OTC9310L OTC9314L OTC9311L OTC9316L OTC9312L OTC9318L

8th Order Butterworth Lowpass Filters

Features

- 8th order Butterworth filter
- 14x11mm LGA-32 package
- 48dB stopband attenuation at 2 x f_C
- Internal reference clock
- 10Hz – 100kHz frequency options
- Fully differential signal path
- Single 3.3V power supply
- Input amplifier useful for compensating for common mode voltage differences (e.g. ground-referenced to differential)
- Reference clock output
- Buffered sample & hold output
- Independent amplifier useful for smoothing filter

Applications

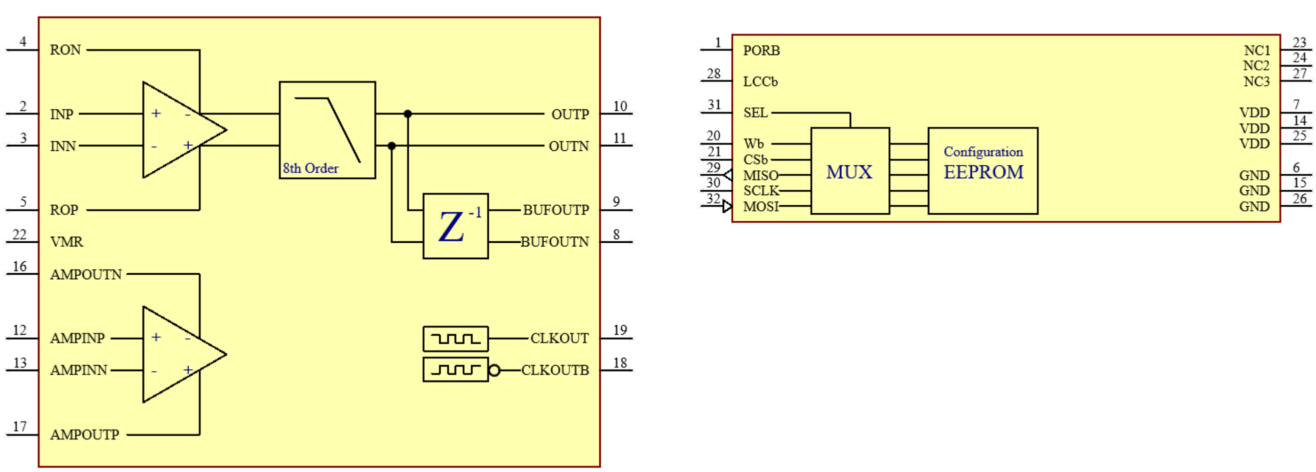
- Antialiasing Filters for ADC Input
- Sensor Signal Conditioning
- Audio and Acoustic Baseband Processing
- Industrial Automation and Process Control
- Biomedical Instrumentation
- Data Acquisition and Test Equipment
- Post-DAC reconstruction and smoothing

Description

The OTC931xL are 8th order Butterworth switched capacitor lowpass filter modules based on the Okika Devices AN231E04 Field Programmable Analog Array (FPAA). An internal EEPROM and internal clock transforms the programmable IC into a fixed-function filter module with characterized performance specifications. Cutoff frequencies are provided between 10Hz and 100KHz. Butterworth filters provide a flat passband, no stopband ripple, and low ringing for step inputs. Additional frequency options and filter topologies are available upon request or by programming the EEPROM of a Chameleon™ OTC9300L module.

An input amplifier allows ground referenced signals to be interfaced to these single-supply modules using only a handful of passive components. A fully differential internal signal path improves common-mode rejection, maximizes dynamic range, reduces susceptibility to ground noise, and prevents offset accumulation through the cascaded filter stages. Differential outputs can connect directly to differential ADCs or single-ended ADCs.

Functional Diagram



Absolute Maximum Ratings

Parameter	Symbol	Min	Typ	Max	Unit	Comment
Power Supply	VDD	-0.5	-	3.6 V	V	Referenced to GND
Max power dissipation	Pmax	-	-	0.4	W	
Input Voltage	Vinmax	VSS-0.5	-	VDD+0.5	V	
Ambient Operating Temperature	Top	-40	-	85	°C	
Storage Temperature	Tstg	-40		125	°C	
Lead Temperature	Tsolder			260	°C	Soldering, 10 seconds

Filter Characteristics

Parameter	Symbol	Units	Min	Typ	Max	Comment
Filter Order	N			8		
Cutoff Frequency OTC9310L OTC9311L OTC9312L OTC9314L OTC9316L OTC9318L	f_C	Hz		 10 100 1k 10k 22k 100k		-3dB
Reference Clock Frequency OTC9310L OTC9311L OTC9312L OTC9314L OTC9316L OTC9318L	f_{REF}	kHz		 1 10 100 1000 2000 4000		
Frequency Accuracy	Δf/f	%		0.1	0.5	At 25°C
Temperature Coefficient of Frequency	TCf	ppm/°C		50		Note 1
Passband Gain @ 0.5fC	APB	dB	-0.5		0.1	At 25°C
Passband Gain Tolerance over Temperature	ΔAPB	dB	-0.5		0.5	Note 1
Stopband Attenuation @ 2 fC	A(2fC)	dB		-48		
Step Response Settling Time OTC9310L OTC9311L OTC9312L OTC9314L OTC9316L OTC9318L	t_{SET}	 ms ms ms us us us		 500 50 5 500 250 50		1V step settling to within 1% of final value
Wideband Noise	N	uVrms		200		Includes Rauch lowpass (10K R1,10K R2, 4.7K R3), input amplifier, filter, sample & hold buffer, and differential to single-ended converter. Sample clock and harmonics removed. Note 1.

1. Parameter characterized but not 100% tested.

Electrical Characteristics

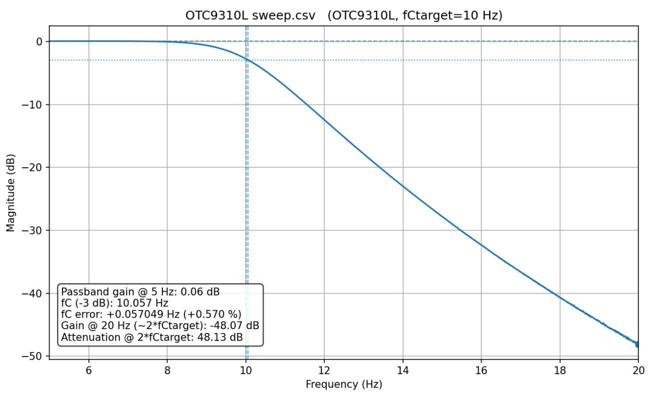
Module electrical characteristics are derived from the AN231E04 product datasheet unless otherwise indicated.

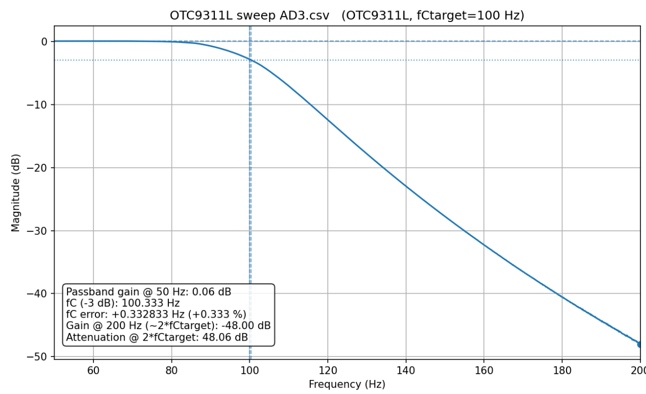
Parameter	Symbol	Units	Min	Typ	Max	Comment
Supply Voltage	VDD	V	3.0	3.3	3.6	
Supply Current	IDD	mA		55	75	100% tested
Power Dissipation	PD	mW		180	270	
Input Common Mode Voltage	VICM	V		1.5		Higher or lower common mode voltages can be used with reduced output voltage swing.
Output Common Mode Voltage	VOCM	V		1.5		
Input Voltage Range	VIN	V		2.75		VMR = 1.5V
Output Voltage Swing	VOUT	V		2.75		VMR = 1.5V
Output Load Resistance	RL	kΩ	1			
Output Load Capacitance	CL	pF			100	
Input Impedance	RIN	MΩ	10			
Output Impedance	ROUT	Ω		33		Buffered output and amplifier output
Power Supply Rejection Ratio	PSRR	dB		TBD		Power supply 3.3V ± 0.2V @ 0.5*fC. 0V DC input via Rauch. Output measured through differential to single-ended converter.
Common Mode Rejection Ratio	CMRR	dB		TBD		INP, INN shorted and driven with 1.5V ± 1.0V @ 0.5*fC.
Reset Configuration Time	tRST	ms			100	Delay from PORB input signal rising to LCCb pin rising.

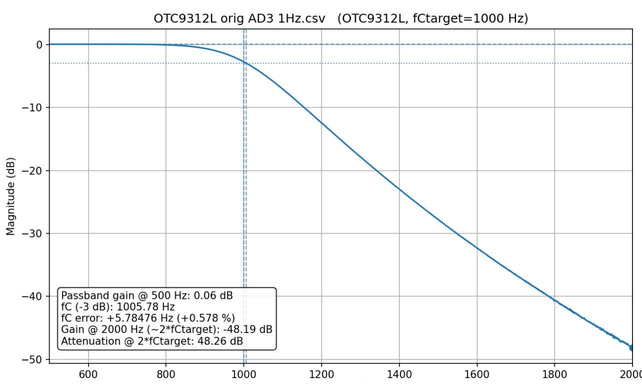
Typical Filter Performance

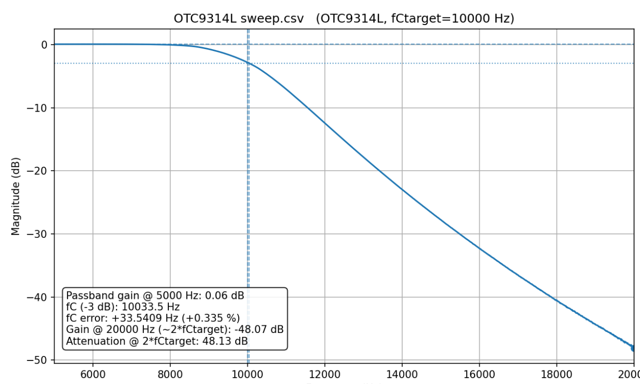
VDD = 3.3V, Room Temperature, Input = 1 Vpp through Rauch lowpass filter with f0 = 2.3 MHz, Buffered Output through Differential to Single-Ended Converter with f0 = 3.3 MHz

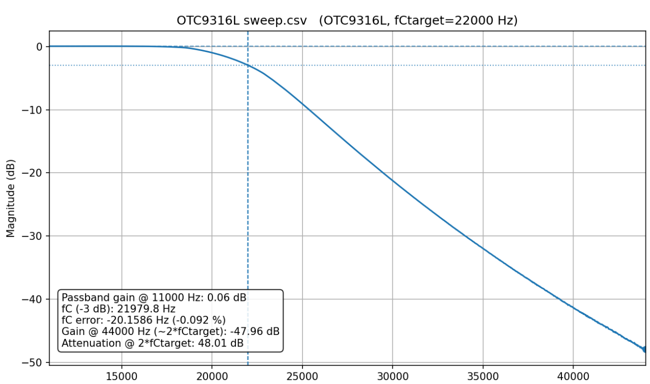
Gain vs Frequency

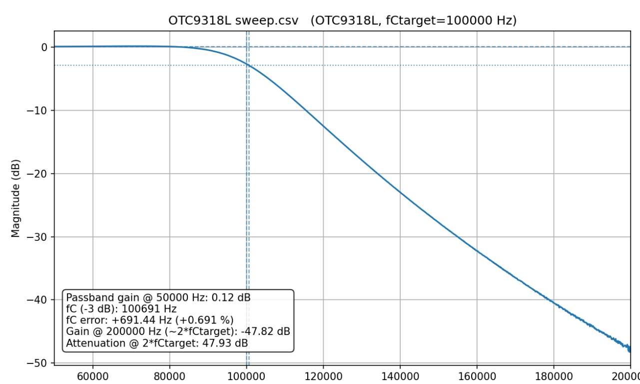




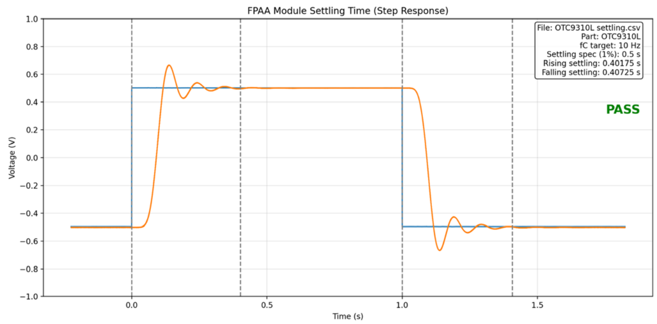


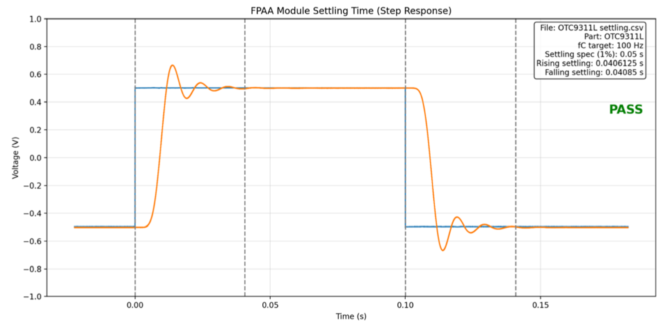


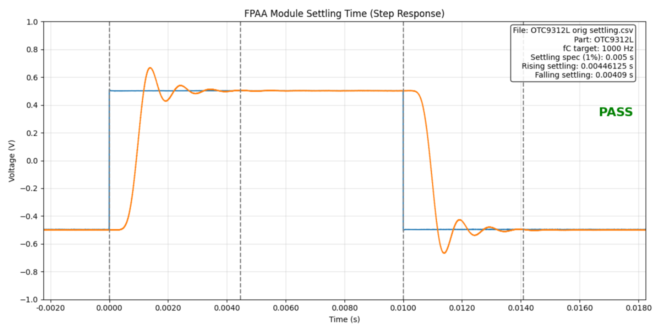


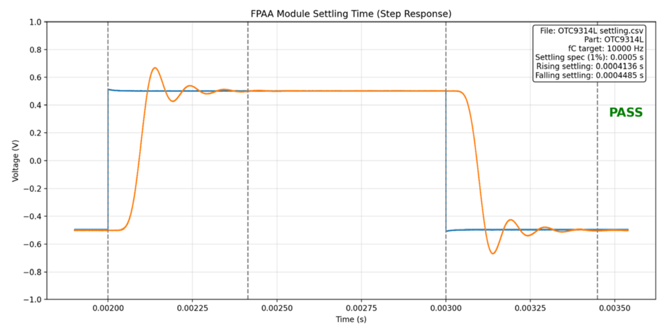


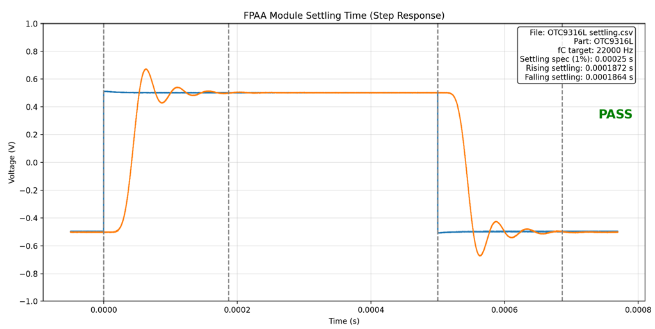
Settling Time

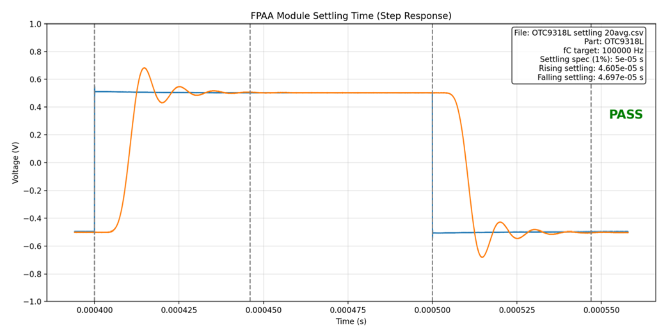










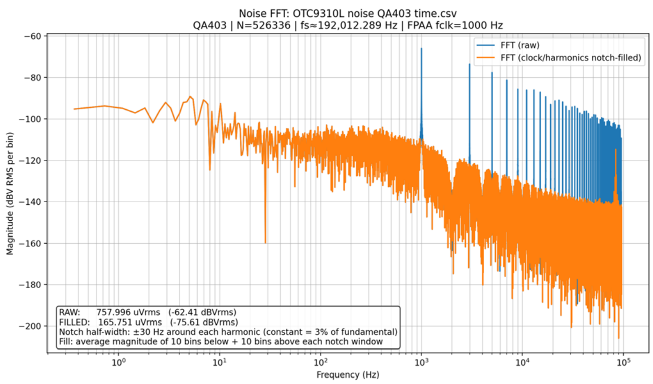


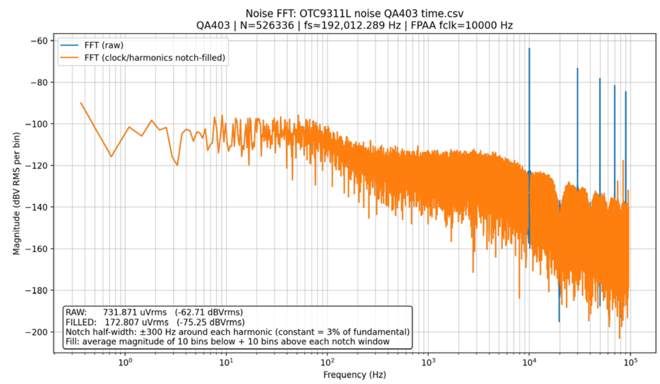
Noise

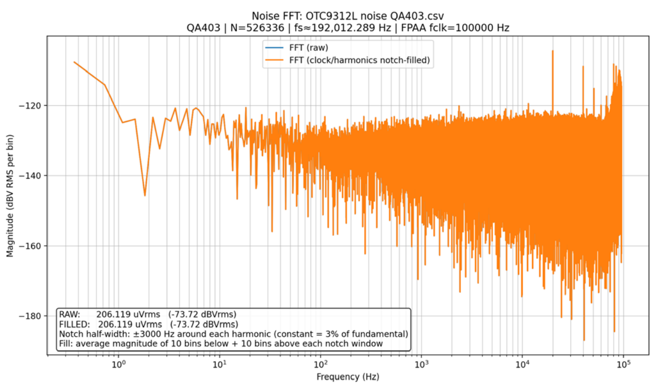
Apparent noise in switched capacitor filters is dominated by sample-clock feedthrough. In typical ADC-connected applications, either clock synchronization or analog post-filtering substantially reduces sample-clock artifacts. The available on-chip amplifier can form a Rauch filter to suppress clock noise. Also, the system ADC can be synchronized with the filter's sample clock, provided at the CLKOUT and CLKOUTB pins, to eliminate relative clock interference.

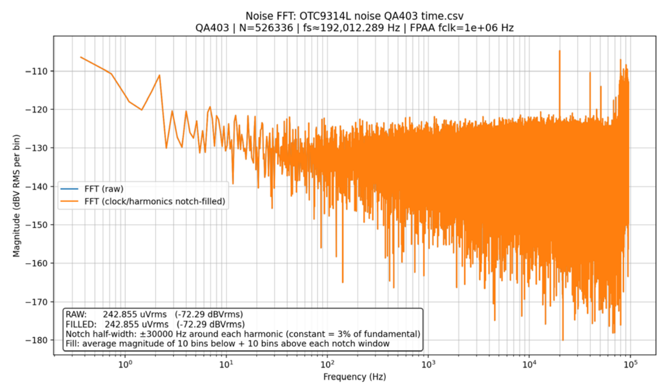
The raw noise profile without filtering or ADC synchronization has been measured using an audio analyzer with a 192 kHz sample rate (96 kHz Nyquist frequency). For low-frequency filters, the filter sample clock falls within the analyzer bandwidth, producing discrete spurs at the sample frequency and its harmonics. For higher-frequency filters, the filter sample clock exceeds the analyzer bandwidth, causing these spurs to alias into the measured spectrum. A sample-clock and harmonic removal algorithm replaces spectral bins near the clock spurs with the average noise from adjacent bins before recalculating the RMS noise level. This approach represents the intrinsic noise floor of the filters when appropriate steps are taken to mitigate sample-clock feedthrough in a system-level design.

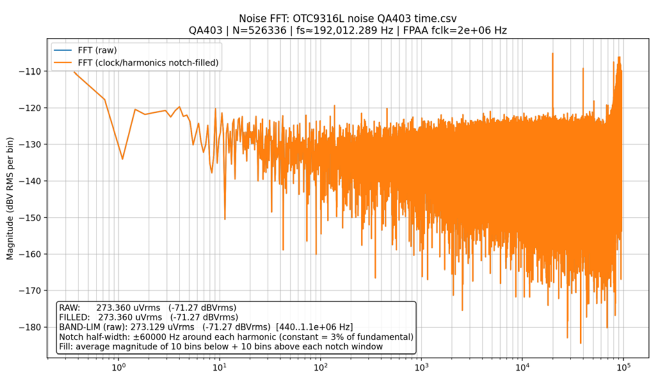
The measured noise with and without sample-clock and harmonic removal are shown below. The removal algorithm has less impact for higher-frequency filters, where the filter sample clock is aliased. Note that these measurements include a differential-to-single-ended stage that is not typically required for ADC applications but simplifies testing. Additionally, the audio analyzer used for these measurements is AC-coupled and is not specified for accuracy below 20 Hz.

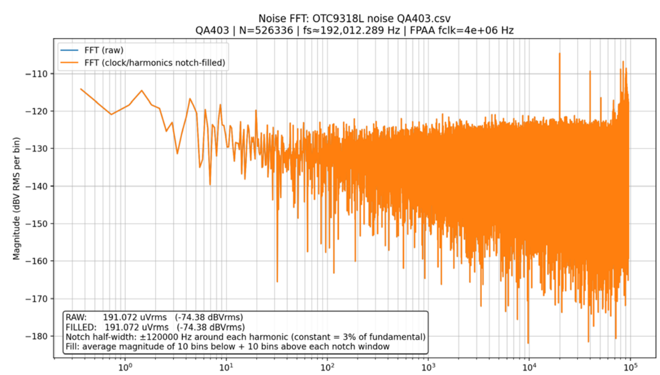












Pin Functions

Pin	Signal	Description
1	PORB	Power on reset signal - active low, internal 10K pullup. PORB must be held low until VDD reaches 3.0V.
2	INP	Differential input positive
3	INN	Differential input negative
4	RON	Rauch filter output negative
5	ROP	Rauch filter output positive
6	GND	Ground (0V reference)
7	VDD	Chip power supply 3.3V
8	BUFOUTN	Buffered sample & hold output negative
9	BUFOUTP	Buffered sample & hold output positive
10	OUTP	Unbuffered output positive. May also be configured for digital (e.g. comparator) output.
11	OUTN	Unbuffered output negative. May also be configured for digital (e.g. comparator) output.
12	AMPINP	Differential amplifier input positive
13	AMPINN	Differential amplifier input negative
14	VDD	Chip power supply 3.3V
15	GND	Ground (0V reference)
16	AMPOUTN	Differential amplifier output negative
17	AMPOUTP	Differential amplifier output positive
18	CLKOUTB	Digital output 2 (default inverted clock output)
19	CLKOUT	Digital output 1 (default clock output)
20	EXT_WB	External SPI interface write protect - active low, internal 10K pulldown. Pin must be driven high externally to program EEPROM. Leave unconnected to avoid accidentally reprogramming the module.
21	EXT_CSB	External SPI interface chip select - active low
22	VMR	Mid-rail reference voltage ~1.5V
23	NC	No internal connection
24	NC	No internal connection
25	VDD	Chip power supply 3.3V
26	GND	Ground (0V reference)
27	NC	No internal connection
28	LCCb	Local configuration complete (done) - active low
29	EXT_MISO	External SPI interface serial data output from EEPROM
30	EXT_SCK	External SPI interface serial clock
31	EXT_SEL	External SPI interface select - enables external pin access to EEPROM when high. 10K internal pulldown. Pin must be driven high to program EEPROM.
32	EXT_MOSI	External SPI interface serial data input to EEPROM

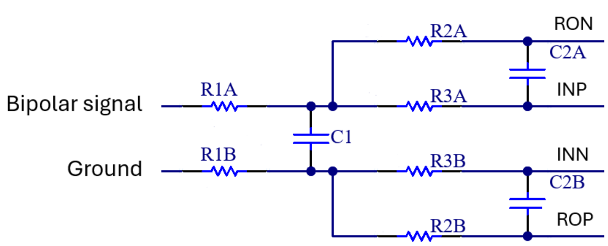
FPAA IC Connections

ChameleonTM modules are configured using Okika's Anadigm Designer 2 software, which also provides accurate and fast simulation capability. The table below defines the connections between the module pins and FPAA pins.

IOCell	FPAA Pins	FPAA Name	ChameleonTM Module Pins	Use on Lowpass Filter Modules
1	1 2 3 4	I1P I1N O1N O1P	INP INN RON ROP	Analog Input
2	6 7 8 9	O2P O2N I2N I2P	Not used	None
3	11 12 13 14	I3P I3N O3N O3P	bufinp(internal) bufinn(internal) BUFOUTN BUFOUTP	Drive off chip circuitry such as analog to digital converter (ADC) from IOCell3 configured as Sample & Hold.
4	21 22 23 24	O4P O4N I4N I4P	AMPOUTP AMPOUTN AMPINN AMPINP	Independent differential amplifier for customer circuits such as a Rauch output smoothing filter.
5	15 16	IO5P IO5N	bufinp(internal) bufinn(internal)	Internal connection of signal to IOCell3 buffer.
6	17 18	IO6P IO6N	OUTP OUTN	Unbuffered analog output.
7	19 20	IO7P IO7N	CLKOUT CLKOUTB	Reference clock outputs.
Digital	39 42	LCC_B MEMCLK	LCCb Internal use	Reserved for LCCb (done) signal and internal MEMCLK.

Analog Input

The analog input of the module is expected to be a differential input to INP and INN with signals centered at VMR (1.5V). Many analog signal sources create bipolar signals referenced to ground. These bipolar inputs can be easily converted to the required levels using a Rauch filter formed by the input amplifier and passive components as shown below. This structure can also be used to interface to differential signals that have a different common mode voltage.



Gain
G = R2 / R1

Low Pass Filter Cutoff Frequency
Fo = [1 / (2*π*R2)] * SQRT[(R1+R2) / (2*C1*C2*R1)]

Filter Quality Factor
Q = SQRT[(C1*R1) / (2*C2*(R1+R2))]

To determine component values for required values of gain, corner frequency and Q, first select a suitable value for R1 (e.g. 10kΩ) and then use the following equations to calculate the other component values:

R2 = R1*G
R3 = R1*G / (G+1)
C1 = Q*(G+1) / (2*π*G*Fo*R1)
C2 = 1 / (4*π*G*Fo*Q*R1)

Suggested component values for different filter frequencies are listed in the following table. These values are chosen to be ~2x the filter frequency to remove higher frequency content without significantly affecting signals up to the corner frequency. All capacitors should be COG/NPO type to minimize voltage and temperature dependence. Where gain accuracy is critical, matching resistor arrays may be used.

Recommended Rauch Component Values

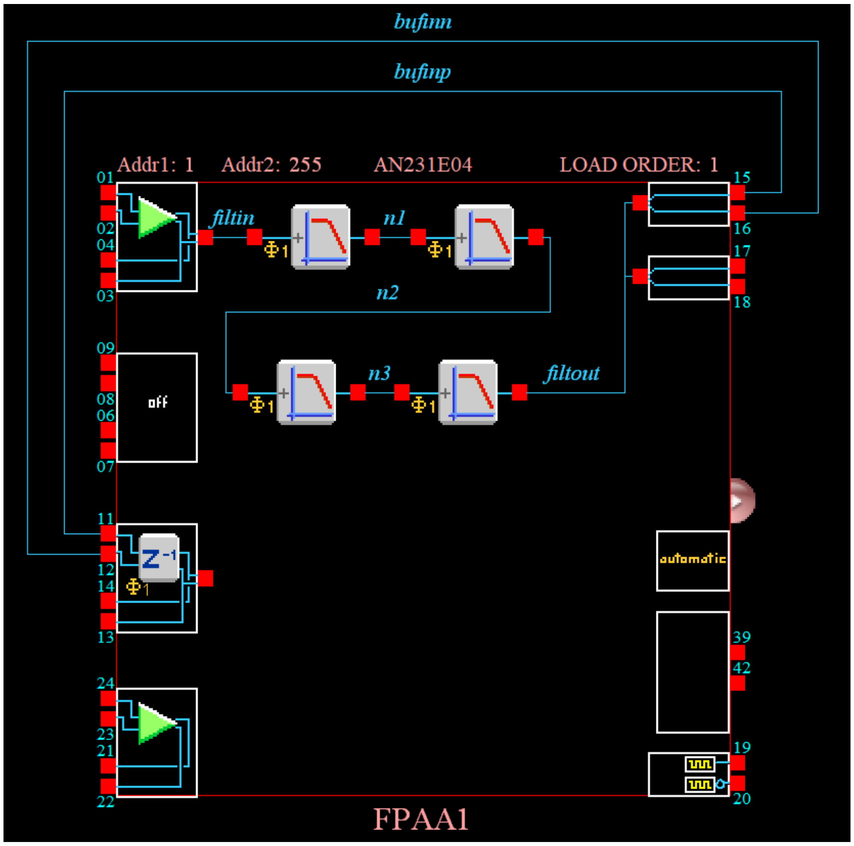
	10 Hz	100 Hz	1 kHz	10 kHz	22 kHz	100 kHz
R1	10K	10K	10K	10K	10K	10K
R2	10K	10K	10K	10K	10K	10K
R3	4.7K	4.7K	4.7K	4.7K	4.7K	4.7K
C1	1 uF	0.1 uF	10 nF	1nF	510 pF	100 pF
C2	0.47 uF	47 nF	4.7 nF	470 pF	270 pF	47 pF
F0	23 Hz	232 Hz	2.3 kHz	23 kHz	43 kHz	232 kHz
Q	0.729	0.729	0.729	0.729	0.687	0.729

Output Smoothing

Switched capacitor filters are discrete time filters and sample the state of inputs using an internal clock. This clock and an inverted version of the clock are provided as an output to the filter module so that it can be used to synchronize a subsequent ADC to the FPAA sample clock. Using this method, the clock-feedthrough inherent to switched capacitor circuits can be mitigated, improving dynamic range and reducing perceived noise.

If it is not practical to synchronize the downstream ADC to the FPAA reference clock, the stair-step output and clock-feedthrough pulses can be smoothed using a filter comprised of the module's independent amplifier (module pins 12, 13, 16, 17) and external passive components. The same Rauch filter structure recommended for conditioning the input can be used to smooth the output.

FPAA Circuit Configuration



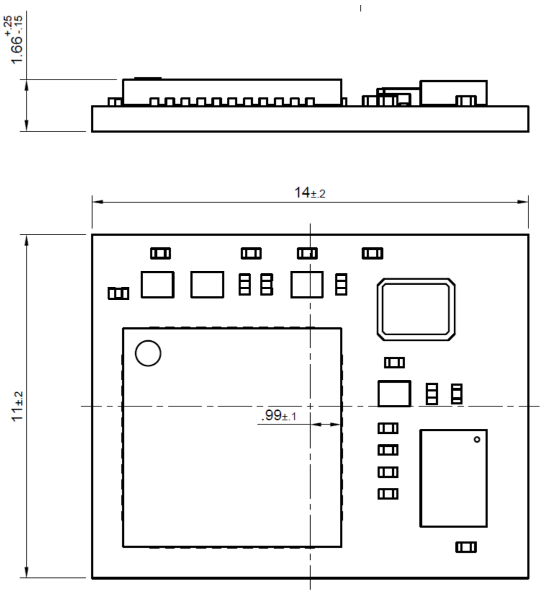
SPI Interface and Product ID

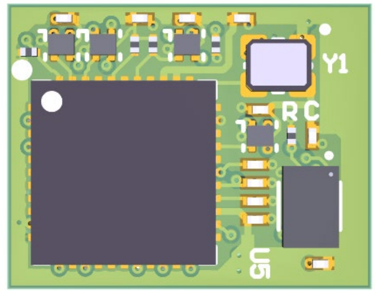
Chameleon fixed function modules are designed to operate without any external programming interface. However, the SPI programming interface remains available and can be used to verify that the module product ID matches the expected part number and revision. The last 16 bytes of the configuration EEPROM are reserved for the product ID, revision and date code as shown below.

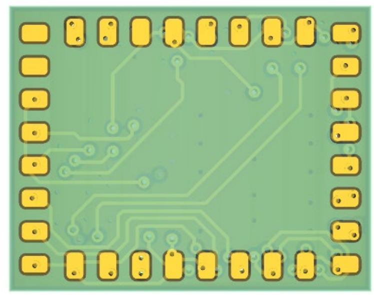
Bytes	Description	Format	Example
1-8	Part Number	OTC93xxL	OTC9310L
9-10	Revision	NN	01
11-16	Date	YYMMDD	260120

To provide access to the programming EEPROM, drive the EXT_SEL pin high. This enables access to the M95080-R EEPROM through the EXT_CSB, EXT_SCK, EXT_MOSI, and EXT_MISO pins. For read-only access, EXT_WB should be driven low or left disconnected to allow the internal pulldown to pull it low. Refer to the M95080-R datasheet for SPI EEPROM timing parameters.

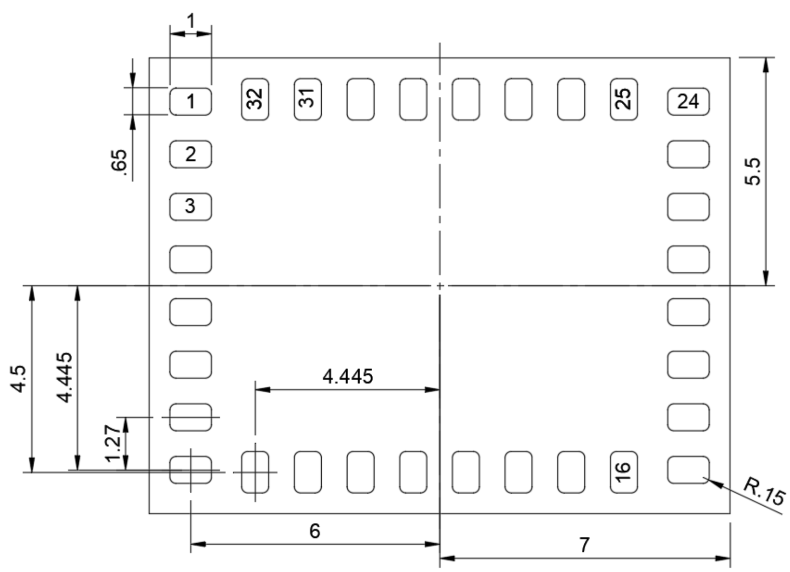
Package Drawing







PCB Footprint (Top View)



All dimensions are in mm

Power Supply Decoupling

Power supply decoupling capacitors are included within the module. A single external 0.1uF decoupling capacitor between pins 6 and 7 of the module is sufficient. Additional capacitors between pins 14 and 15, and between pins 25 and 26 are optional.

Moisture Sensitivity

Dry pack handling is recommended. The packages in the module are qualified to MSL3 (JEDEC Standard, J-STD-020A, Level 3). Once the device is removed from dry pack, 30°C at 60% humidity for not longer than 168 hours is the maximum recommended exposure prior to solder reflow. If out of dry pack for longer than this, the recommended bake out procedure prior to solder reflow is 24 hours at 125°C.

Related Parts

OTC9300L	Chameleon™ Programmable FPAA Module
OTC9300L Prog	Chameleon™ Programming and Test Fixture
AN231E04	FlexAnalog™ FPAA Integrated Circuit 400 kHz
AN241E04	FlexAnalog™ FPAA Integrated Circuit 1.2 MHz
OTC9301L	60 Hz Notch filter
OTC9302L	50 Hz Notch filter
OTC9320L	Dual 10 Hz 4th order lowpass filter
OTC9321L	Dual 100 Hz 4th order lowpass filter
OTC9322L	Dual 1 kHz 4th order lowpass filter
OTC9324L	Dual 10 kHz 4th order lowpass filter
OTC9326L	Dual 22 kHz 4th order lowpass filter
OTC9328L	Dual 100 kHz 4th order lowpass filter
OTC9332L	0.5 Hz highpass filter
OTC9334L	1 Hz highpass, 100 Hz lowpass
OTC9336L	10 Hz highpass, 500 Hz lowpass
OTC9338L	80 Hz highpass filter

Revision History

Date	Description
2/23/2026	Initial Release