise L(f) 10 MHz output, +15 dBm	10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-130 -142 -150 -155	-127 -140 -147 -153	dBc/Hz
Allan deviation $\sigma_y(t)$ Locked to ext reference	f = 5E^6 1 s 10 s 100 s	 - - -	 2.1 E-13 3.2 E-14 2.0 E-14	 - - -	
Allan deviation $\sigma_y(t)$ Locked to ext reference	f = 10E^6 1 s 10 s 100 s	 - - -	 3 E-13 4 E-14 6 E-15	 - - -	
Spurious		-100	-50	-45	dBc
Harmonics		-60	-45	-32	dBc

External Reference: 10.0 MHz ± 2.0 E^{-8} +7 dBm to +15 dBm
DC Tuning Voltage: +/- 5VDC
External Trigger: 400 ns min. pulse width TTL Compatible Levels
AC Power: 110-120 / 220-240 VAC

Rack-mount Enclosure
Size: 3.5" X 16" X 19"
Weight: 20 lbs

LOW NOISE FREQUENCY SYNTHESIZER, LNFS-400

DESCRIPTION

The LNFS-400 is a versatile low noise synthesizer with an output frequency range of 1 to 400 MHz. The instrument has 32 bit frequency resolution, 14 bit phase resolution and a low noise internal time base that can be phase-locked to an external 5 or 10 MHz signal for long term stability. Applications include frequency generation for instrumentation, microwave synthesis, phase noise characterization, radar synthesizers and telecommunication clock generators. The LNFS-400 has FSK and PSK modulation capabilities. The synthesizer is available in a 2U rack-mount enclosure with LCD display and keypad. Remote control of the instrument is available through a RS-232 interface. This unit may be ordered with up to three independent synthesizers locked to the internal time base.

FEATURES

- Frequency range 1 - 400 MHz
- Frequency Resolution: 0.233 Hz
- Phase resolution: 0.38 mRadians
- Low phase noise : 180 MHz output
  -130 dBc/Hz @ 1 kHz
  -140 dBc/Hz @ 100 kHz

APPLICATIONS

- Instrumentation
- Microwave synthesis
- Phase noise characterization
- Radar synthesizers
- Telecom clock generation

LNFS-400 SELECTION GUIDE

Part Number	Number of Synthesizers
LNFS-400	1
LNFS-400 OPT2	2
LNFS-400 OPT3	3

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Phase resolution		-	0.022	-	degrees
Phase offset range		-	+/- 360	-	degrees
Amplitude resolution		-	1.0	-	dBm
Frequency resolution		-	0.233	-	Hz
Frequency tuning range		-	1 - 400	-	MHz
Mech. tuning range		-	+/-1 E-6	-	-
Int. oscillator aging	after 30 days of operation	-	1 E-6	-	Per year
Max sine output level	50 ohm load, accuracy +/-2 dB	+14	+15	+16	dBm
Output isolation		-	60	-	dB
Phase noise L(f) 10 MHz output, +13 dBm	10 Hz 100 Hz 1 kHz >10 kHz	- - - -	-130 -135 -135 -145	-125 -130 -130 -140	dBc/Hz
Allan deviation $\sigma_y(t)$ Locked to ext reference	f = 5E6 1 s 10 s 100 s	 - - -	 2.0 E-12 3.0 E-13 3.0 E-14	 4.0 E-12 4.0 E-13 5.0E-14	
Allan deviation $\sigma_y(t)$ Locked to ext reference	f = 10E6 1 s 10 s 100 s	 - - -	 2.0 E-12 3.0 E-13 3.0 E-14	 3.0 E-13 4.0 E-13 5.0E-14	
Spurious	+13 dBm output level	-65	-50	-45	dBc
Harmonics	+13 dBm output level	-60	-40	-30	dBc

External reference: 10.0 MHz ± 2.0 E^{-8} +7 dBm to +15 dBm
DC tuning voltage: +/- 5VDC
External trigger: 400ns min. pulse width TTL compatible levels
AC power: 110–120/ 220–240VAC

Rack-mount enclosure
Size: 3.5" X 16" X 19"
Weight: 21 lbs

PULSE GENERATOR, PPS-2

DESCRIPTION

The PPS-2 pulse generator is used to generate one pulse per second signals from a sine-wave input signal. The input can be a 1 MHz, 5 MHz or 10 MHz signal. The pulse-per-second (pps) output has a variable pulse width. The input frequency selection and pulse width selections are configured via jumper settings. The output pps can synchronize with an external event. The synchronization is good to +/- ½ of the input clock cycle. The outputs are designed to drive low impedance loads and long 50 or 75-ohm cables. The channel-to-channel delay differences are less than 1 ns. The instrument is available in a 1U full rack mount enclosure and operates on 110 / 220 VAC. Optional DC operation option is available upon request.

FEATURES

- External sync
- High stability
- Low input VSWR
- Low temperature coefficient: 3 ps/ºC

APPLICATIONS

- Reference clock distribution
- Time synchronization
- 1 PPS generation

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SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Rise time	10 - 90 %	-	1.5	2	ns
Fall time	10 - 90 %	-	1.5	2	ns
Differential delay	Channel - Channel	-	200	500	ps
Impedance	input output	- -	50 10	- -	Ohms
Input High Level Input Low Level	Input signal into 50 ohm load Input signal into 50 ohm load	2 -0.7	- -	5 0.8	V
Output High Level Output Low Level	50 ohm load 50 ohm load	3 -	4 0.1	5 0.2	V
Input Signal Level	1 MHz, 5 MHz and 10 MHz	0	+7	+13	dBm
External Sync. Error	1 MHz 5 MHz 10 MHz	- - -	+/- 500 +/- 100 +/- 50	- - -	ns
Temp-delay Coefficient	0 - 50 ºC	-	3	5	ps/ºC

PPS SELECTION GUIDE

Part Number	Enclosure	Description
PPS-2RM-A	1U Full-rack	One generator, rear panel connectors
PPS-2RM-B	1U Full-rack	Two generators, rear panel connectors
PPS-2RM-B1	1U Full-rack	Two generators, front panel connectors

Optional DC operation is available upon request. Please add -DC to the part number when ordering the DC operation option.

6.834 GHz FREQUENCY SYNTHESIZER, RB-1

DESCRIPTION

The 6.834 GHz Synthesizer, RB-1 is a high stability and high resolution signal source designed to be used in the implementation of a Rubidium atomic clock. The RB-1 is provided in two separate enclosures, the Synthesizer Module and the DC Module, both in a 2U, 19 inch rack-mount enclosure. All synthesizer functions are accessed from the front panel or a RS232 interface. An external trigger input may be used to synchronize programmable events such as frequency sweeps, phase modulation and amplitude modulation with external events. The synthesizer is implemented with a flexible modular topology. Two ultra-low noise quartz oscillators are part of the multiplication chain from 5 MHz to 100 MHz. Buffered outputs are provided at the front panel for 5 MHz, 10 MHz and 100 MHz signals. The 100 MHz signal is the highest frequency in the low frequency section of the synthesizer. This 100 MHz signal is distributed using a one input, four output isolation amplifier. One of these 100 MHz signals is used as the reference for a 6.8 GHz DRO. The output of the 6.8 GHz DRO is buffered and used to drive the LO port of a single-sideband mixer. The second 100 MHz signal is used to generate the 200 MHz clock for the DDS synthesizer module. The DDS synthesizer generates a 34.xx MHz signal with 48 bit resolution and complete modulation capabilities. The DDS synthesizer output drives the IF port of the single-sideband mixer. The upper sideband of the mixer is selected as the output generating the 6.834 GHz output signal. The amplitude of the 6.834 GHz output is controlled with 12 bits of resolution and an internal relay may be used to turn off the RF signal.

FEATURES

- Output signals: 5 MHz, 10 MHz, 100 MHz, 34 MHz, 6.8 GHz, 6.834 GHz.
- Synchronization capabilities with external events:
  Frequency sweeps
  Phase modulation
  Amplitude modulation
- Low phase noise

APPLICATIONS

- Atomic frequency standards
- Atomic time scales
- Reference frequency generation

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SPECIFICATIONS

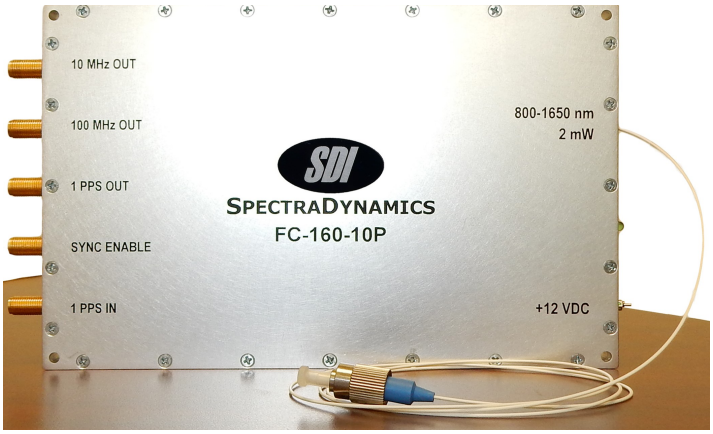
PARAMETER	CONDITIONS	TYP		UNITS
Frequency Stability $\sigma_y(t)$	Averaging time			
	1 s	$1 \cdot 10^{-13}$	-	-
Ref. 5 MHz, +13 dBm	10 s	$1 \cdot 10^{-14}$		
Pair measurement	100 s	$1 \cdot 10^{-15}$		
	1000 s	$2 \cdot 10^{-16}$		
	100000 s	$2 \cdot 10^{-17}$		
	1000000 s	$2 \cdot 10^{-17}$		
Phase Noise L(f)	Offset frequency			
Carrier 6.834 GHz	1 Hz	-57	-54	
(PLL locked at 0.5Hz BW for measurement)	10 Hz	-87	-84	
	100 Hz	-97	-94	dBc/Hz
	1 kHz	-120	-117	
(5MHz to 6.834GHz Multiplication	10 kHz	-127	-124	
Noise at 1 Hz offset is -75dBc/Hz	100 kHz	-129	-126	
at the 6.834 GHz output)	1 MHz	-140	-137	
Phase Noise L(f)	Offset frequency			
Carrier 100 MHz	10 Hz	-126	-123	
	100 Hz	-140	-137	dBc/Hz
	1 kHz	-159	-156	
	>10 kHz	-174	-172	
	Offset frequency			
Phase Noise L(f)	1 Hz	-113	-110	
Carrier 10 MHz	10 Hz	-146	-144	dBc/Hz
	100Hz	-165	-162	
	>1 kHz	-169	-167	
	Offset frequency			
Phase Noise L(f)	1 Hz	-123	-120	
Carrier 5 MHz	10 Hz	-150	-147	dBc/Hz
	100Hz	-167	-165	
	>1 kHz	-175	-173	

External reference : 5.0 MHz ± $2.0 \cdot 10^{-8}$, +7 dBm to +15 dBm
Rack-mount enclosure: 3.5" (2U) X 16" X 19", Weight: 20 lbs

RB-1 SELECTION GUIDE

Part Number	Phase Noise @ 1 Hz 5 MHz Output	Phase Noise @ 1 Hz 6.834 GHz Output
RB-1	-123 dBc/Hz	-57 dBc/Hz
RB-1 Opt C	-130 dBc/Hz	-67 dBc/Hz

OPTICAL TO RF CONVERTER, FC-XXX-10P



DESCRIPTION

The FC-XXX-10P is an ultra-low noise optical to RF frequency converter. This instrument can be used to generate low noise 10 MHz, 100 MHz and 1PPS signals that derive their phase noise and stability from an external 800-1650 nm pulsed optical signal with a repetition rate of 250 MHz for the **FC-250-10P**, 200 MHz for the **FC-200-10P**, 160 MHz for the **FC-160-10P** and 80 MHz for the **FC-080-10P**.

A high speed photodiode is used to convert the optical signal into RF and a proprietary synthesizer is used to generate 10 MHz, 100 MHz and 1PPS outputs. All PPS input signals conform to TTL levels.

The instrument comes in an aluminum module and operates from a + 12 VDC power source.

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output power level		-	+13	+14	dBm
Stability of the 10 MHz Output	Pair Measurement		1 e-14	8 e-14	-
Temperature Stability	@10 MHz, 20-50C @100MHz, 20-50C	-	0.5 1	1 2	ps/C
Residual Phase Noise of the 10 MHz Output	1 Hz 10 Hz 100 Hz 1 kHz >10 kHz	- - - - -	-142 -152 -162 -167 -170	-140 -152 -162 -167 -170	dBc/Hz
Residual Phase Noise of the 100 MHz Output	1 Hz 10 Hz 100 Hz 1 kHz >10 kHz	- - - - -	-127 -137 -147 -152 -155	-122 -132 -142 -147 -150	dBc/Hz
Harmonic Distortion		-	-35	-30	dBc
1 PPS External Sync Error		-	-	5	ns

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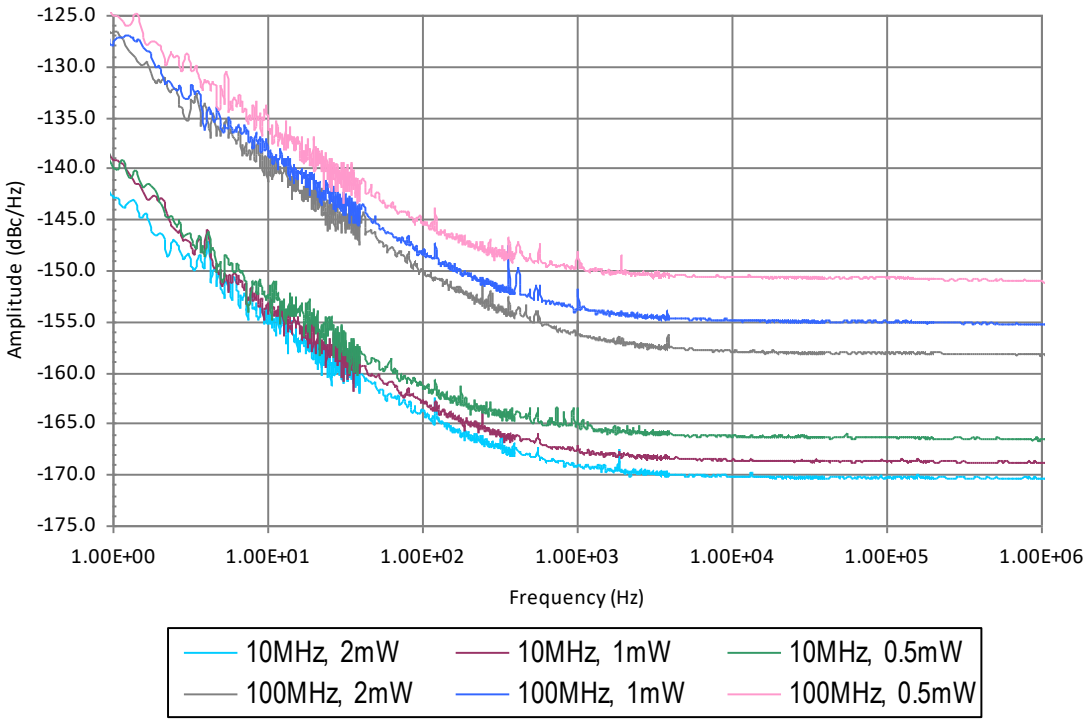
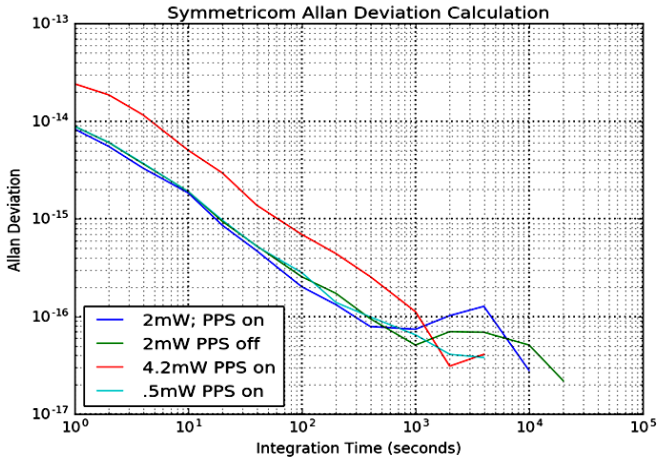
PHASE NOISE:

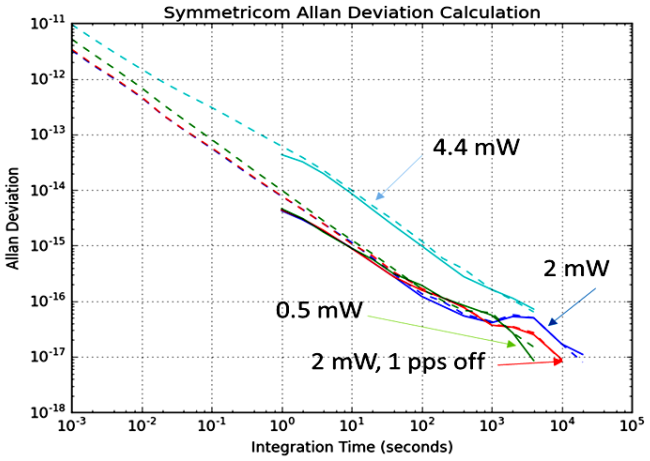
FC-160-10P Frequency Converter Phase noise
1560nm light with pulse repetition rate of 160 MHz



10 MHz OUTPUT:



100 MHz OUTPUT:



OPTICAL TO RF CONVERTER, FC-250-10P

DESCRIPTION

The FC-250-10P is a Low Noise Frequency Converter for Optical to RF Signals. This instrument can be used to generate low noise 10 MHz, 100 MHz and 1PPS signals that derive their phase noise and stability from an external 800-1650 nm pulsed optical signal with a repetition rate of 250 MHz. A high speed photodiode is used to convert the optical signal into RF and a proprietary synthesizer is used to generate 10 MHz, 100 MHz and 1 PPS outputs.

This instrument is designed to operate with a 100 to 240 VAC, 47 to 63 Hz power source and is housed in a 2U, half rack enclosure.

FEATURES

- Low phase noise
- Outputs:
  10 MHz signal with 12 +/- 2 dBm.
  100 MHz signal with 7 +/- 2 dBm.
  1 Pulse per Second TTL signal
  Unsynchronized signal = 8 ns long pulse width
  Synchronized signal = 512 us long pulse width
- Synchronization capabilities with external PPS.

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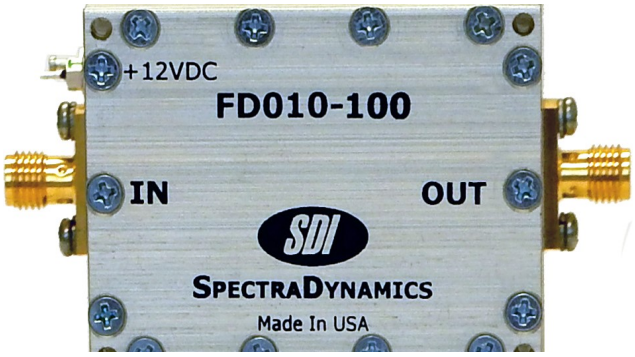
SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
10 MHz output level		+12	+13	+14	dBm
100 MHz output level		+6	+7	+9	dBm
Stability of 10 MHz Output	Pair Measurement		1 e-14	2 e-14	-
Temperature Stability	@10 MHz, 20-50 °C	-	0.5	1	ps/K
	@100MHz, 20-50 °C		1	2	
Residual Phase Noise	1 Hz	-	-142	-138	dBc/Hz
10 MHz Output	10 Hz	-	-152	-150	
	100 Hz	-	-162	-160	
	1 kHz	-	-167	-165	
	>10 kHz	-	-169	-167	
Frequency Stability	1	-	2.8 E-14	3 E-14	
10 MHz Output	10	-	3.6 E-15	5 E-15	
	100	-	5 E-16	1 E-15	
	1000	-	1 E-16	5 E-15	
	10000	-	4 E-17	1 E-16	
Residual Phase Noise	1 Hz	-	-127	-125	dBc/Hz
of the 100 MHz Output	10 Hz	-	-137	-135	
	100 Hz	-	-147	-145	
	1 kHz	-	-152	-150	
	>10 kHz	-	-155	-155	
Frequency Stability	1	-	5 E-15	3 E-14	
100 MHz Output	10	-	1 E-15	5 E-15	
	100	-	5 E-16	5 E-16	
	1000	-	7 E-17	3 E-16	
	10000	-	1 E-17	1 E-16	
Harmonic Distortion		-	-35	-30	dBc
1 PPS output level	50 ohm load	2.5	3.9	5	V
1 PPS External Sync Error		-	< 5	10	ns

LOW NOISE 100 MHz TO 10 MHz FREQUENCY DIVIDER, FD010-100LT



DESCRIPTION

The FD010-100LT is a low noise frequency divider which takes a sinewave input at 100 MHz and divides it down to a 10 MHz sinewave output. This module has been designed for ultra low phase noise and very high stability. The module is temperature compensated to keep the overall delay temperature coefficient below 5 ps/K. SpectraDynamics Dividers are available for different input and output frequencies with similar performance.

SPECIFICATIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency Stability $\sigma_y(t)$ Measured @ 10MHz output Locked to common 100MHz	Averaging time 1 s	-	$1 \cdot 10^{-14}$	$8 \cdot 10^{-14}$	
Phase Noise L(f) Residual noise @ 10 MHz output	Offset frequency 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz	-	 -142 -152 -162 -167 -170 -170	 -140 -152 -162 -167 -170 -170	dBc/Hz
Input Level	-	0	+13	+15	dBm
Output Level	-	+10	+13	+14	dBm
Impedance	input output	- -	50 50	- -	Ohms
Delay Temp-Coefficient	0 - 50 °C	-	3	5	ps/°C

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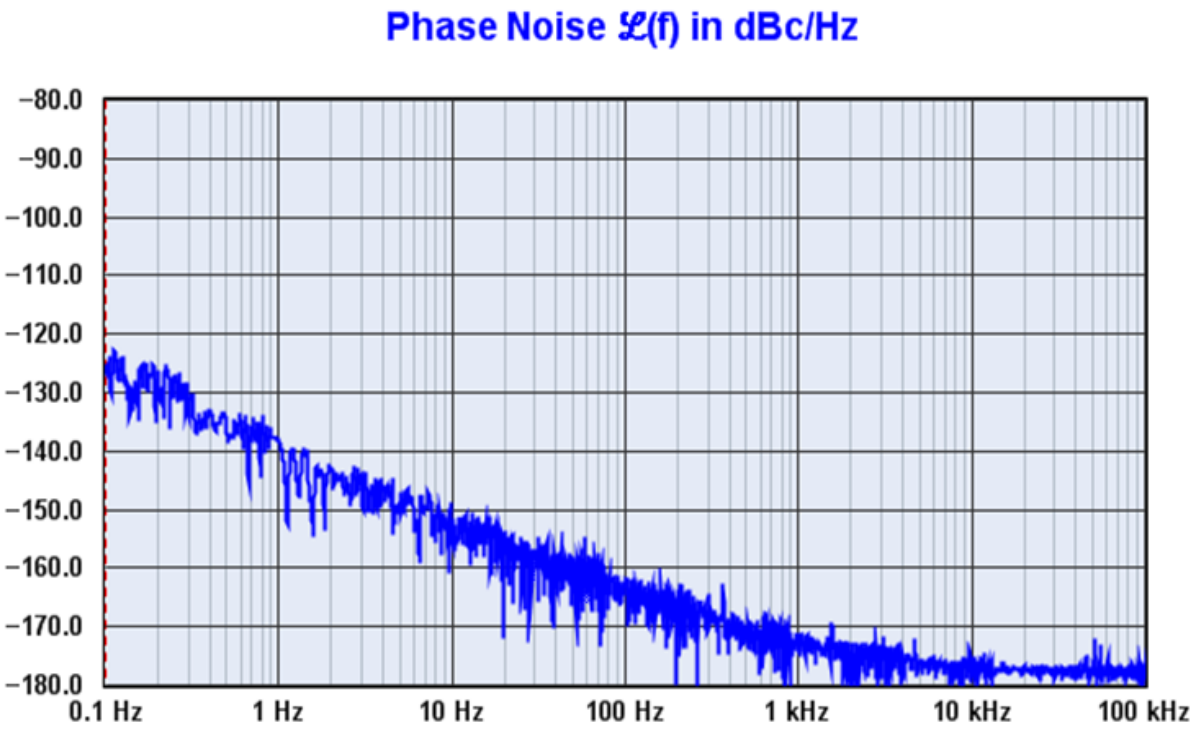
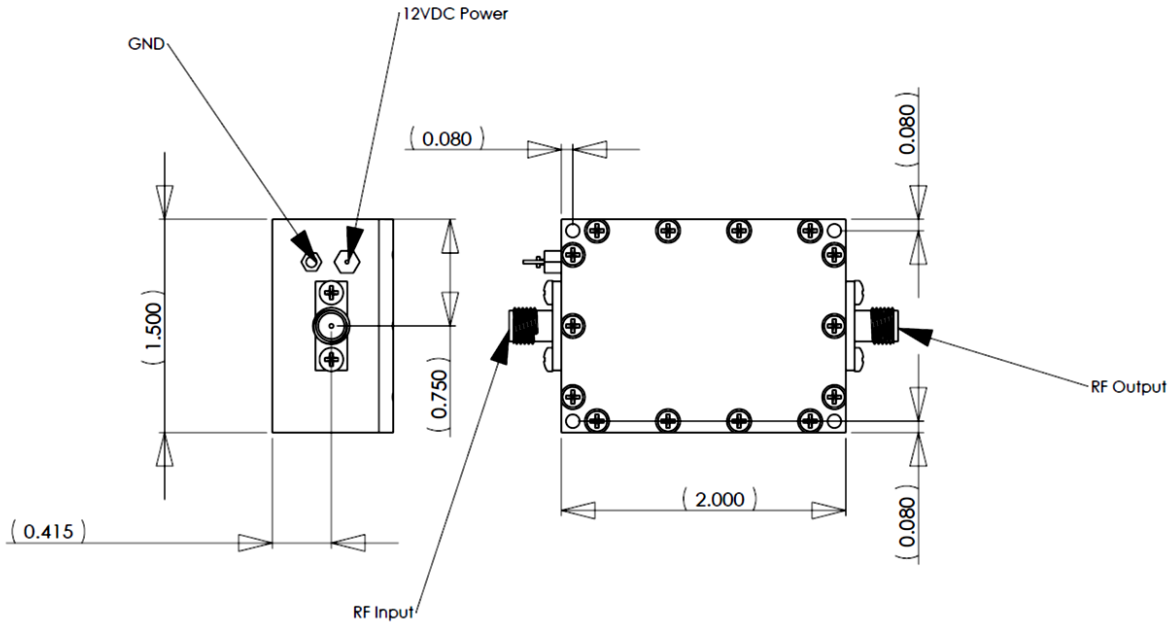
PHASE NOISE:



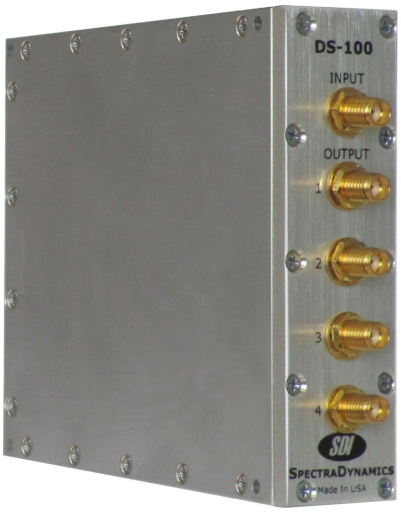
POWER REQUIREMENTS

DC operation: +12 VDC, 150 mA



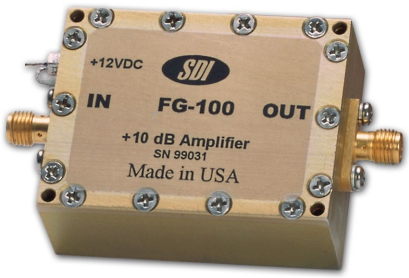
CUSTOM PRODUCTS

SpectraDynamics, Inc. is aware of the challenges that standard products may represent for a particular application or for the development of a specific project. Therefore SpectraDynamics is happy to provide you with custom engineered solutions and a variety of modular products that may be customized to fit your particular needs:



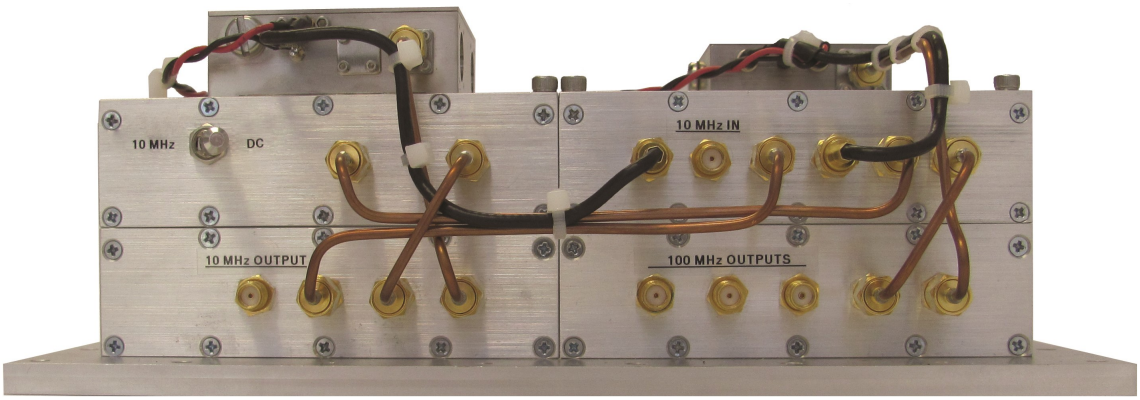
DS-100
Distribution Amplifier 1-200 MHz

- Unity gain
- Low VSWR
- High isolation: 70 dB @ 5 MHz
  50 dB @ 100 MHz
- Low phase noise: -150 dBc/Hz @ 10 Hz
  -170 dBc/Hz @ 10 kHz
- Low distortion: -40 dBc
- Max. output: +15 dBm



FG-100
Fixed Gain Amplifier

- User specified fixed gain: +10 to +20 dB
- Low phase noise: -160 dBc/Hz @ 10 Hz
  -175 dBc/Hz @ 10 kHz
- Low distortion: -40 dBc @ +13 dBm
- 3 dB BW 1 MHz to 1 GHz



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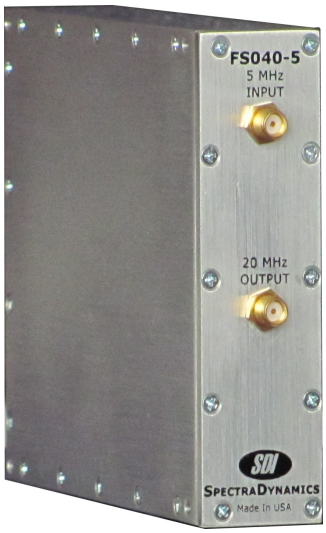
FREQUENCY MULTIPLIERS



FS020-X, FS040-X, FS080-X, FS100-X

- Frequency Multiplier
- **X** = User specified input frequency
- 020 = Times two
- 040 = Times four
- 080 = Times eight
- 100 = Times ten

- Ultra-Low Phase Noise: -143 dBc/Hz @ 1 Hz
  -170 dBc/Hz @ 1 kHz
  -176 dBc/Hz @ 100 kHz
- Very Low Spurious: -50 dBc

- Voltage requirements: +12 VDC
- Input power requirement: > +11dBm

FREQUENCY DIVIDERS

- Low phase noise: -140 dBc/Hz @ 1 Hz Typ.
  -175 dBc/Hz @ 10 kHz Typ.
- Voltage requirement: +12 VDC
- Input power requirement: +11 to +15 dBm
- Return loss: -15 dB

FD002-10

- Input freq: 10 MHz
- Output: 5 MHz

FD010-100

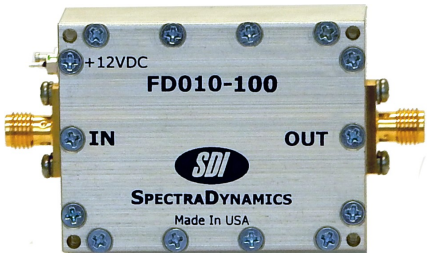
- Input freq: 100 MHz
- Output: 10 MHz
- High Stability - Optional

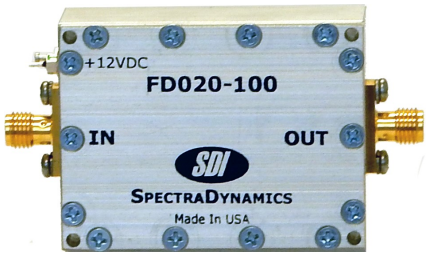
FD020-100

- Input freq: 100 MHz
- Output: 5 MHz
- High Stability - Optional

FD020-2-100

- Input frequency: 100 MHz
- Two outputs: 10 MHz
- Two outputs: 5 MHz
- Return loss: -25 dB
- Voltage requirement: +12 VDC





If you have any questions concerning a particular application, or would like to know about the possibility of customizing an existing product, please do not hesitate to contact us. Remember that for us it is a pleasure to serve you!

SALES CONTACTS

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2. **QUOTATIONS AND PRICES.** All Quotations are valid for ninety (90) days. Unless otherwise stated in writing by SpectraDynamics, all prices set forth on the Quotation shall be exclusive of shipping, insurance, taxes, license fees, customs duties and other charges related thereto, and Buyer shall pay all such charges related thereto.

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4. **SHIPPING**. Shipping and delivery dates are estimates only, and in no event shall SpectraDynamics be liable for any delay in delivery or assume any liability in connection with shipment. All Products shall be delivered F.O.B. destination. Unless otherwise contracted, shipping costs shall be prepaid by Buyer if requested by SpectraDynamics. Risk of loss and damage thereto shall be borne by SpectraDynamics until delivery to the F.O.B. destination point, and any loss or damage thereafter shall not relieve Buyer from any payment obligation, rather SpectraDynamics will be responsible to replace any lost or damaged item(s). Unless otherwise contracted, the carrier shall be deemed an agent of SpectraDynamics.

5. **INSPECTION.** All Products delivered hereunder shall be deemed accepted by Buyer, unless written notice of defect or nonconformity is received by SpectraDynamics within ten (10) days of receipt of Products at Buyer's designated receiving address; provided that Buyer may only reject Products for failure to meet the Products' specifications.

6. **WARRANTY**. SpectraDynamics hereby warrants to Buyer, that during the applicable Warranty Period (Standard 12 months from date of shipment) the Products will conform to SpectraDynamics' published specifications and will be free of defects in materials or workmanship when used, installed and maintained in accordance with SpectraDynamics' published specifications. SpectraDynamics' sole liability and Buyer's sole and exclusive remedy for breach of warranty shall be limited to, at SpectraDynamics' option, either repairing or replacing the defective product or crediting Buyer for the amount Buyer has paid to SpectraDynamics for the applicable Product. SpectraDynamics' liability shall apply only to Products which are returned to the factory, with shipping charges prepaid by Buyer, and which are, after examination, determined to SpectraDynamics' satisfaction to be defective due to defects in materials or workmanship. SpectraDynamics will only accept returns authorized by a SpectraDynamics representative and with a valid RMA number. Any Extended Warranty option is only available at the time of order, original Product purchase. SpectraDynamics may extend the standard Warranty by 12 months periods up to 48 months from the shipping date for 2.5% of the Product price per year. For Products that are discontinued, SpectraDynamics' liability shall terminate at the end of the 12 month standard Warranty Period. Except for the warranty stated herein and to the extent permitted by applicable law SpectraDynamics, Inc. SPECIFICALLY DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NONINFRINGEMENT.

7. **LIMITATION OF LIABILITY.** To the extent not prohibited by applicable law: (a) SpectraDynamics, Inc. aggregate liability to Buyer for claims relating to the Products, whether for infringement, breach or in tort, including negligence, is limited to the amounts Buyer has paid to SpectraDynamics for the Products; and (b) SPECTRADYNAMICS WILL NOT BE LIABLE FOR ANY INDIRECT, PUNITIVE, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OF SALE, THE QUOTE, THE PRODUCTS OR THE SALE, INSTALLATION, MAINTENANCE, USE, PERFORMANCE OR NON- PERFORMANCE OF THE PRODUCTS (INCLUDING, BUT NOT LIMITED TO, REPLACEMENT COSTS OR LOSS OF BUSINESS, REVENUE, PROFITS, USE, DATA, OR OTHER ECONOMIC ADVANTAGE), HOWEVER THEY ARISE, WHETHER FOR BREACH OR IN TORT, INCLUDING NEGLIGENCE, EVEN IF SPECTRADYNAMICS, INC. HAS BEEN PREVIOUSLY ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. The parties acknowledge that if SpectraDynamics provides the Products to Buyer, it does so in reliance upon the limitations of liability and the disclaimers of warranties and damages set forth herein, and that the same form an essential basis of the bargain between the parties. Liability for damages will be limited and excluded as set forth in this paragraph, even if any exclusive remedy provided for in these Terms of Sale fails of its essential purpose.

8. **INTELLECTUAL PROPERTY.**

a) **Intellectual Property Rights.** Any Intellectual Property Rights on a worldwide basis, including, without limitation,

patentable inventions (whether or not applied for), patents, patent rights, copyrights, work of authorship, moral rights, trademarks, service marks, trade names, trade dress trade secrets and all applications and registrations of all of the foregoing resulting from the performance of these Terms of Sale that is conceived, developed, discovered or reduced to practice by SpectraDynamics, shall be the exclusive property of SpectraDynamics. Specifically, SpectraDynamics shall exclusively own all rights, title and interest (including, without limitation, all Intellectual Property Rights throughout the world) in and to the Products and any and all inventions, works of authorship, layouts, know-how, ideas or information discovered, developed, made, conceived or reduced to practice, by SpectraDynamics, in the course of the performance of these Terms of Sale.

b) **Reverse Engineering.** Buyer agrees not to engage in, or cause a third party to engage in, the disassembly, analysis, or testing of the product for the purpose of extracting knowledge regarding the design, material content, or fabrication methods.

9. CHANGES, DELAYS OF SHIPMENT, OR CANCELLATION.

a) All orders of SpectraDynamics standard manufactured products, EXCLUDING custom orders, may be cancelled upon SpectraDynamics approval and may be subject to restocking fees plus compensation for any resulting loss or damage including, without limitation, the cost of labor, materials, and overhead expenses. Compensation fee should not be less than 40% of the purchase order and no more than 70%.

b) Customer initiated delays of shipments exceeding 180 days from the original delivery date will be deemed a cancellation and fall under this cancellation policy.

10. REMEDIES. SpectraDynamics shall have the right to terminate any order, or to delay the shipment thereof, by reason of Buyer's bankruptcy or insolvency, breach of any terms herein, unauthorized assignment, or the pendency of any proceedings against Buyer under any statute for the relief of debtors.

11. EXPORT CONTROL. The Buyer agrees to comply with all applicable U.S. export control laws and regulations, specifically including, but not limited to the requirements of the Arms Export Control Act, 22 U.S.C. 2751-2794, including the International Traffic in Arms Regulation (ITAR), 22 C. F. R. 120 et seq.; and the Export Administration Act, 50 U.S.C. app. 2401-2420, including the Export Administration Regulations, 15 C.F.R. 730-774; including the requirement for obtaining any export license if applicable. Without limiting the foregoing, the Buyer agrees that it will not transfer to foreign persons or entities any items, data, or services it receives from the Seller that constitutes any export of controlled items, data, or services, to include transfer to foreign persons employed by or associated with, or under contract to the Buyer or the Buyer's suppliers, without the authority of an export license, agreement, or applicable exemption or exception. The Seller agrees to notify the Buyer if any product, data, or service the Seller supplies to the Buyer is restricted by export laws or regulations. Buyer will defend, indemnify and hold Seller harmless for any damages or costs to Seller arising from Buyer's failure to comply with these terms. Buyer agrees to indemnify Seller for any fines, penalties, claims, losses, damages, costs (including legal costs), expenses and liabilities that may arise as a result of Buyer's breach of this Section.

12. APPLICABLE LAW. This Agreement, and any disagreement arising thereof, will be governed by the laws of the State of Colorado without regard to that State's choice of laws, with exclusive jurisdiction and venue in the Colorado state courts of Boulder County, Colorado (or, if there is exclusive federal jurisdiction, the United States District Court for the State of Colorado). Buyer shall bring action relating to any dispute Buyer may have hereunder within one (1) year of the accrual of such dispute.

13. MISCELLANEOUS. Nothing in these Terms of Sale or the sale of the Products shall imply any license or other rights with respect to any intellectual property rights of SpectraDynamics or its suppliers, and SpectraDynamics reserves all such rights. All waivers of any right hereunder must be in writing and signed by SpectraDynamics. Waiver of a breach by the other party of any provision of these Terms of Sale shall not be deemed a waiver of future compliance therewith. If any provision of these Terms of Sale is held invalid by any U.S. law or regulation or by any U.S. court having valid jurisdiction, such invalidity will not affect the enforceability of other provisions. These Terms of Sale and Buyer's rights hereunder may not be assigned by Buyer without the prior written consent of SpectraDynamics, Inc. and any unauthorized assignment by Buyer shall be void. These Terms of Sale constitute the entire agreement between Buyer and SpectraDynamics with respect to Buyer's purchase of the Products and supersedes all prior agreements and understandings with respect to such purchase and may not be changed or amended, or superseded by conflicting terms and conditions submitted by Buyer, except by a written instrument signed by an authorized SpectraDynamics representative.