FREQUENCY DEVICES™, INC.

818 Series

1 kHz to 1.28 MHz 8-Bit Programmable

2" x 4" 8-Pole Filters

Description

The 818 Series are digitally programmable low-pass and high-pass active filters that are tunable over a 256:1 frequency range. 818 filters are available with any one of five standard factory-set tuning ranges or 8-bit custom ranges from 1 kHz to 1.28 MHz. These units contain 8 CMOS logic inputs.

818 Series models are convenient, low profile, easy to use fully finished filters which require no external components or adjustments. They feature low harmonic distortion, and near theoretical amplitude characteristics. 818 filters operate from non-critical ±12 to ±18 Vdc power supplies, have a 5 kΩ (min.) input impedance, a 10Ω (max.) output impedance and low-pass models offer dc voltage offset adjustment.

Features/Benefits:

- Low harmonic distortion and wide signal-to-noise ratio to 12-bit resolution
- Digitally programmable corner frequency allows selecting cut-off frequencies specific to each application
- Plug-in ready-to-use, reducing engineering design and manufacturing cycle time
- Factory-set tuning range, no external clocks or adjustments needed
- Broad range of transfer characteristics and corner frequencies to meet a wide range of applications

Applications

- Anti-alias and band-pass filtering
- Data acquisition systems
- Satellite and telecommunications
- Acoustic and vibration analysis and control
- Aerospace, navigation and sonar
- Medical research and electronic equipment
- Engine test and simulation
- Noise elimination
- Video systems
- Signal reconstruction

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Digital Tuning Characteristics

The digital tuning interface circuits are two 4042 quad CMOS latches which accept the following CMOS-compatible inputs: eight tuning bits (D_0 - D_7), a latch strobe bit (C), and a transition polarity bit (P).

Filter tuning follows the tuning equation given below:

$$f_c = (f_{max}/256) [1 + D_7 \times 2^7 + D_6 \times 2^6 + D_5 \times 2^5 + D_4 \times 2^4 + D_3 \times 2^3 + D_2 \times 2^2 + D_1 \times 2^1 + D_0 \times 2^0]$$

where D_1 - D_7 = "0" or "1", and
f_{max} = Maximum tuning frequency;
f_c = corner frequency;
Minimum tunable frequency = $f_{max}/256$ (D_0 thru D_7 = 0);
Minimum frequency step (Resolution) = $f_{max}/256$

Data Control Specifications

Data Control Lines

Functions	Latch Strobe (C)
	Transition Polarity (P)

Data Control Modes

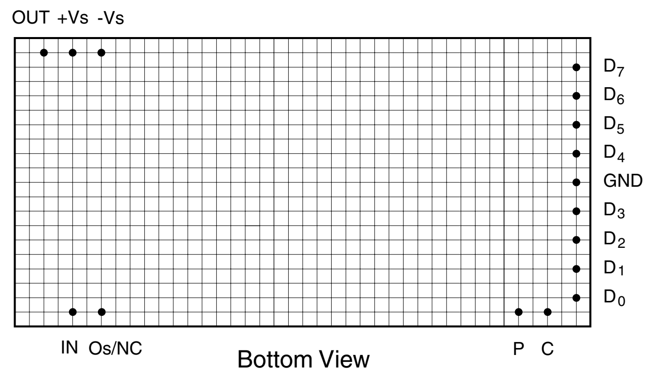
Mode 1	P = 0; C = 0	frequency follows input codes
	P = 0; C = 0⇑	frequency latched on rising edge
Mode 2	P = 1; C = 1	frequency follows input codes
	P = 1; C = 1⇓	frequency latched on falling edge

Input Data Levels	**(CMOS Logic)**	
Input Voltage (Vs = 15 Vdc)		
Low Level In	0 Vdc min.	4 Vdc max.
High Level In	11 Vdc min.	15 Vdc max.
Input Current		
High Level In	- 10^{-5} µA typ.	-1 mA max.
Low Level In	+10^{-5} µA typ.	+1 µA max.
Input Capacitance	5 pF typ	7.5 pF max.
Latch Response		
Data Set Up Time[1]	25 nS	
Data Hold Time[2]	50 nS	
Strobe Pulse Width	80 nS min.	
Input Data Format	**Frequency Select Bits**	
Positive Logic	Logic "1" = +Vs	
	Logic "0" = Gnd	
Bit Weighting	(Binary-Coded)	
D_0	LSB (least significant bit)	
D_7	MSB (most significant bit)	
Frequency Range	256 : 1, Binary Weighted	

Notes:
1.Frequency data must be present before occurrence of strobe edge.
2.Frequency data must be present after occurrence of strobe edge.

Pin-Out Key

IN	Analog Input Signal	D_7 Tuning Bit 7 (MSB)
OUT	Analog Output Signal	D_6 Tuning Bit 6
GND	Power and Signal Return	D_5 Tuning Bit 5
"P"	Transition Polarity Bit	D_4 Tuning Bit 4
"C"	Tuning Strobe Bit	D_3 Tuning Bit 3
+Vs	Supply Voltage, Positive	D_2 Tuning Bit 2
-Vs	Supply Voltage, Negative	D_1 Tuning Bit 1
Os	Optional Offset Adjustment	D_0 Tuning Bit 0 (LSB)
NC	No Connect (Highpass Models)	



Bottom View

MSB	---	---	---	---	---	---	LSB	Bit Weight
2^7 D_7	2^6 D_6	2^5 D_5	2^4 D_4	2^3 D_3	2^2 D_2	2^1 D_1	2^0 D_0	fc Corner Frequency
0	0	0	0	0	0	0	0	$f_{max}/256$
0	0	0	0	0	0	0	1	$f_{max}/128$
0	0	0	0	0	0	1	1	$f_{max}/64$
0	0	0	0	0	1	1	1	$f_{max}/32$
0	0	0	0	1	1	1	1	$f_{max}/16$
0	0	0	1	1	1	1	1	$f_{max}/8$
0	0	1	1	1	1	1	1	$f_{max}/4$
0	1	1	1	1	1	1	1	$f_{max}/2$
1	1	1	1	1	1	1	1	fmax

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8-Bit Programmable

8-Pole Low-Pass Filters

Model	818L8B	818L8L	818L8E	818L8D80
Product Specifications				
Transfer Function	8-Pole, Butterworth	8-Pole, Bessel	8-Pole, 6 zero, Elliptic	8-Pole, 6 zero, Constant Delay
Size	2.0" x 4.0" x 0.4"	2.0" x 4.0" x 0.4"	2.0" x 4.0" x 0.4"	2.0" x 4.0" x 0.4"
Range f_c	1 kHz to 128 MHz	1 kHz to 1.28 MHz	1 kHz to 1.28 MHz	1 kHz to 1.28 MHz
Theoretical Transfer Characteristics	Appendix A Page 9	Appendix A Page 4	Appendix A Page 24	Appendix A Page 21
Passband Ripple (theoretical)	0.0 dB	0.0 dB	± 0.035 dB	0.15 dB
DC Voltage Gain (non-inverting)	0 ± 0.1 dB max. 0 ± 0.05 dB typ.	0 ± 0.1 dB max. 0 ± 0.05 dB typ.	0 ± 0.1 dB max. 0 ± 0.05 dB typ.	0 ± 0.1 dB max. 0 ± 0.05 dB typ.
Stopband Attenuation Rate	48 dB/octave	48 dB/octave	80 dB min.	80 dB min.
Cutoff Frequency	f_c ± 3% max.	f_c ± 3% max.	f_r ± 3% max.	f_c ± 3% max.
Stability	± 0.01% /°C	± 0.01% /°C	± 0.01% /°C	± 0.01% /°C
Amplitude	- 3 dB	- 3 dB	- 0.035 dB	- 3 dB
Phase	-360°	-182°	- 323.5°	-306°
Filter Attenuation (theoretical)	0.12 dB 0.80 f_c 3.01 dB 1.00 f_c 60.0 dB 2.37 f_c 80.0 dB 3.16 f_c	1.91 dB 0.80 f_c 3.01 dB 1.00 f_c 60.0 dB 4.52 f_c 80.0 dB 6.07 f_c	0.035 dB 1.00 f_r 3.01 dB 1.13 f_r 60.0 dB 1.67 f_r 80.0 dB 1.77 f_r	3.01 dB 1.00 f_c 60.0 dB 3.08 f_c 80.0 dB 3.57 f_c
Phase Match[1]	See page 5 & 6	See page 5 & 6	See page 5 & 6	See page 5 & 6
Amplitude Accuracy (theoretical)	0 - 0.6 f_c ± 0.5 dB max. ± 0.25 dB typ. 0.6 f_c - 1.0 f_c ± 1.0 dB max. ± 0.6 dB typ.	0 - f_c ± 0.8 dB max. ± 0.4 dB typ.	0 - 0.8 f_r ± 0.5 dB max. ± 0.25 dB typ. 0.8 f_c - 1.0 f_r ± 1.0 dB max. ± 0.5 dB typ.	0 - 0.8 f_c ± 0.5 dB max. ± 0.25 dB typ. 0.8 f_c - 1.0 f_c ± 1.0 dB max. ± 0.5 dB typ.
Total Harmonic Distortion @ 1 kHz	< - 88 dB typ.	< - 88 dB typ.	< - 88 dB typ.	< - 88 dB typ.
Wide Band Noise (5 Hz - 2 MHz)	300 µVrms typ.	300 µVrms typ.	350 µVrms typ.	300 µVrms typ.
Narrow Band Noise (5 Hz - 100 kHz)	75 µVrms typ.	75 µVrms typ.	75 µVrms typ.	75 µVrms typ.
Filter Mounting Assembly	FMA-04A	FMA-04A	FMA-04A	FMA-04A

1.Unit to unit match for the same transfer function, set to the same frequency and operating configuration, and from the same manufacturing lot.

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8-Bit Programmable

8-Pole High-Pass Filters

Model	818H8B	818H8E		
Product Specifications				
Transfer Function	8-Pole, Butterworth	8-Pole, 6-zero, Elliptic		
Size	2.0" x 4.0" x 0.4"	2.0" x 4.0" x 0.4"		
Range fc	1 kHz to 1.28 MHz	1 kHz to 1.28 MHz		
Theoretical Transfer Characteristics	Appendix A Page 29	Appendix A Page 37		
Passband Ripple (theoretical)	0.0 dB	± 0.035 dB		
Voltage Gain (non-inverting)	0 ± 0.5 dB to 1.28 MHz	0 ± 0.5 dB to 1.28 MHz		
Power Bandwidth	(-6 dB) 5 MHz	(-6 dB) 5 MHz		
Stopband Attenuation Rate	48 dB/octave	80 dB		
Cutoff Frequency	fc ± 3% max.	fr ± 3% max.		
Stability	± 0.01% /°C	± 0.01% /°C		
Amplitude	- 3 dB	- 0.035 dB		
Phase	-360°	-323.5°		
Filter Attenuation (theoretical)	80 dB 0.31 fc 60 dB 0.42 fc 3.01 dB 1.00 fc 0.00 dB 2.00 fc	80.0 dB 0.56 fr 60.0 dB 0.60 fr 3.01 dB 0.88 fr 0.03 dB 1.00 fr 00.0 dB 2.00 fr		
Amplitude Accuracy (theoretical)	1.0 - 1.25 fc ± 0.5 dB max. ± 0.3 dB typ. 1.25fc-1.28MHz± 1.0 dB max. ± 0.5 dB typ.	1.00 - 1.25 fr ± 0.5 dB max. ± 0.3 dB typ. 1.25fr-1.28MHz± 1.0 dB max. ± 0.5 dB typ.		
Total Harmonic Distortion @ 1 kHz	< - 88 dB typ.	< - 88 dB typ.		
Wide Band Noise	400 µVrms typ.	450 µVrms typ.		
Narrow Band Noise	100 µVrms typ.	100 µVrms typ.		
Filter Mounting Assembly	FMA-04A	FMA-04A		

1.Unit to unit match for the same transfer function, set to the same frequency and operating configuration, and from the same manufacturing lot.

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Phase and Phases Match Considerations

1 kHz to 1.28 MHz

Phase Deviation from Theoretical:

The phase response of the amplifiers and the capacitance of the frequency control switches of the 818 series contribute to the overall phase response and cause it to deviate from theoretical. For the higher frequency models (-4 and -5), where the cutoff frequencies can be programmed up to 1.28MHz, the deviation from theoretical can be substantial.

Figure 1 is a normalized plot of the phase deviation from theoretical for an 818L8E-5 for programmed cutoff frequencies from 5kHz (fc min) to 1.28MHz (fc max). For fc of 5kHz, the deviation from the 323° theoretical phase shift is 2° but for fc of 1.28MHz the deviation is 78°. This set of curves can be used to estimate the deviation from theoretical phase for other models in the 818 series.

Figure 1 represents a "maximum deviation from theoretical phase" situation. Other models (i.e. -1 to -4) will exhibit a similar set of phase deviation curves with the phase scale being reduced by the ratio of the f max of the model to the f max of the -5. For example, an L8E-1, whose programming frequency range is from 1kHz to 256kHz (1/5 of the range of the -5 model) will have a similar set of phase deviation curves but the maximum phase deviation, at the highest frequency setting (fc max), will be approximately 1/5 that of the -5 model (78/5 = 15.6°). The other programmed settings of the -1 will also produce proportionally reduced phase deviations.

Unit to Unit Phase Match[2]

The actual phase shift through a filter at a frequency " f " is determined by its programmed frequency " fc ", the theoretical phase response of the transfer function (B, L, E, or D80) and the phase deviation from theoretical which in turn depends upon component tolerances, the model # (i.e. -1 through -5) and frequency to which it is programmed. It is therefore not possible to have a meaningful unit to unit phase match that is specified by a single number.

For a group of the same model type and number, programmed to the same frequency, the unit to unit phase match can be approximated as a percentage of the theoretical phase shift with a correction term added to accommodate amplifier induced phase deviations.

EXAMPLE: Phase Match Calculation

$\Delta\Phi(f)max = 0.02° \times \Phi\tau(f) + \underline{4.0°} \times f/fc \times fmax/1.28MHz$

4.0° - L8L
3.0° - L8B & L8D80
2.0° - L8L

$\Delta\Phi(f)typ = 0.5 \times \Delta\Phi(f)max$

where:
- $\Delta\Phi(f)$ = phase match at frequency f
- $\Phi\tau$ (f) = theoretical phase shift at f
- f = frequency of interest
- f max = maximum fc of the model
- fc = frequency to which the filter is programmed

Eg. - for an 818L8E-3, the phase deviation from theoretical at a frequency of 192kHz, when the cutoff frequency fc is programmed to 384kHz is:

f/fc = 192kHz/384kHz = 0.5, fmax = 768kHz
$\Phi\tau(f)$ = 133° (from data table at f/fc = 0.5)

Phase Match:

$\Delta\Phi(f)max = 0.02° \times \Phi\tau(f) + 4.0° \times f/fc \times fmax/1.28MHz$
$= 0.02 \times (-133°) + 4.0° \times 0.5 \times 768kHz/1.28MHz$
$= 2.66° + 1.20° = +3.86°$

$\Delta\Phi(f)typ = 0.5 \times \Delta\Phi(f)max = 0.5° \times 3.86° = 1.93°$

818L8E Phase Deviation (in degrees "°") from Theoretical vs. Normalized Input Frequency

programmed setting of fc

f/fc	5kHz	10kHz	20kHz	40kHz	80kHz	160kHz	320kHz	640kHz	1.28MHz
0.10	0.15	0.18	0.17	0.08	-0.12	-0.52	-1.18	-2.57	-5.32
0.20	0.30	0.32	0.30	0.17	-0.39	-1.03	-2.41	-5.17	-10.76
0.30	0.34	0.42	0.40	-0.18	-0.57	-1.59	-3.66	-7.89	-16.29
0.40	0.20	0.40	0.50	-0.20	-0.90	-2.30	-5.10	-10.80	-22.10
0.50	0.20	0.32	0.60	-0.40	-1.20	-3.00	-6.70	-14.00	-28.20
0.60	0.00	0.00	-0.10	-0.80	-1.90	-4.10	-8.70	-17.70	-35.10
0.70	-0.21	-0.30	-0.60	-1.30	-2.70	-5.40	-11.00	-21.80	-42.60
0.80	-0.50	-0.60	-1.30	-2.10	-3.80	-7.20	-13.90	-26.90	-51.30
0.85	-0.80	-1.00	-1.80	-2.80	-4.70	-8.40	-15.80	-30.10	-56.40
0.90	-1.20	-1.60	-2.50	-3.70	-5.80	-10.00	-18.40	-33.80	-62.30
0.95	-1.90	-2.40	-3.50	-4.80	-7.30	-12.00	-21.10	-38.30	-69.20
1.00	-2.50	-3.30	-4.60	-6.20	-8.90	-14.10	-24.30	-43.30	-77.50

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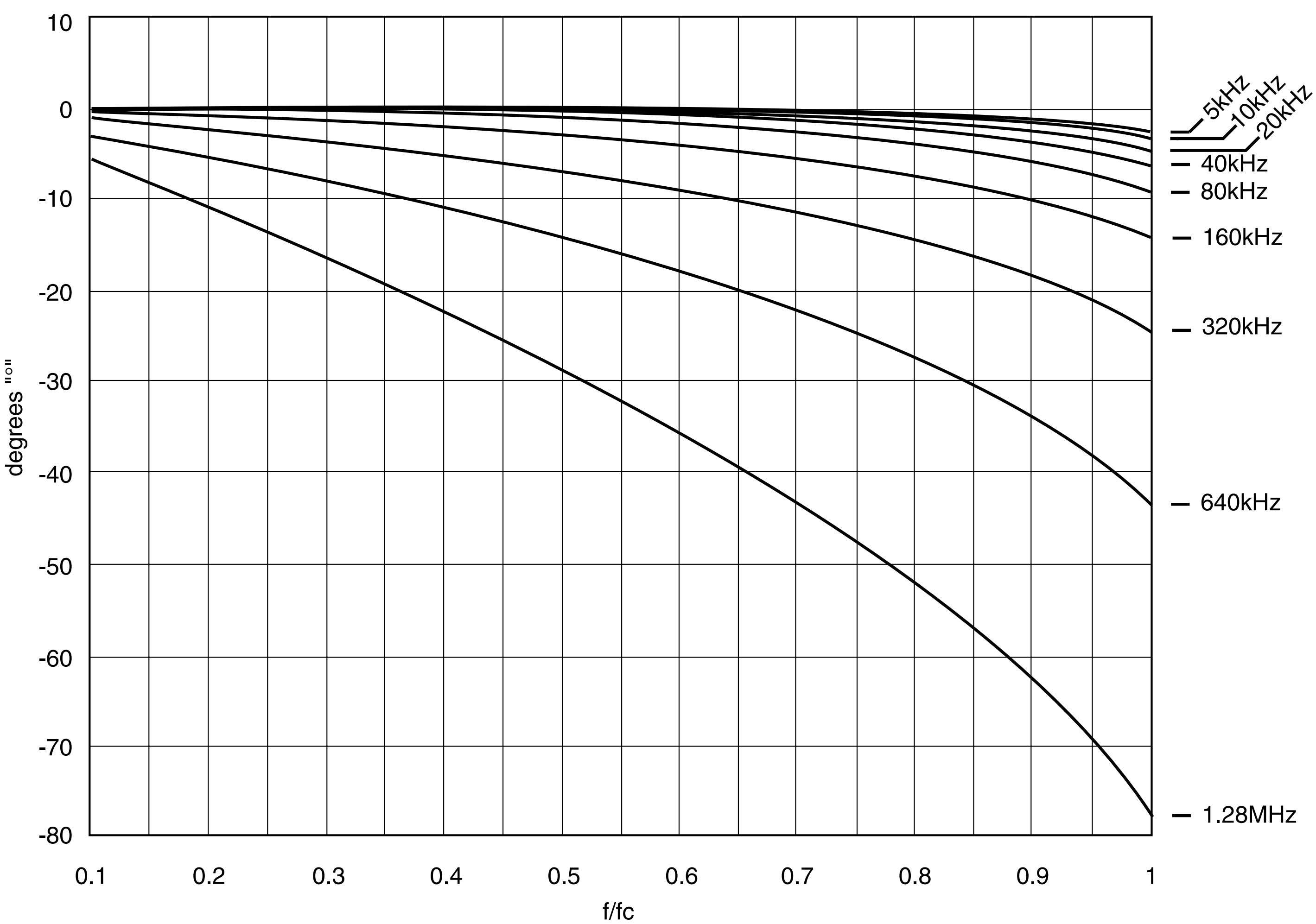
Phase Deviation from Theoretical



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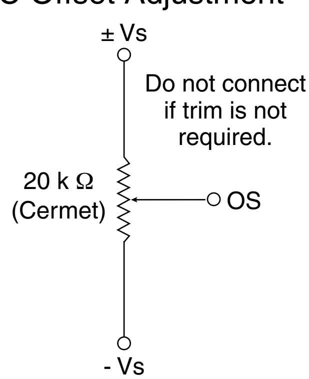
Specification
(25°C and Vs ± 15 Vdc)

Pin-Out and Package Data
Ordering Information

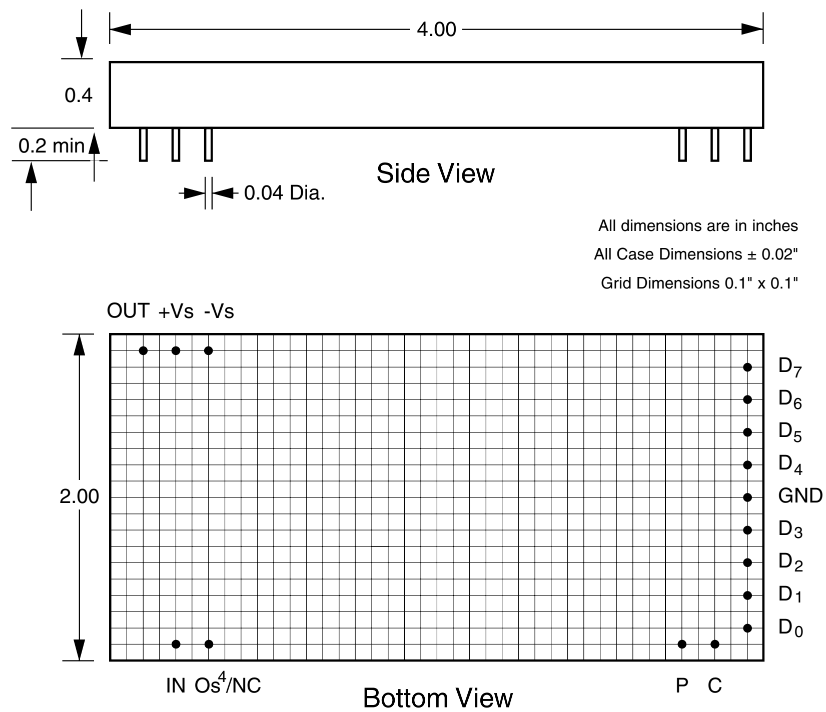
Analog Input Characteristics[1]	
Impedance	5 k Ω min.
Voltage Range	± 10 Vpeak
Max. Safe Voltage	±Vs
Analog Output Characteristics	
Impedance (Closed Loop)	1 Ω typ.
	10 Ω max.
Linear Operating Range	±10V
Maximum Current[2]	±5 mA
Offset Voltage[3]	2 mV typ.
	10 mV max.
Offset Temp. Coeff.	50 μV/°C
Power Supply (±V_S)	
Rated Voltage	±15 Vdc
Operating Range	±12 to ±18 Vdc
Maximum Safe Voltage	±18 Vdc
Quiescent Current	100 mA typ.
	120 mA max.
Temperature	
Operating	0 to +70°C
Storage	-25 to +85°C

Notes:
1. Input and output signal voltage referenced to supply common.
2. Output is short circuit protected to common. DO NOT CONNECT TO ±Vs.
3. Adjustable to zero.
4. Units operate with or without offset pin connected.

DC Offset Adjustment



Pin-Out & Package Data



Filter Mounting Assembly-See FMA-04A

Ordering Information

Filter Type
- **L** - Low Pass
- **H** - High Pass

Transfer Function
- **B** - Butterworth
- **L** - Bessel
- **E** - elliptic
- **D80** - constant delay

818L8E-5

Model Number	Tuning Range (kHz)	Minimum Step (kHz)
1	1kHz to 256kHz	1kHz
2	2kHz to 512kHz	2kHz
3	3kHz to 768kHz	3kHz
4	4kHz to 1,024kHz	4kHz
5	5kHz to 1,280kHz	5kHz

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Programmable Filter Modules Power Sequence & ESD

November 2000

Programmable Filters Modules

818, 824, 828, 828BP, 828BR, 854, 858, R854, R858

I. Scope

The following precautions are necessary when handling and installing Frequency Devices programmable filter modules.

II. Digital Circuit Description

The digital input pins connect directly to 4000 series CMOS logic, such as the 4053 analog switch. The power supply (Vss) for the digital logic on the module comes directly from the +15 Volt pin on the module. This sets the threshold voltage at 11.0 V minimum to 15.0 V maximum for a "1" (High) level and 0.0 V minimum to 4.0 V maximum for a "0" (Low) level. Applying a voltage between 4.0 and 11.0 V will produce unpredictable operation. Connecting 5 Volt or 3.3 V logic devices directly to the filter module without using a voltage translator will result in erratic operation of the filter.

III. (VERY IMPORTANT) Power-Up and Power-Down Sequence

Do not plug-in or un-plug module while power is applied. It is imperative that power is supplied to the + 15 V pin on the filter module before or at the same instance that any digital pin is pulled High (> 0.0 V). Failure to do this will result in excessive current flowing through the digital input pin and through a protection diode internal to the 4000 logic, which will result in damage to the module. The proper power-up and power-down sequence is:

1. Connect filter module ground.
2. Connect filter module +15 V.
3. Connect filter module -15 V.
4. Connect the input signal.

All four of the above steps can also occur simultaneously. Power-down should occur in the reverse order.

IV. ESD Issues

Like most modern electronic equipment, the modules can be damaged by electrostatic discharge (ESD). The modules are shipped from the factory in sealed, anti-static packaging and should be kept in the sealed package prior to mounting on a circuit board. The following additional rules should also be observed when handling the modules after they are removed from the factory packaging:

1. Only a person wearing a properly grounded wrist strap should handle the modules.
2. Any work surface that the modules are placed on must be properly ESD grounded.
3. Any insulating materials capable of generating static charge (such as paper) should be kept away from the modules.

Static generating clothing should be covered with an ESD-protective smock.

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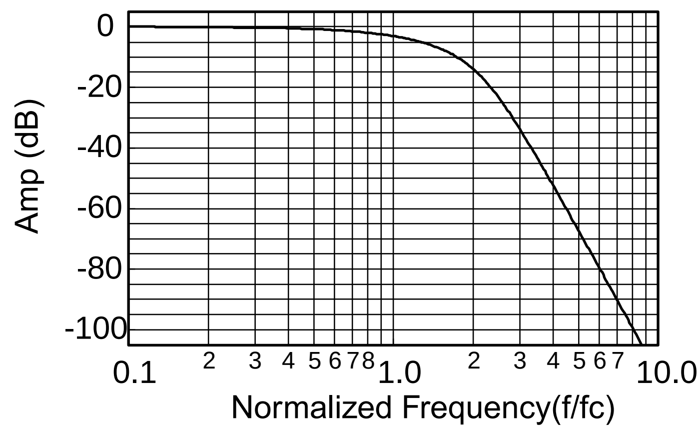
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	.506
0.10	-0.029	-18.2	.506
0.20	-0.117	-36.4	.506
0.30	-0.264	-54.7	.506
0.40	-0.470	-72.9	.506
0.50	-0.737	-91.1	.506
0.60	-1.06	-109	.506
0.70	-1.45	-128	.506
0.80	-1.91	-146	.506
0.85	-2.16	-155	.506
0.90	-2.42	-164	.506
0.95	-2.71	-173	.506
1.00	-3.01	-182	.506
1.10	-3.67	-200	.506
1.20	-4.40	-219	.506
1.30	-5.20	-237	.506
1.40	-6.10	-255	.505
1.50	-7.08	-273	.504
1.60	-8.16	-291	.502
1.70	-9.36	-309	.498
1.80	-10.7	-327	.492
1.90	-12.1	-345	.482
2.00	-13.7	-362	.468
2.25	-18.1	-402	.417
2.50	-23.1	-436	.352
2.75	-28.3	-465	.291
3.00	-33.4	-489	.241
3.25	-38.3	-509	.201
3.50	-43.1	-526	.170
4.00	-51.8	-552	.126
5.00	-66.8	-587	.077
6.00	-79.2	-610	.052
7.00	-89.8	-626	.038
8.00	-99.0	-638	.029
9.00	-107	-647	.023
10.0	-114	-655	.018

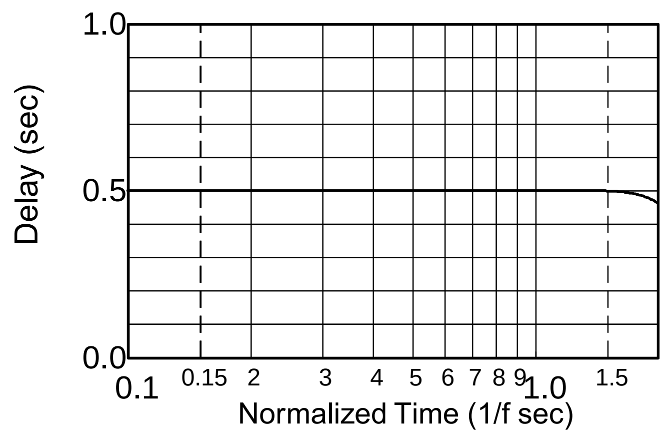
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz. The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

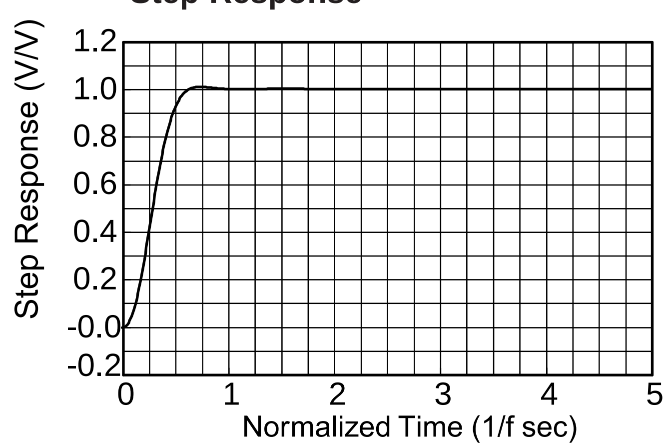
Frequency Response



Delay (Normalized)



Step Response



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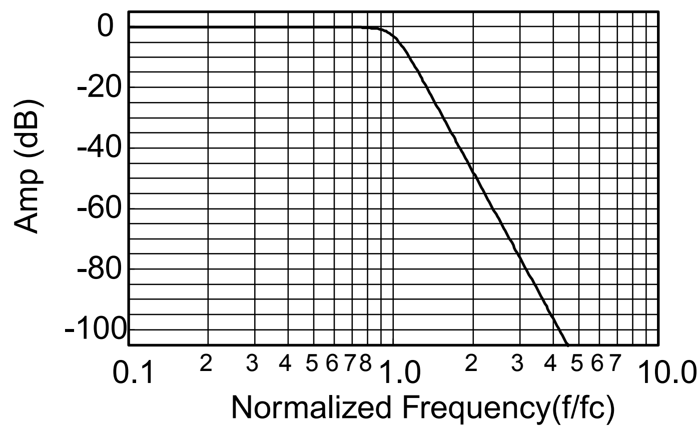
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	.816
0.10	0.00	-29.4	.819
0.20	0.00	-59.0	.828
0.30	0.00	-89.1	.843
0.40	0.00	-120	.867
0.50	0.00	-152	.903
0.60	-0.001	-185	.956
0.70	-0.014	-221	1.04
0.80	-0.121	-261	1.19
0.85	-0.311	-283	1.29
0.90	-0.738	-307	1.40
0.95	-1.58	-333	1.48
1.00	-3.01	-360	1.46
1.10	-7.48	-408	1.17
1.20	-12.9	-445	.873
1.30	-18.2	-472	.672
1.40	-23.4	-494	.540
1.50	-28.2	-511	.448
1.60	-32.7	-526	.380
1.70	-36.9	-539	.328
1.80	-40.8	-550	.287
1.90	-44.6	-560	.253
2.00	-48.2	-568	.226
2.25	-56.3	-586	.174
2.50	-63.7	-600	.139
2.75	-70.3	-611	.113
3.00	-76.3	-621	.094
3.25	-81.9	-629	.080
3.50	-87.1	-635	.069
4.00	-96.3	-646	.052
5.00	-112	-661	.033
6.00	-125	-671	.023
7.00	-135	-678	.017
8.00	-144	-683	.013
9.00	-153	-687	.010
10.0	-160	-691	.008

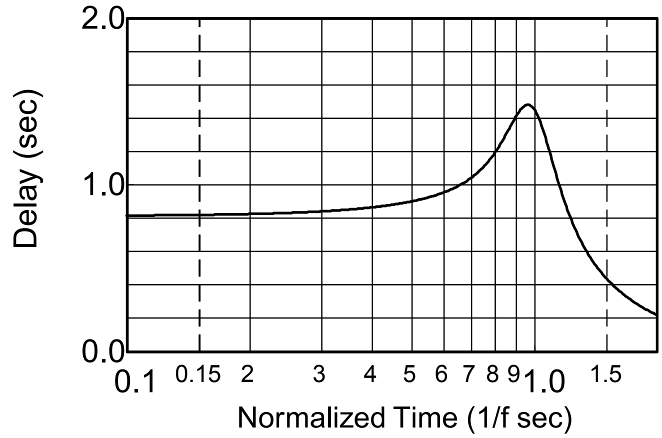
1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

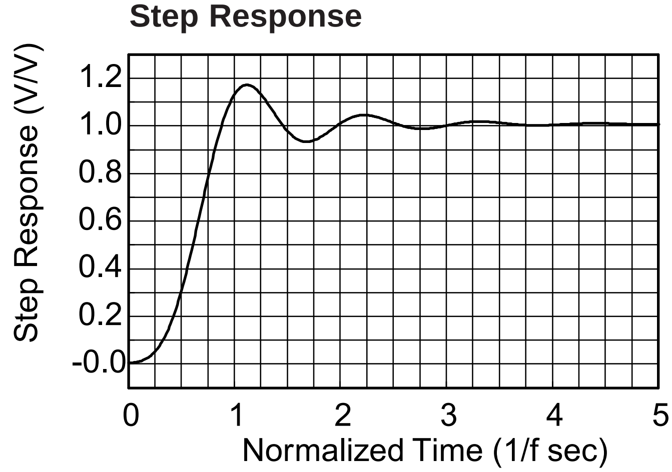
Frequency Response



Delay (Normalized)



Step Response



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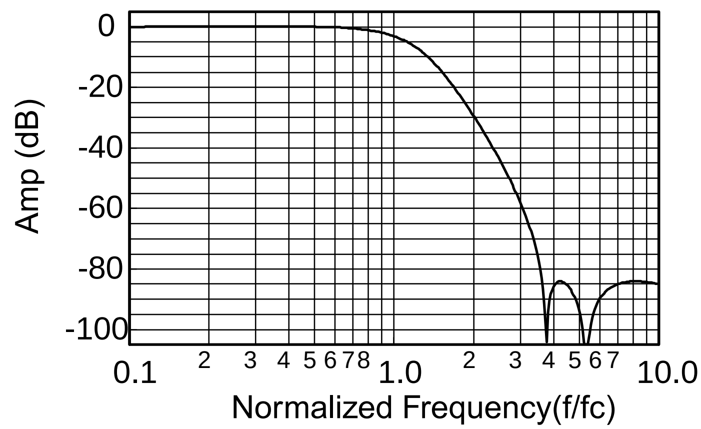
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	.852
0.10	0.017	-30.7	.852
0.20	0.058	-61.3	.852
0.30	0.099	-92.0	.852
0.40	0.105	-123	.852
0.50	0.034	-153	.852
0.60	-0.157	-184	.852
0.70	-0.510	-215	.852
0.80	-1.07	-245	.851
0.85	-1.44	-261	.850
0.90	-1.89	-276	.849
0.95	-2.41	-291	.846
1.00	-3.01	-306	.841
1.10	-4.50	-336	.821
1.20	-6.39	-365	.783
1.40	-11.3	-417	.656
1.60	-17.1	-459	.512
1.80	-23.2	-492	.396
2.00	-29.1	-517	.312
2.25	-36.3	-542	.239
2.50	-43.4	-561	.189
2.75	-50.3	-576	.153
3.00	-57.6	-589	.127
3.25	-62.5	-599	.107
3.50	-75.4	-608	.092
3.75	-98.3	-616	.079
4.00	-86.3	-442	.069
4.25	-84.1	-448	.061
4.50	-85.1	-454	.054
4.75	-87.9	-458	.049
5.00	-92.8	-462	.044
5.25	-104	-466	.040
5.50	-101	-289	.036
5.75	-93.3	-293	.033
6.00	-89.9	-295	.030
6.50	-86.6	-300	.026
7.00	-85.1	-305	.022
8.00	-84.1	-312	.017
9.00	-84.3	-317	.013
10.0	-84.9	-321	.011

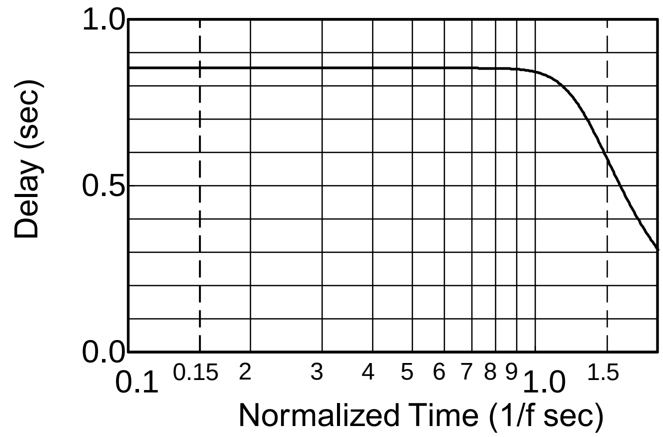
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz. The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

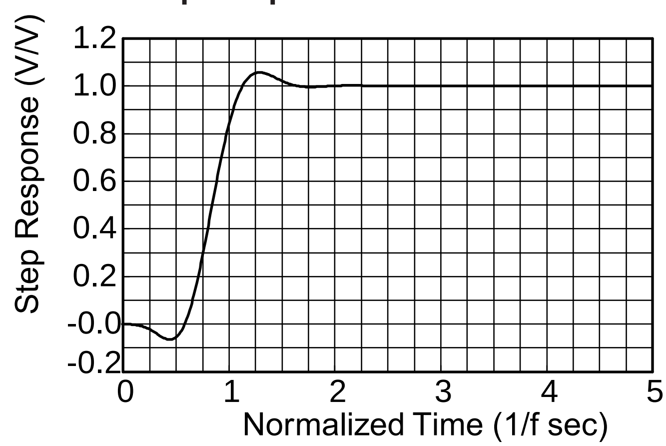
Frequency Response



Delay (Normalized)



Step Response



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8-Pole, 6-Zero

Elliptic, 1.77

Low-Pass

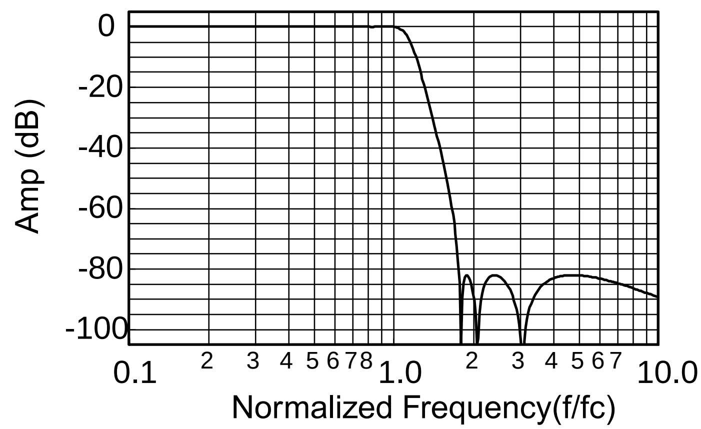
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	0.713
0.10	-0.004	-25.7	0.716
0.20	-0.014	-51.6	0.724
0.30	-0.024	-77.9	0.740
0.40	-0.020	-105	0.767
0.50	0.007	-133	0.811
0.55	0.022	-148	0.840
0.60	0.033	-163	0.872
0.65	0.031	-179	0.908
0.70	0.014	-196	0.946
0.75	-0.015	-213	0.989
0.80	-0.041	-232	1.04
0.85	-0.046	-251	1.12
0.90	-0.016	-272	1.23
0.95	-0.025	-296	1.40
1.00	-0.035	-323	1.65
1.10	-1.76	-392	2.14
1.20	-8.28	-467	1.86
1.30	-18.4	-522	1.19
1.40	-29.3	-558	0.753
1.50	-40.1	-578	0.517
1.60	-51.5	-594	0.381
1.70	-65.2	-606	0.296
1.75	-75.0	-611	0.265
1.80	-113.0	-616	0.239
1.85	-83.6	-440	0.217
1.90	-82.0	-444	0.198
1.95	-83.7	-447	0.182
2.00	-87.8	-450	0.168
2.20	-85.8	-280	0.126
2.40	-82.0	-289	0.099
2.60	-83.5	-295	0.081
2.80	-88.2	-301	0.067
3.00	-99.9	-305	0.057
3.50	-87.2	-134	0.040
4.00	-83.1	-140	0.030
5.00	-82.1	-148	0.018
6.00	-83.1	-154	0.013
7.00	-84.6	-157	0.009
8.00	-86.2	-160	0.007
9.00	-87.8	-163	0.005
10.0	-89.3	-164	0.004

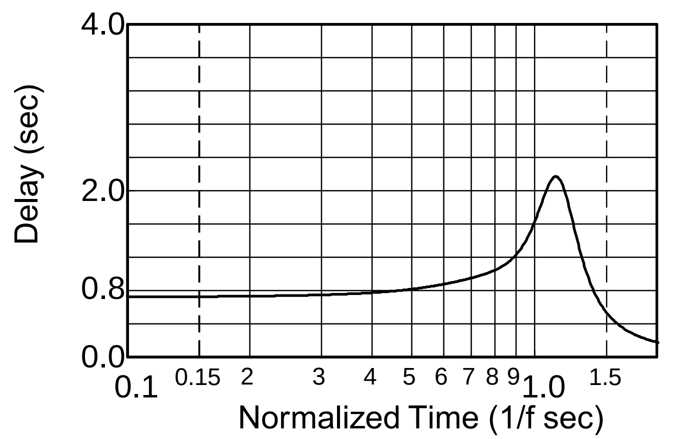
1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

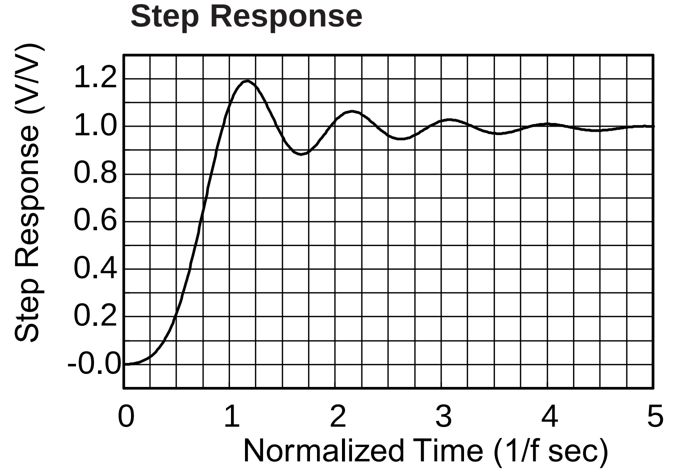
Frequency Response



Delay (Normalized)



Step Response



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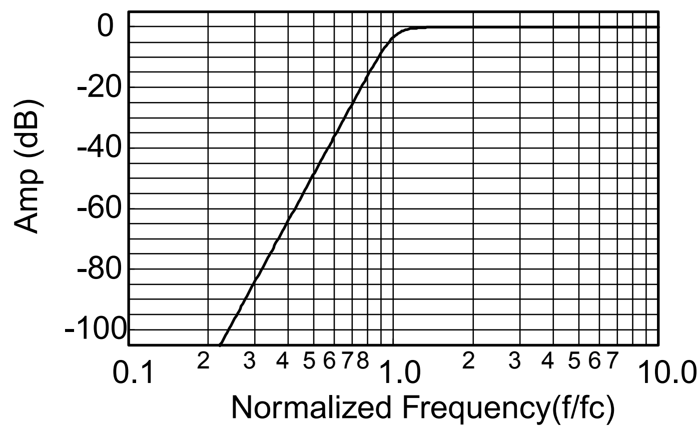
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.10	-160	691	0.819
0.20	-112	661	0.828
0.30	-83.7	631	0.843
0.40	-63.7	600	0.867
0.50	-48.2	568	0.903
0.60	-35.5	535	.956
0.70	-24.8	499	1.04
0.80	-15.6	459	1.19
0.85	-11.6	437	1.29
0.90	-8.06	413	1.40
0.95	-5.15	386	1.48
1.00	-3.01	360	1.46
1.20	-0.229	275	0.873
1.40	-0.020	226	0.540
1.60	-0.002	194	0.380
1.80	0.00	170	0.287
2.00	0.00	152	0.226
2.50	0.00	120	0.139
3.00	0.00	99.2	0.094
4.00	0.00	74.0	0.052
5.00	0.00	59.0	0.033
6.00	0.00	49.0	0.023
7.00	0.00	42.1	0.017
8.00	0.00	36.8	0.013
9.00	0.00	32.7	0.010
10.0	0.00	29.4	0.008

Frequency Response



1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

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8-Pole, 6-Zero

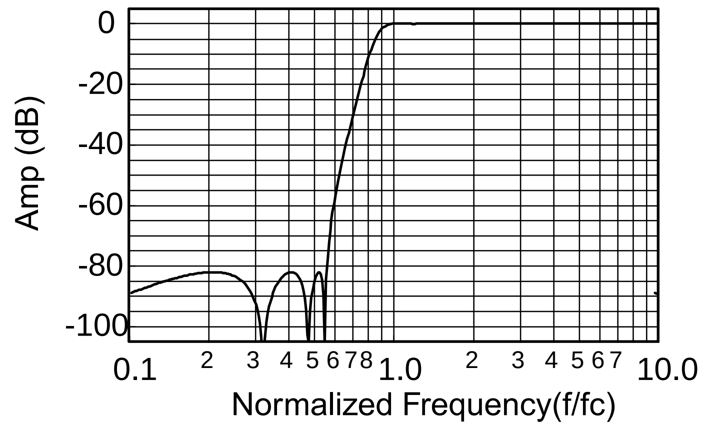
Elliptic, 1.77

High-Pass

Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.10	-89.3	164	0.440
0.20	-82.1	148	0.459
0.30	-90.6	131	0.495
0.40	-82.4	292	0.559
0.50	-87.8	450	0.671
0.55	-90.0	437	0.761
0.60	-60.2	603	0.890
0.70	-32.4	563	1.37
0.80	-13.1	498	2.35
0.85	-6.28	451	2.77
0.90	-2.21	401	2.66
0.95	-0.51	358	2.15
1.00	-0.03	324	1.64
1.10	-0.01	277	1.04
1.20	-0.05	225	0.757
1.30	-0.03	221	0.596
1.40	0.01	201	0.486
1.50	0.03	185	0.409
1.60	0.03	172	0.347
1.70	0.03	160	0.299
1.80	0.02	150	0.260
1.90	0.01	141	0.229
2.00	0.01	133	0.203
2.50	-0.02	105	0.123
3.00	-0.02	86.9	0.083
4.00	-0.02	64.7	0.046
5.00	-0.01	51.6	0.029
6.00	-0.01	42.9	0.020
7.00	-0.01	36.8	0.015
8.00	-0.01	32.1	0.011
9.00	-0.01	28.6	0.009
10.0	0.00	25.7	0.007

Frequency Response



1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

$$\text{Actual Delay} = \frac{\text{Normalized Delay}}{\text{Actual Corner Frequency (fc) in Hz}}$$

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